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Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge

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Abstract

The present study investigated effects of two hypermedia environments on 95 preservice university teachers' self-regulated learning (SRL) in the context of technological pedagogical content knowledge (TPCK): hypermedia with metacognitive instruction (HYP + META) and without (HYP). The study combined online reflections with self-report measures to assess SRL processes. Results showed that exposure to metacognitive support using the IMPROVE self-questioning method may enhance preservice teachers' ability to reflect on and regulate their learning processes. This, in turn, can develop their TPCK, both as learners (comprehension skills) and as teachers (design skills). Further analysis indicated high correlations within SRL measures (self-reports, online reflections) and between SRL and TPCK tasks. Implications are discussed for teacher training in SRL-integrated TPCK contexts.

Keywords: Preservice teachers; Technological pedagogical content knowledge; Self-regulated learning; Hypermedia

1. Introduction

Research indicates that, despite the many efforts, researchers and educators have invested over the years in preparing teachers in the educational uses of technology, teachers continue to lack the skills and knowledge needed to be able to teach successfully with technology (Angeli & Valanides, 2005, 2008a, 2008b; Niess, 2005). Researchers propose that the lack of theoretical and conceptual frameworks to inform and guide the integration of technology into teaching and learning is a major weakness in the educational technology literature (Angeli & Valanides, 2005, 2008a; Margerum-Lays & Marx, 2003; Mishra & Koehler, 2006; Niess, 2005). These researchers advocate that teaching with technology requires the development of theoretical "pedagogical content knowledge" (PCK; Shulman, 1986, 1987) as it extends into the domain of teaching with technology, termed "technological pedagogical content knowledge" (TPCK).

Researchers have also begun to direct increasing attention to individual self-regulation in learning as a means for enhancing academic outcomes (Pintrich, 2000; Zimmerman, 2000). Self-regulated learners are good strategy users. They plan, set goals, select strategies, organize, self monitor, and self-evaluate at various points during the process of acquisition (Pintrich, 2000; Schraw, Crippen, & Hartley, 2006). To enhance understanding of developing teachers' knowledge in the field of educational technology, the present study suggests a model for integrating self-regulated learning (SRL) into preservice teachers' preparation of TPCK in hypermedia environment. In line with this claim, our study raises the main question: How can teacher preparation program for SRL guides preservice teachers' development of a TPCK and SRL for changing teaching and learning in classroom?

Prior to describing the present exploratory study's design, there is a brief overview of TPCK, SRL, and the presentation of a supporting model for integrating SRL into preservice teachers' preparation of TPCK as these concepts were utilized in the present study.

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1.1. Technological pedagogical content knowledge

Shulman (1986, 1987) described teachers' PCK as the ways content, pedagogy, and knowledge of learners are blended into understanding about how particular topics to be taught are represented and adapted to learners in order to engage students extensively in tasks that require comprehension. Several conceptions of how to extend PCK into the context of teaching with technology exist in the literature under different labeling schemes, such as "PCK of educational technology" (Margerum-Lays & Marx, 2003), "TPCK" alone (Koehler, Mishra, & Yahya, 2007; Mishra & Koehler, 2006; Niess, 2005), and Information and Communication Technology TPCK (ICT-TPCK) as a strand of TPCK (Angeli & Valanides, 2005, 2008a, 2008b). In the present article, the acronym TPCK will be used henceforth and will be related to the ICT-TPCK framework introduced by Angeli and Valanides (2005, 2008a, 2008b).

Angeli and Valanides (2008a, p. 5) described TPCK as integrated knowledge in which components should not be acquired separately and then put together somehow, but rather should be developed concurrently via technology-rich lessons designed "toward transformation of these contributing knowledge bases into something new". At the heart of the TPCK conceptualization is the view that technology is not a vehicle that simply delivers information; rather, it facilitates acquisition of cognitive tools that amplify students' higher-order cognitive processing (e.g., critical thinking, problem-solving) and extends the thinking processes of their users (Jacobson & Archodidou, 2000; Jonassen, 2000; Linn & Muilenburg, 1996). To achieve this objective, teachers should know that successful implementation of technology involves a considerable change in teachers' roles. The traditional teacher-centered role of acting as a "source of knowledge" should be replaced by learner-centered learning and by the role of initiating and coaching students' inquiries and problem-solving while using the cognitive tools offered by technology (Hannafin & Land, 1997; White & Horwitz, 1987).

1.2. TPCK in a hypermedia context

In the present study, TPCK was investigated within a particular type of technology-based learning environment, a hypermedia context. Hypermedia is a technology environment whose characteristics are conducive to developing teaching and learning knowledge as recommended by TPCK researchers (Angeli & Valanides, 2005, 2008a, 2008b; Mishra & Koehler, 2006; Niess, 2005). As a nonlinear environment, hypermedia provides new possibilities for teaching about the structure of domain knowledge by using representations or delivery media (e.g., video clips, sound bite graphics, hypertexts, animations). Hypermedia is considered a powerful cognitive tool that transforms abstract content into more concrete or realistic forms of knowledge, and, as such, it may facilitate conceptual knowledge development (Azevedo, 2005; Dillon & Jobst, 2005; Jacobson & Archodidou, 2000; Jonassen, 2000; Lajoie & Azevedo, 2006; Shapiro, 1999; Winters, Green, & Costich, 2008). Furthermore, hypermedia allows for learner-centered learning through navigating in the environment, namely, for deciding what to learn, how to learn, whether one understands the material, when to change learning plans and strategies, and when to increase efforts (Azevedo, Cromley, & Seibert, 2004; Azevedo & Jacobson, 2008; Winters et al., 2008).

Based on evidence from empirical investigations, learners' simultaneous development of TPCK components is a complex process that demands various capabilities (Angeli & Valanides, 2005, 2008a, 2008b; Mishra & Koehler, 2006; Niess, 2005). Although hypermedia can readily provide multiple tools and opportunities to manipulate them in the pedagogical uses, it is often up to the teacher to: (a) identify which task is suitable for teaching in technology; (b) determine which tool is most helpful to infuse in teaching/learning and why; (c) find when and how to use it; and (d) select the optimal pedagogical method to support that choice. Such careful, considered engagement by teachers is indicative of self-regulated learning (Pintrich, 2000; Schraw et al., 2006; Zimmerman, 2000). Thus, the theoretical framework of SRL and its role in developing TPCK in the hypermedia context are highlighted in the following sections.

1.3. Integrating SRL into the TPCK hypermedia context

In recent years, the role of SRL in education has elicited much interest. Research has focused on SRL skills as a means to attain successful learning. There are many different SRL models that propose different constructs, but they do share some basic assumptions about learning and regulation (Butler & Winne, 1995; Pintrich, 2000; Schraw et al., 2006; Zimmerman, 2000, 2008). Specifically, SRL is an active process referring to "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000, p. 14). SRL involves a combination of cognitive, metacognitive, and motivational processes used in a learning context (Pintrich, 2000; Zimmerman, 2000). Cognitive processes refer to information-processing strategies like rehearsal, elaboration, and organization. Metacognitive processes refer to monitoring and control of cognitive skills, usually involving the planning, monitoring, and evaluation of one's own learning in terms of achieving personal goals. The motivational processes refer to students' willingness to learn and to attain academic self-efficacy. Finally, the learning context refers to learning conditions such as the type of task or technology.

Educators and researchers believe (Leelawong et al., 2002; Putnam & Borko, 2000) that preparing to teach in a self-directed open-ended technology environment like hypermedia is tied to preservice teachers' own self-regulation abilities in two ways. First, preservice teachers must be able to achieve SRL for themselves (the learner's perspective in SRL), that is, be themselves self-regulated learners. Second, preservice teachers must be able to understand how to help their students achieve SRL (the teacher's perspective in SRL). Each SRL perspective can be developed through TPCK tasks focusing on different skills, that is, comprehension skills to develop the learner's perspective and design skills to develop the teacher's perspective.

Comprehension skills constitute basic component of TPCK, and require that the teacher processes data concerning existing information. Comprehension tasks in TPCK, which require teachers' own SRL (the learner's perspective) are based on evaluating ready-made materials like video-captured lessons. Such activities demand essential skills such as understanding the learning goals; identifying ways of engaging students in learning with technology; and analyzing difficulties in learning with technology (see description in subchapter 2.3.1).

Design skills in TPCK, which represent the teacher's understanding of how to promote their students' SRL (the teacher's perspective) are more complex, requiring higher-order thinking in TPCK (Zohar & Schwartzer, 2005).

Design tasks in TPCK demand that teachers synthesize and create learning activities in using technology. Teachers are asked to identify relevant topics for teaching with technology, select appropriate computer tools, and plan materials and strategies for infusing technology in the lessons (see description in subchapter 2.3.2).

When designing tasks, preservice teachers must be sensitive to students' zone of proximal development that places the learner at the center of the learning process in order to explore, collaborate with others, express a point of view, or resolve cognitive conflict. Designing tasks require from the preservice teachers to be active in the decision of **when** and **why** to integrate technology into learning and **how** to engage students in such activities (Angeli & Valanides, 2008a; Jacobson & Archodidou, 2000; Linn & Muilenburg, 1996).

Research has demonstrated (Kramarski, 2008; Randi & Corno, 2000) that SRL is not spontaneously acquired by teachers, and this is the case in hypermedia contexts also. Often, learners of all ages using hypermedia do not know whether they are on the right track, what strategies to use, and when and how to use the strategies (Azevedo, 2005; Azevedo & Cromley, 2004; Kramarski & Michalsky, 2009). Researchers have suggested that teachers' SRL may be shaped and developed through participation in programs that provide opportunities for the teachers to be in control of their own learning and teaching (Kramarski, 2008; Kramarski & Michalsky, 2009; Putnam & Borko, 2000; Randi & Corno, 2000). Taken together, these findings suggest that teacher training programs should incorporate training practices that explicitly promote knowledge and skills for enhancing teachers' acquisition of SRL skills in technology-based pedagogical contexts, both regarding their own learning and their teaching. We shall next present a teacher training model that integrates SRL with the hypermedia context.

1.4. Metacognitive support

Researchers believe (Schraw et al., 2006; Zimmerman, 2000, 2008) that the role of metacognition is especially important in the SRL process. Metacognition enables learners to plan and allocate learning resources, monitor their current knowledge and skill levels, and evaluate their current learning level at various points during the acquisition process. Metacognitive support aims to increase learning competence by means of systematic explicit guidance to learners as they think and reflect on their tasks (Bannert, 2008; Lin, Schwartz, & Hatano, 2005; Quintana, Zhang, & Krajcik, 2005; Schraw et al., 2006; Veenman, Van Hout-Wolters, & Afflerbach, 2006; White & Frederiksen, 1998; Winters et al., 2008). Research findings revealed that different metacognitive supports in different learning conditions may empower self-regulation skills. For example, Lin et al. (2005) found that adaptive metacognitive training of teachers, which involved teachers' flexible responsiveness "to a wide range of classroom social and instructional variability" (p. 245) increased teachers' ability to ask cognitive questions (information) and metacognitive questions (how and why) on a given pedagogical event. Van den Boom, Paas, van Merrienboer, and van Gog (2004) reported that undergraduate students who were provided with metacognitive prompts gained higher scores on ratings of self-regulation. Kramarski et al. (Kramarski & Gutman, 2006; Kramarski & Mizrachi, 2006) found that learners who were exposed to cooperative e-learning with metacognitive support outperformed on SRL measures learners who were exposed to the same learning condition without metacognitive support.

Mevarech and Kramarski's (1997) metacognitive method, known as IMPROVE, encourages learners to become involved in thinking and reflecting on their task and their learning by using self-questioning. The IMPROVE acronym represents all of the teaching steps in the classroom: Introducing new concepts; Metacognitive questioning; Practicing in small groups; Reviewing; Obtaining mastery; Verification, and Enrichment and remediation. IMPROVE self-questioning engages learners actively through guidance using four kinds of questions: (a) comprehension, (b) connection, (c) strategy, and (d) reflection. Comprehension questions help learners understand the task's or problem's information (e.g., "What is the problem/task?" and "What is the meaning of…?"). Connection questions prompt learners to understand the task's deeper-level relational structures by articulating thoughts and explicit explanations (e.g., "What is the difference/similarity?" and "How do you justify your conclusion?"). Strategy questions encourage learners to plan and to select the appropriate strategy (e.g., "What is the strategy?" and "Why?"). Reflection questions play an important role in helping learners monitor and evaluate their problem-solving processes, by encouraging learners to consider various perspectives and values regarding their selected solutions (e.g., "Does the solution make sense?" and "Can the solution be presented in another way?").

The IMPROVE method is grounded in the SRL theoretical framework. The four kinds of questions used empower learners' self-regulation. The questions direct learners' thoughts and actions throughout the three cyclical SRL phases of the solution process (Zimmerman, 2000, 2008): (a) pre-action (planning), (b) on-action (monitoring), and (c) post-action (evaluation). The method is also grounded in socio-cognitive theories of learning, which extend the view of metacognition to encompass not only self-directed dialogue but social aspects as well. Such aspects include practice of tasks and metacognitive group discussion between peers of comparable expertise, thus making the processes of monitoring and regulation overt (Brown & Campione, 1994). When learners explain and justify their thinking, and challenge the explanations of their peers, they also engage in clarifying their own thinking which, in turn, may facilitate the use of their SRL skills more efficiently (Kramarski, 2004; Kramarski & Mevarech, 2003).

Research findings revealed strong positive effects of the IMPROVE metacognitive method on school students' mathematical reasoning in different learning conditions such as e-learning (Kramarski & Gutman, 2006; Kramarski & Mizrachi, 2006), cooperative learning (Kramarski, 2004; Kramarski & Zoltan, 2008), and face-to-face learning (Kramarski & Mevarech, 2003; Kramarski & Mizrachi, 2006). Based on these previous findings, the present study aimed to adapt the IMPROVE method to support preservice teachers' SRL in a hypermedia context. We believe that it is important to start with preservice teachers' preparation, because they will be students' future teachers. To the best of our knowledge, little research exists on the benefits and pitfalls of a systematic metacognitive method such as IMPROVE in promoting preservice teachers' TPCK and SRL in hypermedia within professional training programs.

Furthermore, the present study used a more comprehensive and holistic examination of SRL than in previous studies that examined the effects of the IMPROVE self-questioning strategy on SRL outcomes. Previous research used only aptitude measures (Kramarski, 2004; Kramarski & Mizrachi, 2006). Aptitude is defined as a relatively enduring trait attribute of a person that predicts future behavior, and is usually assessed via self-report questionnaires (Veenman, 2007; Winne & Perry, 2000; Zimmerman, 2008). In the present study, SRL was measured not only as an aptitude but also by using a complementary measure of SRL as an event. Event-based SRL is defined as an online process that is examined in real time during learning, which may be a more accurate measure of processes related to SRL (Azevedo, 2005; Perry, 1998; Veenman et al., 2006; Winne & Perry, 2000; Zimmerman, 2008). Thus, the present study used a self-report questionnaire to assess preservice teachers' self-perceptions of their SRL skills and event-based SRL based on online reflections regarding the tasks they are working on.

1.5. The present study

In the present study, preservice teachers participated in one of two professional training programs embedded within a hypermedia environment. Preservice teachers worked in pairs, either with the IMPROVE metacognitive method (HYP + META) or without this explicit metacognitive method (HYP). The aim of the study was threefold. It compared the differential effects of HYP + META vs. HYP, first, on the preservice teachers' TPCK skills regarding comprehension skills (as a learner) and design skills (as a teacher) and, second, on their SRL as an aptitude (self-report questionnaire) and event-based SRL (online reflections). In addition, the relations between SRL (aptitude and event-based) and TPCK (comprehension and design skills) were examined in each professional training program (HYP + META **vs**. HYP).

The assumptions for successful learning were based on the SRL theoretical framework (Pintrich, 2000; Zimmerman, 2000) and on socio-cognitive theories (Brown & Campione, 1994). It was expected that the IMPROVE method by encouraging metacognitive peer discussion of pedagogical issues in different perspectives, that is, as a learner and as a teacher, in a hypermedia environment (HYP + META) would help preservice teachers become more actively engaged in comprehending the TPCK (as a learner; e.g., ''Identifying the topics that are taught with technology'') and in optimally designing lessons for their students' learning in a technological environment (as a teacher; e.g., ''Designing the learning environment that puts the learner in the center''), than would such peer discussions that did not include the metacognitive component (HYP). Thus, it was hypothesized (Hypothesis 1) that the HYP + META group would outperform the HYP group on both TPCK measures (comprehension and design skills).

It was also assumed that metacognitive self-questions of all types as included in IMPROVE would enhance teachers' self-regulation more than would the HYP environment alone, for both aptitude (e.g., cognition, metacognition and motivation) and event measures (e.g., planning, monitoring and evaluation). Consequently, we hypothesized that the HYP + META group would outperform the HYP group on both SRL measures (Hypothesis 2).

Furthermore, it was hypothesized that there would be significantly higher positive relations within SRL measures (aptitude and event), and between the TPCK-related measures (comprehension and design) and SRL (both measures), in the HYP + META group than in the HYP group (Hypothesis 3).

2. Method

2.1. Participants

Participants were 95 preservice high-school science teachers (57 females, 38 males) in their first year of teacher education at a university in central Israel. Their mean age was 24.5 years ($SD = 6.8$), and their grade point average for major subject was 80% ($SD = 5.3$). All participants were enrolled in the mandatory first-year course ''Designing Learning Activities with a Hypermedia Environment'', but were randomly assigned to one of two learning environments for participation in the course forming two groups, the HYP + META group ($n = 47$) and the HYP group ($n = 48$). Statistical pretest comparisons between the two learning environments showed no significant differences in demographic characteristics (e.g., gender, SES, ethnicity), or in any of the study variables, all t-tests $(93) < 1.37$, $p > 0.05$.

2.2. Training program

2.2.1. Teacher training

The two female teachers who taught the preservice course "Designing Learning Activities with a Hypermedia Environment" each held a university PhD degree in education. Each teacher had more than 10 years of teaching experience and was considered by the students to be an expert teacher. For the purpose of the present study, each teacher was trained separately in a 3-h, one-day, inservice training seminar at the university. The training instructor (the second author) informed the two teachers that they were participating in an experiment in which new materials were being used/designed in a world wide web hypermedia environment, including pedagogical cases that demand comprehension and design tasks (both learner and teacher perspectives). Appendix A presents sample screen shots of such a comprehension task and a design task.

The training was implemented in two parts. In the first one and a half hour of training, the teacher of the HYP + META group was introduced to the rationale of integrating SRL within a TPCK framework (Angeli & Valanides, 2005, 2008a) and to the IMPROVE method of support (as mapped out on Fig. 1 below). The training instructor discussed using computer tools and the importance of metacognitive self-questioning in solving TPCK tasks, for both comprehension and design. She modeled ways for using pop-ups on the computer screen to introduce the metacognitive approach in both SRL perspectives, as a learner and as a teacher (see Appendix A). In the remaining one and a half hour of the training, the teacher of the HYP + META group was guided in how to use hypermedia, and how to encourage forum and class discussion with the metacognitive method. She was asked to solve the tasks herself, and to think about possible difficulties she might encounter in the class. Emphasis was given to the teacher's role while students work with the computer. She received guidance on how to encourage forum and class discussion, cope with students' difficulties in developing self-directed learning in TPCK with hypermedia. The teacher was also guided in how to manage student-centered learning by clarifying but not directly answering students' questions.

Unlike the teacher of the HYP + META group, the teacher of the HYP group was not introduced to the metacognitive approach. However, she was exposed to the same amount and structure of training related to teaching pedagogical issues with hypermedia. In the first one and a half hour of training, she was introduced to the rationale of the TPCK framework (Angeli & Valanides, 2005, 2008a, 2008b), and to the use of computer tools for solving TPCK tasks, both in comprehension and design (in the learner and teacher perspectives). In the remaining one and a half hour, the teacher received guidance in how to use hypermedia and solve the tasks, manage her role while students work with the computer, and maintain student-centered learning by clarifying but not directly answering students' questions.

During the period of the study, the second author observed both teachers six times (every second week) to help ensure adherence to implementation of the instructional approaches. In addition, the authors met each teacher after the observations and discussed any deviations from the approach, to monitor treatment fidelity in the two groups.

2.2.2. Shared structure and curriculum for the two learning environments

The two learning environments (HYP + META and HYP) comprised 14 pedagogical workshops lasting 4 h each week, comprising 56 h of total training for the participating preservice teachers. Workshops focused on implementing teaching and learning methods for TPCK activities based on Angeli and Valanides's (2005, 2008a, 2008b) theoretical framework. First, participants were taught that TPCK is a unique body of knowledge that is constructed from the interaction of its individual contributing knowledge bases. Furthermore, participants were exposed to discussion of pedagogical uses of various computer tools (e.g., internet, representations, animations, and hyperlinks) following the four TPCK principles by identifying: (a) topics to be taught with technology (e.g., complex systems in which certain factors function

TPCK / IMPROVE[a] self-questioning	Identifying objectives in hypermedia	Selecting content in hypermedia	Planning didactic material in hypermedia	Designing hypermedia learning environment
Comprehension questions: "What is the task's goal?"	Do I understand the aim of the task? Explain.	Do I understand the content-matter in task? Explain.	Do I understand the didactics in the task? Explain.	Do I understand the uniqueness of the task? Explain.
Connection questions: "What are the similarities between tasks?"	Are the goals I identified similar to what I was exposed to in the course? Demonstrate.	Are the terms connected to the subject of the lesson? Explain how.	What prior knowledge is important?	Which theories are connected to the learning environments?
Strategy questions: "What are the tools/strategies appropriate for solving the task, and WHY?"	Which tools will help me to analyze the learning objectives? Demonstrate.	Which tools will help me analyze the content? Demonstrate.	Which tools/strategies will help me understand whether the material is appropriate? Demonstrate.	Which tools will I use to design a task? Demonstrate.
Reflection questions: "Does the solution make sense?"	Are the contents of the unit related to the objectives? Demonstrate.	Have I missed material that is important to the study? Demonstrate.	Are the links I selected suitable to task? Explain.	Is the learning environment I designed well organized? Explain.

Fig. 1. Types of IMPROVE metacognitive self-questioning embedded in technological pedagogical content knowledge (TPCK), for preservice teachers in both perspectives, as a learner and as a teacher, with examples. This figure is based on the categories presented in Kramarski and Michalsky (2009), with an emphasis here on the use of metacognitive questioning in a technology environment (TPCK). The learner or the teacher perspective was prompted by an electronic pop-up question following each online task (see Appendix A for sample graphic representations of such questions).

systemically and need to be simulated or modeled); (b) representations for transforming the content to be taught into forms that are comprehensible to learners (e.g., interactive representations); (c) learning and teaching strategies that are resistant to traditional implementation (e.g., exploration and discovery in virtual worlds such as virtual museums); and (d) appropriate strategies for the infusion of technology in the classroom, which includes any strategy that puts the learner at the center of the learning process.

Each of the workshops in both environments contained the same structure. First, the teacher presented the lesson's subject (e.g., human vascular system) and analyzed it according to the four TPCK principles. Practice was based on the world wide web hypermedia learning environment, which provided pedagogical tasks of varying complexity that required comprehension and design skills. The tasks were followed by links for additional resources in order to solve the task, and forum discussions. Pairs of participants were encouraged to participate in reflective discourse regarding interpretation of pedagogical events, understanding difficulties, and raising solutions for the problems those events presented, and then each pair presented its conclusions to the whole class. Finally, the teacher presented a summary in the classroom, addressing any difficulties that arose.

2.2.3. Unique structure and curriculum in the HYP + META learning environment

Preservice teachers in the HYP + META group were exposed during the entire lesson to SRL support, based on the IMPROVE model (Kramarski & Mevarech, 2003; Mevarech & Kramarski, 1997). Like in its previous applications for school students, the model for preservice teachers utilized a series of four metacognitive self-guided questions focusing on comprehension, connection, strategy, and reflection. However, unlike the initial model, which emphasized only the learner's SRL perspective, the present study expanded the model to incorporate two perspectives of SRL for preservice teachers: as a learner and as a teacher. In both perspectives, the preservice teacher was instructed to use the metacognitive self-guided questions before, during, and after the solution process, whether that solution involved analyzing and comprehending a task (learner perspective) or designing learning activities (teacher perspective). Fig. 1 presents the IMPROVE metacognitive self-questioning model embedded in TPCK for preservice teachers. Preservice teachers employed these questions to identify/design topics, representations, and learning and teaching strategies with hypermedia, in line with Angeli and Valanides's (2005, 2008a, 2008b) four TPCK principles. The IMPROVE metacognitive self-questions are described next.

2.2.3.1. Comprehension questions. They were designed to prompt preservice teachers to reflect on the task before solving it (as learners) or before designing the activity (as teachers). Preservice teachers employed comprehension questions to identify/design the topics to be taught with hypermedia. These topics could include abstract concepts that need to be visualized, phenomena that need to be animated, complex systems in which certain factors function systemically and need to be simulated or modeled, and topics that require multimodal transformations (i.e., textual, iconic, auditory).

2.2.3.2. Connection questions. They were designed to prompt teachers' focus on similarities and differences between activities that the teachers had already used or designed, and to explain why. In addressing the connection questions, teachers had to focus on prior knowledge, and to define the structural features of the task and the information provided. Preservice teachers employed connection questions to identify/design the representations for transforming contents to interactive representations, and for dynamic transformation of data.

2.2.3.3. Strategic questions. They were designed to prompt teachers to consider which strategies were appropriate for solving or teaching the given problem/task and for what reasons. In addressing the strategic questions, teachers had to describe which strategy they selected, how they suggested it should be implemented, and why this specific strategy was the most appropriate one for solving or teaching the task. Preservice teachers employed strategic questions to identify/design strategies that were difficult or impossible to implement via traditional means. For example, such strategies could include exploration and discovery in virtual worlds (i.e., virtual museums), testing of hypotheses and/or application of ideas into contexts that could not possibly be experienced in real life, complex decision-making, long-distance communication and collaboration with peers, personalized learning, adaptive learning, and context-sensitive feedback. Such strategies put the learner at the center of the learning process.

2.2.3.4. Reflection questions. They were designed to prompt teachers to self-regulate their comprehension and design of learning activities. In addressing the reflection questions, teachers monitored and evaluated their understanding and different ways to solve problems or different teaching approaches. Preservice teachers employed reflection questions to control the infusion of technology in the classroom.

These four types of metacognitive questions were embedded in the electronic pages and were displayed onscreen as automatic pop-ups at certain times during the practice of a pedagogical skill (see Appendix A for an example). The preservice teachers were encouraged to use them explicitly in solving their tasks (learner perspective), and in their designing tasks (teacher perspective).

Table 1 summarizes the design of the TPCK training program by learning environment, indicating that only on metacognitive support did the two groups differ.

2.3. Measures

Four measures were administered in the study at two testing occasions, namely at the pretest and the posttest. Two measures assessed TPCK, that is, comprehension skills (learner perspective) and design skills (teacher perspective).

Table 1
Summary of the preservice TPCK training program by learning environment.

TPCK training program element	HYP + META	HYP
Theoretical teaching and learning framework	TPCK approach: computer as a cognitive tool that amplifies student learning; focus on learner-directed learning such as active and cooperative learning and inquiry; socio-cognitive theories.	
Training (for the two teachers)	Three-hour, one-day, inservice training seminar, and teachers' observations.	
Preservice course on using and designing learning activities in a hypermedia environment	One-semester course, 14 meetings, 56 h in total, for high-school science teachers: (a) Instructor discusses pedagogical uses of various computer tools (e.g., internet, representations, animations, and hyperlinks) according to the four TPCK principles; (b) Student pairs practice pedagogical cases in www-hypermedia environment and online forum discussions; cases demand comprehension and design skills (learner and teacher perspectives, respectively); (c) Instructor presents a summary in the classroom, addressing any difficulties.	
Metacognitive support	SRL model: IMPROVE self-questioning computer pop-ups on comprehension, connection, strategy, and reflection.	None

The other two measures assessed SRL dimensions (i.e., aptitudes and events).

2.3.1. Comprehension skills

To measure TPCK comprehension skills, the task given to preservice teachers was a structured study unit following the pedagogical implementation of technology with PCK based on Angeli and Valanides's (2005) principles, Simpson's (2005) pedagogical standards, and Bloom's (1956) assessment taxonomy. The study unit in both testing occasions referred to the same topic "Technology enhances the quality of humanity". However, the given unit in the pretest differed from the one given in the posttest to avoid familiarity effects (for the pretest, "the effects of cloning on people's lives"; for the posttest, "opportunities for determining the gender of the expected baby").

At each testing occasion, the preservice teachers were given 1 h to peruse the study unit and to complete a paper-and-pencil task. The paper-and-pencil task was a questionnaire with five subscales of two open questions each. The five subscales tap different TPCK comprehension skills that were confirmed by two raters with expertise in TPCK. The interrater reliability was 84%. The skills reflected in the five subscales were the following: (a) understanding ("What are the goals of the teaching unit and what is required to meet them?" and "Identify the topics that are taught with technology"); (b) application (e.g., "Sort the learning activities that engage the students in dynamic activities"); (c) analysis (e.g., "What are the difficulties expected in learning/teaching strategies to be implemented by traditional means? Explain"); (d) synthesis (e.g., "Based on the present task, suggest another strategy for the infusion of technology into the classroom. Explain"), and (e) evaluation (e.g., "What is the ideal teaching method in your opinion? Explain").

Participants' comprehension skills were scored from 1 (low), 2 (medium), to 3 (high), or 0 (no answer). Scores ranged between 0 and 30. A score of 3 in each question required participants to provide in their response three elements from the study unit (e.g., for the evaluation question: providing two TPCK teaching methods and a clear justification). A score of 1 or 2 indicated provision of one or two elements, respectively (e.g., for the evaluation question: providing 1–2 elements without justification). Participants' responses were coded by two trained raters with expertise in TPCK. Interrater reliability, calculated with Cohen's kappa measure for the same 30% of the responses coded by both raters, yielded high reliability coefficients: understanding: 0.96; application: 0.93; analysis: 0.93; synthesis: 0.94; and evaluation: 0.92. Disagreements on the scoring and coding of comprehension skills were resolved through discussion (e.g., identifying clear justification).

2.3.2. Design skills

To measure TPCK design skills, the task given to preservice teachers was a structured study unit regarding the effects of drugs on people's lives. Each participant was given one and a half hour to design a two-lesson study unit including the use of technology. The design of the two-lesson study unit followed a TPCK Index (adapted from Angeli & Valanides, 2005; Kramarski & Michalsky, 2009; Leou, 1998). This index focuses on four categories of design skills (see Fig. 1): (a) identifying learning objectives, (b) selecting content, (c) planning didactic material, and (d) designing the learning environment. Each category was assessed by four rubrics on a response scale from 1 (low: partial answer) to 4 (high: full answer), and 0 for no answer, with total scores ranging from 0 to 16. The same raters, experts in TPCK, scored the participants' design skills as evidenced in these study units.

Participants received a full score of 4 for identifying learning objectives when their study unit design presented clear learning objectives, specific for the topic, detailing the capacities that students are supposed to develop, and identifying computer tools for the topic – computer tools referred to using Internet resources, hypermedia, export materials, pictures, animations, etc. (e.g., using internet resources to answer students' research questions).

A full score of 4 for selecting content referred to a study unit design that selected relevant information, experience, and computer tools and indicated the extent to which each tool could support content transformation (e.g., selecting visualization techniques to help students learn abstract concepts).

A full score of 4 for planning didactic material referred to a set of materials (computer tools) for student use and justification of how these tools place the learner at the center of the learning process (e.g., selecting hypermedia for problem-solving inquiry activities).

A full score of 4 for designing the learning environment referred to integrating three learning strategies in designing the learning environment for infusing technology in the classroom, and justifying their choices (e.g., planning peer dialogue with the students during the learning, online communication, and context-sensitive feedback).

A partial answer was scored 1 when the designed lessons did not clearly indicate use of technology. Other partial answers were scored as 2 for a design that lacked justification for a specific technology or were scored as 3 for a design that did not clearly justify such technology usage.

All raters underwent training to analyze and rate the open-ended responses. Interrater reliability was calculated for the same 30% of the responses coded by both raters, yielding high Cohen's kappa reliability coefficients (identifying learning objectives: 0.90; selecting content: 0.85; planning didactic material: 0.86; and designing the learning environment: 0.87). Disagreements on the scoring and coding of design skills were resolved through discussion (e.g., justifying strategies).

2.3.3. SRL as an aptitude

The Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991) comprising 50 items assessed preservice teachers' self-reported SRL components, namely cognition, metacognition, and motivation that were adapted to the pedagogical context in previous study (Kramarski & Michalsky, 2009). Sixteen items referred to three cognitive strategies: (a) rehearsal strategies (e.g., "When I read material for the course, I say the words over and over to myself to help me remember"), (b) elaboration strategies such as summarizing and paraphrasing (e.g., "When I study for this course, I put important ideas into my own words"), and (c) organizational strategies (e.g., "I outline the chapters in my task to help me study"). Twenty items referred to three processes of metacognition: (a) planning (e.g., "When I begin to work on the task for the course, I think what would be a good way to do it"), (b) monitoring (e.g., "During the task process I often ask myself if I am going in the right direction"), and (c) evaluation (e.g., "At the end of the task I ask questions to make sure I know the material I have been studying"). Fourteen items referred to two motivational factors: (a) intrinsic value of learning (e.g., "I think what we are learning in this pedagogical course is interesting") and (b) persistence in the face of difficulties (e.g., "Even when the study materials are dull and uninteresting, I keep working until I finish"). Participants rated each item on a seven-point Likert-type scale, ranging from 1 (not at all true for me) to 7 (very true for me). Higher scores indicated a higher level of SRL.

An exploratory factor analysis (EFA) with orthogonal rotation according to the varimax method revealed three factors, that is, cognition, metacognition, and motivation, which explained 59.4% of the variance (24.3%, 18.4%, and 16.7%, respectively) and Cronbach's alphas were 0.78, 0.73, and 0.71, respectively.

2.3.4. Event-based SRL measure

Preservice teachers' written reflections were collected for analysis from the course's online forum discussion twice, at the beginning of the study (during the 2nd workshop) and before the end of the semester (between the 13th and 14th workshops).

At each testing occasion, preservice teachers were asked to reflect online on two kinds of events, the TPCK comprehension tasks and design tasks by completing the Regulation of Cognition Index (Schraw & Dennison, 1994). The index includes eight items, two in each of its four subscales; one item for the learner perspective and one for the teacher perspective. The four subscales reflecting a different category each were: (a) planning (for the comprehension: "Describe the goals of the task and explain how and why you set them prior to learning, referring to TPCK"; for design, "Define the goals of the TPCK task, and explain how and why do you select these activities"), (b) monitoring (for comprehension, "When and how did you assess TPCK activity, during analysis of the task?; Please provide some examples"; for design, "When and how did you assess your activity, during your TPCK planning process? Please provide some examples"); (c) debugging (for comprehension, "Did you encounter any difficulties or errors while analyzing the learning TPCK task? Please provide some examples"; for design, "Did you encounter any difficulties while building the sequence of the TPCK lesson? Please provide some examples); and (d) evaluation (for comprehension, "Describe the benefit you obtained from your cooperative learning process and how it helped you in advancing your TPCK learning task. Please provide some examples"; for design, "How and in what ways have you improved your functioning during the planning of the TPCK learning unit? Please provide some examples").

For assessing the event-based SRL measure, participants received two reflection scores, one for reflections on the comprehension tasks and the other for reflections on the design tasks. Reflections were assessed with four rubrics, which referred to the four categories, that is, planning, monitoring, debugging, and evaluation of the process (Birenbaum & Amdur, 1999). Scoring was on a three-point response scale from 1 (low: partial answer) to 3 (high: full answer). Full use was scored 3 when the participant referred to all four categories: planning referred to defining, clarifying, and justifying a goal setting; monitoring referred to strategies and monitoring considerations underlying the implementation of one strategy or another; debugging referred to identification of, description of, and focus on difficulties and errors; and evaluation referred to evaluating goals, a plan of action, strategies, and outcomes. A score of 2 was given when the participant referred to two categories in each rubric, a score of 1 was given for one category, and 0 was given for no answer. All raters underwent training in analyzing and coding the open-ended responses. Interrater reliability was calculated for the same 30% of the responses coded by both judges who were experts in TPCK, yielding the following interrater reliability (Cohen's kappa) for planning, 0.87; for monitoring, 0.90; for debugging, 0.86; and for evaluation, 0.86.

2.4. Procedure

Instruction began at the beginning of the second academic semester and continued for 56 h. Instruction was implemented in two computer labs with computers for everyone. The hypermedia teaching program was the same in each classroom, but the instructional environments were adapted according to the research design. The pre- and posttest measures were administered by the teachers in the classroom setting on the first and last days of the course (lasting 2 h each time). The measures were administered in the same order on both testing occasions: MSLQ (SRL aptitude), followed by TPCK study unit (comprehension skills), and then by the TPCK two-lesson study unit (design skills). In addition, students' reflections (event-based SRL) were collected from the forum discussions in the beginning (second workshop) and before the last week of the semester. Participants were informed that these measures were part of a research study to determine the effectiveness of preservice training. All students in the course participated in the study.

3. Results

3.1. Comprehension and design skills

The differential effects of the two learning environments (HYP + META **vs.** HYP) on the preservice teachers' development of TPCK skills (comprehension and design skills) were compared. Table 2 presents the means, standard deviations, and Cohen's d effect sizes for the TPCK skills, by testing occasion (pre- and posttest) and group (HYP + META and HYP). A MANOVA for the pretest results indicated that before the course began, no significant differences emerged between the two learning groups on the TPCK skills, Wilks's $\lambda = 0.62$, $F(2, 192) = 1.02$, $p > 0.43$, partial $\eta^2 = 0.11$.

The repeated measures 2(testing occasion) × 2(group) ANOVA on each of the two measures of TPCK skills indicated a significant main effect of testing occasion on both TPCK skills, $F(1, 93) = 34.17$, $p < 0.001$, partial $\eta^2 = 0.24$, and $F(1, 93) = 38.23$, $p < 0.001$, partial $\eta^2 = 0.32$, for comprehension and design skills, respectively. Significant interaction effects also emerged between group and testing occasion on each of the two TPCK skills, $F(1, 92) = 6.37$, $p < 0.001$, partial $\eta^2 = 0.14$, and $F(1, 92) = 3.68$, $p < 0.001$, partial $\eta^2 = 0.14$, for comprehension and design skills, respectively.

The effect sizes (Colen's d) for the pre- and posttest differences within each group showed that at the end of the study the preservice teachers exposed to HYP + META learning environment outperformed (Cohen's $d = 1.64$ and 0.74, for comprehension and design skills, respectively) those exposed to HYP alone (Cohen's $d = 1.43$ and 0.79, for comprehension and design skills, respectively), on both measures of TPCK skills (see Table 2).

3.2. SRL as an aptitude

Table 3 presents the mean scores and standard deviations of the scores for the three MSLQ factors (cognition, metacognition, and motivation) by testing occasion (pre- and posttest) and group (HYP and HYP + META). A MANOVA for the pretest results indicated that before the course began, no significant differences emerged between the two groups on any of the SRL components, Wilks's $\lambda = 0.57$, $F(3, 281) = 1.17$, $p > 0.41$, partial $\eta^2 = 0.15$.

The repeated measures 2(testing occasion) × 2(group) ANOVA on each of the three components of SRL indicated a significant main effect of testing occasion for all SRL components, $F(1, 93) = 22.15$, $p < 0.001$, partial $\eta^2 = 0.34$, $F(1, 93) = 32.41$, $p < 0.001$, partial $\eta^2 = 0.51$, and $F(1, 93) = 47.68$, $p < 0.001$, partial $\eta^2 = 0.39$, for cognition, metacognition, and motivation, respectively. Significant interaction effects also emerged between group and testing occasion on each of the three SRL components, $F(1, 92) = 4.82$, $p < 0.001$, partial $\eta^2 = 0.17$, $F(1, 92) = 7.64$, $p < 0.001$, partial $\eta^2 = 0.18$, and $F(1, 92) = 16.74$, $p < 0.001$, partial $\eta^2 = 0.35$, for cognition, metacognition, and motivation, respectively.

The effect sizes (Colen's d) for the pre- and posttest differences within each group showed that at the end of the study the preservice teachers exposed to HYP + META learning environment were more effective in fostering the various components of SRL than those exposed to HYP alone (see Table 3). Specifically, preservice teachers who were exposed to metacognitive support (HYP + META group) reported at the posttest higher cognition, metacognition, and motivation (Cohen's $d = 1.07$, 0.93, and 0.85, respectively), than those not exposed to metacognitive support (HYP), (Cohen's $d = 0.40$, 0.36, and 0.48, respectively).

Table 2
Preservice teachers' means (and SD) and Cohen's d effect sizes for comprehension and design skills, by testing occasion and group.

	Group					
	HYP + META ($n = 47$)			HYP ($n = 48$)		
	Pretest	Posttest	d	Pretest	Posttest	d
Skills	M (SD)	M (SD)		M (SD)	M (SD)	
Comprehension skills	14.9 (6.4)	25.7 (7.5)	1.64	15.2 (6.8)	20.1 (7.2)	0.74
Design skills	7.4 (5.1)	14.7 (5.8)	1.43	7.0 (5.3)	11.7 (5.6)	0.79

Table 3
Preservice teachers' means (and SD) and Cohen's d effect sizes for the three SRL components by testing occasion and group.

SRL components	Group					
	HYP + META ($n = 47$)			HYP ($n = 48$)		
	Pretest	Posttest	d	Pretest	Posttest	d
	M (SD)	M (SD)		M (SD)	M (SD)	
Cognition	4.1 (1.3)	5.6 (1.5)	1.07	4.0 (1.3)	4.4 (1.3)	0.40
Metacognition	3.6 (1.3)	4.9 (1.5)	0.93	3.5 (1.3)	4.0 (1.3)	0.36
Motivation	4.5 (1.4)	5.9 (1.9)	0.85	4.4 (1.3)	5.0 (1.8)	0.48

3.3. Event-based SRL

A repeated measures 2(testing occasion) × 2(group) × 2(task) ANOVA on each of the four reflection categories with testing occasion as within subjects factor. Table 4 presents the mean scores, standard deviations and effect sizes of the comparisons, and Table 5 presents the *F* values and effect sizes.

The results indicated significant main effects of testing occasion and task, and interactions between all independent variables (testing occasion, group, and task) regarding the dependent variables of reflection categories. At the end of the study, preservice teachers in both groups improved their reflections on each of the four categories (planning, monitoring, debugging, and evaluation). However, the HYP + META group outperformed the HYP students in all reflection categories and in both perspectives, that is, learner (comprehension task) and teacher (design task) perspective.

The effect sizes (Colen's *d*) for the pre- and posttest differences within each group showed that at the end of the study the preservice teachers in both groups revealed better quality reflections from the learner's perspective (in the comprehension task) compared to the reflections from the teacher's perspective (in the design task), mainly on the planning and evaluation categories. In particular, at the end of the study (Cohen's $d = 1.18$ and 0.37 for planning, and 1.69 and 0.86 for evaluation, for HYP + META and HYP groups, respectively).

3.4. Relations between SRL and TPCK

Table 6 presents the significant correlations between the two SRL dimensions (SRL as an aptitude and event-based SRL reflections) and the two TPCK skills (comprehension vs. design skills) in the total sample and in each learning environment separately (HYP + META and HYP). As seen for the whole sample, significant correlations emerged. Furthermore, significant correlations emerged between the SRL components and the TPCK skills. However, the reflection scores on comprehension and design tasks (learner and teacher perspective, respectively) correlated higher with the design skills than with the comprehension skills. As seen for the lower two parts of the table, significantly higher correlations (Fisher's *Z*) emerged between all measures in the HYP + META group than in the HYP group.

4. Discussion

The findings of the present study indicated that preservice teacher training for TPCK in a hypermedia environment, when combined with metacognitive support in the form of self-questioning guidelines (HYP + META), was more effective in developing TPCK (both for comprehension and design skills), and fostering SRL (both as an aptitude and as event-based online reflections), compared to such training without explicit metacognitive support, thus, verifying Hypotheses 1 and 2. Furthermore, the findings indicated significantly higher correlations (Fisher's *Z*) between all measures in the HYP + META group than in the HYP group, thus, verifying Hypothesis 3. These outcomes suggest interesting directions for unraveling the effects of preparing preservice teachers' SRL for developing TPCK in hypermedia environments.

4.1. TPCK in the hypermedia environment

The findings of the present study indicated that both groups (HYP + META and HYP) developed their TPCK for comprehension and design skills. In particular, the results showed that the HYP + META group succeeded more in designing TPCK units that integrated technological cognitive tools for constructing meaning in learner-centered environments. These findings support conclusions that "it is what people do with the machine, not the machine itself that makes a difference" (Mehan, 1989, p. 19). In particular, the present results coincide with Angeli and Valanides's (2005, 2008a, 2008b) findings that preservice teachers must be explicitly taught about the interactions among technology, content, and pedagogy. Our findings are in line with the conclusion that metacognitive support is a vehicle for promoting learning (Kramarski, 2008; Kramarski & Mevarech, 2003; Kramarski & Michalsky, 2009; Quintana et al., 2005; Schraw et al., 2006; Veenman et al., 2006). IMPROVE metacognitive questions tapping comprehension, connection, strategy use, and reflection, could help teachers to (a) think what learning/teaching steps they need to take in their work; (b) identify which content of a task is suitable for teaching in technology context; (c) decide how they should transform the content to make it

Table 4
Preservice teachers' means (and SD) and Cohen's *d* effect sizes for reflection categories by task, testing occasion, and group.

Reflection categories	Group						Group					
	HYP + META ($n = 47$)			HYP ($n = 48$)			HYP + META ($n = 47$)			HYP ($n = 48$)		
	CO	Design	*d*	CO	Design	*d*	CO	Design	*d*	CO	Design	*d*
	M (SD)	*M* (SD)		*M* (SD)	*M* (SD)		*M* (SD)	*M* (SD)		*M* (SD)	*M* (SD)	
Planning	1.97 (0.51)	1.32 (0.55)	1.22	1.22 (0.62)	1.01 (0.58)	0.35	2.29 (0.62)	1.57 (0.60)	1.18	1.43 (0.58)	1.21 (0.51)	0.37
Monitoring	2.02 (0.64)	1.74 (0.57)	0.47	1.39 (0.51)	1.12 (0.58)	0.50	2.39 (0.51)	2.17 (0.58)	0.40	1.66 (0.58)	1.39 (0.57)	0.47
Debugging	1.84 (0.52)	1.41 (0.57)	0.78	1.29 (0.64)	1.17 (0.59)	0.19	2.21 (0.64)	2.08 (0.60)	0.20	1.48 (0.59)	1.33 (0.54)	0.27
Evaluation	2.12 (0.44)	1.57 (0.54)	1.12	1.55 (0.40)	1.24 (0.44)	0.73	2.55 (0.40)	1.84 (0.44)	1.69	1.74 (0.44)	1.36 (0.44)	0.86

CO = Comprehension.

Table 5
F values and partial η^2 effect sizes of the repeated measures ANOVAs for reflection categories by task, testing occasion, and group.

Variable or interaction	Reflection category							
	Planning		Monitoring		Debugging		Evaluation	
	F(1, 91)	Partial η^2	F(1, 91)	Partial η^2	F(1, 91)	Partial η^2	F(1, 91)	Partial η^2
Testing occasion (pretest vs. posttest)	47.24	0.41	54.13	0.54	42.17	0.37	58.44	0.58
Group (HYP + META vs. HYP)	39.78	0.39	32.14	0.34	43.19	0.43	48.16	0.49
Task (comprehension vs. design task)	54.13	0.52	39.18	0.31	40.11	0.34	51.16	0.48
Testing occasion × group	45.18	0.48	29.18	0.26	31.18	0.29	38.01	0.42
Testing occasion × task	67.46	0.57	72.16	0.62	75.36	0.71	78.24	0.78
Group × task	38.54	0.35	31.43	0.29	34.71	0.31	36.62	0.32
Testing occasion × group × task	18.35	0.25	24.19	0.29	16.14	0.21	12.18	0.18

$p < 0.001$.

teachable to their students; and (d) find out how tool affordances could support constructing meanings with learner-centered pedagogy; and (e) why. Further research should examine this conclusion in different hypermedia environments and different kinds of metacognitive support regarding preservice teachers' preparation.

The findings revealed an effect of the task context on preservice teachers' TPCK. We found a positive correlation between comprehension and design skills in both hypermedia environments ($r = 0.58$ and 0.49, respectively, for the HYP + META and HYP groups). These findings support the conclusion about the importance of explicitly practicing comprehension skills, as a prerequisite for establishing design skills. Furthermore, the findings demonstrated (Table 4) a higher level of self-reflections on the comprehension task, whereas preservice teachers continued to demonstrate relative difficulties in reflecting on the design task. Our results suggest that designers of preservice teacher instructional programs should invest more explicit metacognitive support focusing directly on the perspective (as learner or as teacher) taken by the teacher (Leelawong et al., 2002; Perry, Phillips, & Hutchinson, 2006).

Table 6
Correlations Fisher's Z between SRL as an aptitude, event-based SRL, and TPCK Skills in the whole sample and the two groups.

	SRL			TPCK	
	Aptitude	Reflections (comprehension)	Reflections (design)	Comprehension skills	Design skills
Whole sample ($n = 95$)					
SRL as an aptitude	–				
Reflections on comprehension task (learner perspective)	0.46**	–			
Reflections on design task (teacher perspective)	0.41**	0.39**	–		
Comprehension skills	0.31*	0.35**	0.41*	–	
Design skills	0.37**	0.49**	0.53**	0.52**	–
HYP + META ($n = 47$)					
SRL aptitude	–				
Reflections on comprehension task (learner perspective)	0.57**	–			
Reflections on design task (teacher perspective)	0.52**	0.48**	–		
Comprehension skills	0.37*	0.41**	0.49*	–	
Design skills	0.43**	0.55**	0.57**	0.58**	–
HYP ($n = 48$)					
SRL aptitude	–				
Reflections on comprehension task (learner perspective)	0.38**	–			
Reflections on design task (teacher perspective)	0.42*	0.31*	–		
Comprehension skills	0.27*	0.36**	0.41**	–	
Design skills	0.37**	0.42**	0.48**	0.49**	–

* $p < 0.01$. ** $p < 0.001$.

4.2. SRL as an aptitude and as event-based

Most theories on self-regulation claim that better self-regulation leads to better learning outcomes (Butler & Winne, 1995; Pintrich, 2000; Schraw et al., 2006; Zimmerman, 2000, 2008). According to Veenman (2007), many instructional studies merely report effects on learning outcomes rather than on the mediating role of self-regulatory behavior. However, in order to account for the effectiveness of SRL, ‘‘a causal chain of instruction leading to improved self-regulatory behavior and, thus, leading to better learning outcomes should be established’’ (Veenman, 2007, p. 178). The present study supports this claim, inasmuch as the findings indicated higher positive relations between SRL measures (self-reports and online reflections), and between the TPCK and SRL (both measures) within the HYP + META group than among the HYP preservice teachers.

The findings of the present study on SRL outcomes for the two hypermedia learning conditions substantiate previous research, which concluded that explicit provision of metacognitive support is necessary to understand the rationale and effective procedures of self-regulation (Kramarski & Gutman, 2006; Kramarski & Michalsky, 2009; Schraw et al., 2006; Veenman et al., 2006; Zimmerman, 2000, 2008). Furthermore, the online reflections allow for empirical observation on real time self-regulation components, including planning, monitoring, debugging, and self-evaluation. It seems that the preservice teachers' process of repeatedly answering metacognitive questions can be conceptualized as a kind of self-regulation of their learning process, which has a synergic effect on all SRL components (cognitive, metacognitive, and motivational beliefs).

It was found that the HYP + META group exhibited a learner perspective advantage, that is, more reflections on the comprehension task, at the pretest. This may be explained by the fact that the SRL event reflections were collected from the forum discussions in the second 4-h workshop. It might be that preservice teachers' reflections were affected by their instructor's SRL behaviors that were internalized from the SRL training. Future research should address this issue of controlling such initial effects.

4.3. Practical implications, future research, and limitations

The study described here makes an important contribution to theoretical research and practical implications regarding teacher technology-related education (TPCK), moving it in a new direction by integrating SRL into the TPCK framework. The TPCK of preservice teachers who learn in HYP + META environments is a relatively new topic that has not yet been investigated. The data presented here indicate that beginning teachers can engage in practices that promote SRL for comprehending and designing tasks in technology environments (TPCK). Attention to features of SRL dimensions that support learner-centered approaches in TPCK contexts should be a continuing goal. The current research expanded the IMPROVE model to technological pedagogical contexts for university students, and we suggest that further studies devise and apply not only this but also other metacognitive models for preservice and inservice teachers studying in different technology environments.

Although the present study potentially offers contributions to theoretical research examining the role of SRL in preparing preservice teachers in TPCK contexts, we recognize several limitations inherent in the study. First, implementation of each learning environment by only one teacher in one classroom could have confounded the teacher/classroom with the instructional environment. Second, teaching ability was assessed only by assessing teachers' understanding of tasks and design of a study unit in a hypermedia environment rather than by observing their actual classroom practice. Similarly, SRL self-reports do not necessarily demonstrate whether teachers are actually better at SRL and whether they actually better foster their students' SRL as measured by learning outcomes. Further research should examine the effects of different SRL technology environments on a larger preservice scale, and by observing actual classroom practice. Such data should be connected directly to students' SRL as measured by learning outcomes. Furthermore, comparisons to control groups that are not exposed to technology may help in understanding the effects of SRL in TPCK contexts.

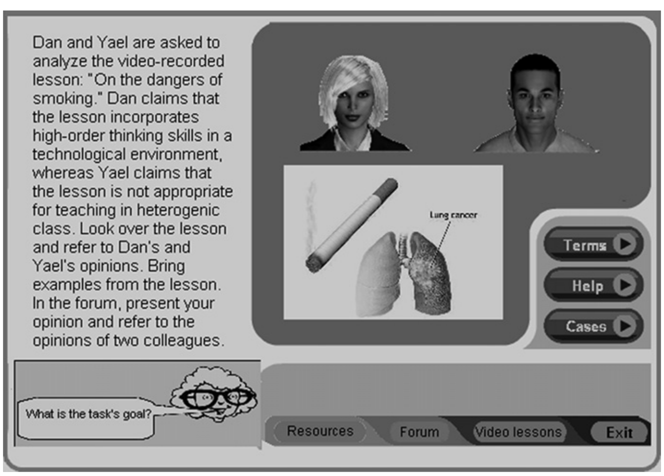
The aim of the present study was to examine the effects of metacognitive support on SRL as an aptitude and as event-based. The SRL online reflection measure provided rich data referring to various components of SRL processes in both perspectives (learner and teacher). However, these data were gathered in real time only twice, at the beginning and the end of the learning process; thus, we cannot draw conclusions on the pattern of SRL behaviors during the whole learning period. Event-based online reflections were assessed only twice because reflecting on the learning process using the Regulation of Cognition Index (Schraw & Dennison, 1994) asks participants to refer in writing to their planning, monitoring, debugging, and evaluation of the process; if it were continuously administered during learning, then that would function as a metacognitive support. Therefore, we were concerned about the possible confounding effect of using two metacognitive supports concurrently. Future studies should implement other event-based measures with time-series analysis techniques to maintain observation of only one metacognitive support (Zimmerman, 2008). Moreover, it was found that SRL was promoted in real time by both interventions, but it is less clear whether there are ‘‘enduring’’ dispositional changes. Further research should conduct long-term follow-ups to test this claim (e.g., at 6 months and 12 months after intervention), including evaluations of both kinds of SRL (as an aptitude and as event-based).

In the present study, preservice teachers practiced in pairs on online forums. However, their regulation of learning was assessed individually. The need to use other methods to assess co-regulation of each pair in authentic settings is obvious. Such methodologies should employ complementary means to assess SRL as an aptitude (questionnaires) and as event, such as thinking aloud, observations, log-files, and forum discussions, which may shed further light on the effects of metacognitive support on cooperative regulation and academic performance (Azevedo, 2005; Veenman, 2007).

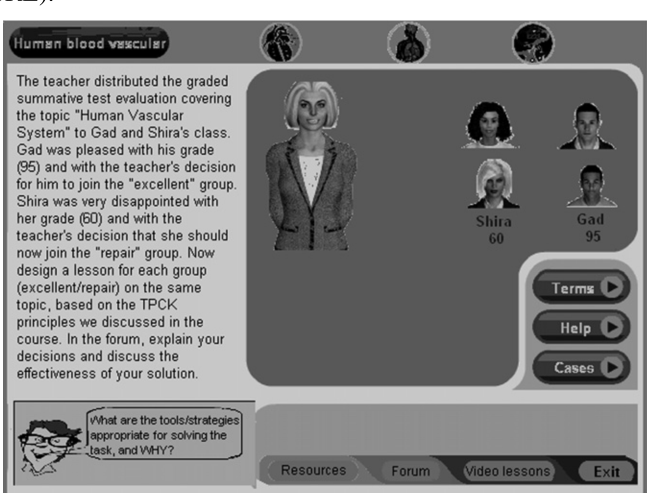
In conclusion, the present study calls for further scrutiny of how preservice teachers' SRL in TPCK emerges in the context of self-regulatory learning environments. This call for research reflects the urgency of the new goals in teacher training. These goals suggest that teacher training should find ways to help preservice teachers construct TPCK knowledge through learner-centered approaches in diverse technology environments (National Council for the Accreditation of Teacher Education, 2002).

Appendix A. Sample hypermedia screen shots for two pedagogical cases with pop-up question for HYP + META condition only

Screen 1: Comprehension task (Learner's perspective: Preservice Teachers' SRL).



Screen 2: Design task (Teacher's perspective: Students' SRL).



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