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Effects of 'Environmental Chemistry' Elective Course Via Technology-Embedded Scientific Inquiry Model on Some Variables

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Abstract The purpose of this study is to examine the effects of 'environmental chemistry' elective course via Technology-Embedded Scientific Inquiry (TESI) model on senior science student teachers' (SSSTs) conceptions of environmental chemistry concepts/issues, attitudes toward chemistry, and technological pedagogical content knowledge (TPACK) levels. Within one group pre-test–post-test design, the study was conducted with 117 SSSTs (68 females and 49 males—aged 21–23 years) enrolled in an 'environmental chemistry' elective course in the spring semester of 2011–2012 academic-years. Instruments for data collection comprised of Environmental Chemistry Conceptual Understanding Questionnaire, TPACK survey, and Chemistry Attitudes and Experiences Questionnaire. Significant increases in the SSSTs' conceptions of environmental chemistry concepts/issues, attitudes toward chemistry, and TPACK levels are attributed to the SSSTs learning how to use the innovative technologies in the contexts of the 'environmental chemistry' elective course and teaching practicum. The study implies that the TESI model may serve a useful purpose in experimental science courses that use the innovative technologies. However, to generalize feasibility of the TESI model, it should be evaluated with SSSTs in diverse learning contexts.

Keywords Technology-Embedded Scientific Inquiry · Conception · Attitude · TPACK · Environmental Chemistry · Senior science student teacher

Introduction

An explosion at information communication technology (ICT), which has occurred at the beginning of the new millennium, has displayed great impacts on education (Xie and Reider 2013). For this reason, educational researchers have paid more attention on how to integrate or incorporate these technologies into instructional activities to scaffold students' learning (Zhang 2013). These attempts have yielded various functions and features of the technologies. For example, Linn (2003) labeled the technologies in science education in five areas: science texts and lectures; science discussions and collaboration; data collection and representation; science visualization; and science simulation and modeling. These technologies are called information technology (IT) (e.g., Xie and Reider 2013),

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information communication technology (ICT) (e.g., Linn 2003), learning technology (e.g., Atwater 2000; Krajcik 2002; Lynch 2000), new technology (e.g., Krajcik et al. 2000), or innovative technology (InT) (e.g., Calik 2013; Ebenezer et al. 2011, 2012; Xie and Reider 2013). For this current study, 'Innovative Technology (InT)' term addresses the technologies (e.g., online discussion boards, Technology-Embedded Scientific Inquiry (TESI) Web site, sensors, probes, Logger Pro software, GPS) that senior science student teachers (SSSTs) initially encountered in the 'environmental chemistry' elective course. Phrased differently, InT means an innovation for the sample under investigation, not a broader sense of the innovation (e.g., Karasar 2004).

Whatever terms are used, they ultimately have advantageous impact on science teaching and learning (Linn 2003). For example, they can enable the students and teachers to (a) extend their thinking, (b) create multiple representations of their understanding, (c) communicate with each other, (d) experience scientific phenomena, and (e) conduct investigations to perform scientific inquiry (e.g., Edelson 1998; Krajcik 2002; Linn 1998; Spitulnik et al. 1998; Zhang 2013). This means that the technological tools hold promise to change science classrooms by supporting students in inquiry and an in-depth understanding of science concepts (e.g., Krajcik 2002).

Given National Research Council's (NRC) (2011) statement '*Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. Both elements—knowledge and practice—are essential* (p. 2–3),' the technologies used in science education have a great potential to combine scientific concepts with hand-on and/or minds-on (technological) practices in science learning (e.g., Xie and Reider 2013). For instance, Sánchez and Olivares (2011) deployed mobile serious games (MSGs) as primary platforms to implement several learning activities of science concepts (e.g., fish, amphibian, reptile, bird, habitat, biological evolution) for the development of secondary students' problem-solving and collaborative skills. They reported that the experimental group performed better in perceiving their own collaboration skills and planning execution dimension of the problem-solving cycle than did the non-equivalent control group. Similarly, Ebenezer et al. (2011, 2012) employed InT and IT to train the teachers in the summer institutes. Hence, the teachers and their students made sense of how technologies were connected and behaved in the scientific inquiry and environmental research projects. Further, Xie and Reider (2013) analyzed the outcomes of an innovative technology experience (i.e., geographic information system and information assurance) for students and teachers (ITEST) project funded by the NSF ITEST program. They found that the Mayor's Youth Technology Corps (MYTC) students indicated a great growth in nearly every area in the surveys, containing dispositions about Science, Technology, Engineering and Mathematics (STEM) career and learning. To sum up, the foregoing studies reveal that the balance between knowledge and practice requires the students/teachers to possess technological skills and link them with science concepts or learning or career. That is, the technological tools play a significant complimentary role to stimulate students' interests toward science/chemistry and their construction of scientific knowledge. This calls for equipping student teachers or teachers with integration of technological tools into science learning/teaching.

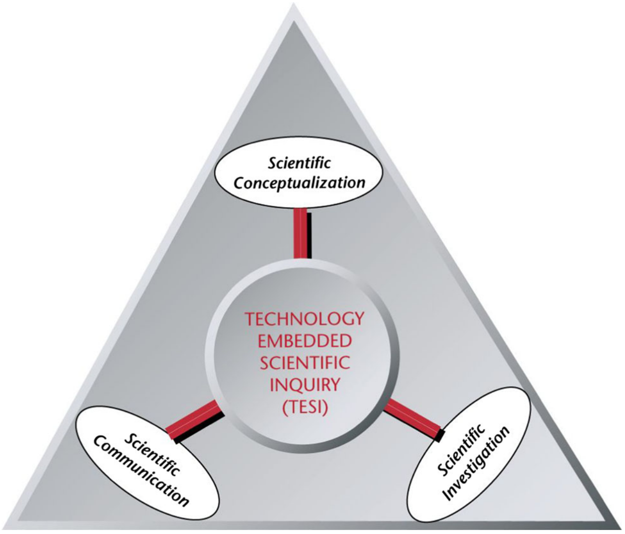


Fig. 1 TESI model (Ebenezer et al. 2011, p. 97)

Construction of scientific knowledge involves higher-order thinking skills that include scientific reasoning and critical thinking (e.g., Roth and Roychoudhury 1993; Tamir and Lunetta 1981). Because scientific inquiry as a higher-order thinking skill asks for student engagement (e.g., National Research Council 1996; Roschelle et al. 2000), the students' understanding of scientific knowledge and scientific processes depends on an epistemic framework relevant to physical, intellectual, and social contexts (e.g., Cobb and Bowers 1999; Çalık and Coll 2012; Çalık et al. 2013b). For this reason, many governments have globally made investments for adapting technologies in public schools (e.g., Kutluca 2012; Özsevgeç 2011) and encouraged the researchers to seek alternative models that enhance (student) teachers' technological competencies (e.g., Calik 2013). In this context, Ebenezer et al. (2011) suggest an epistemic framework called TESI (see Fig. 1) rooted in the US National Scientific Inquiry Standards (National Research Council 1996, 2000). Their preliminary researches (Ebenezer et al. 2011, 2012) showed that the TESI model was effective in improving professional development of teachers and fostering them to transfer their gained skills into science classes. Given the idea ‘teachers teach as they were taught,’ this current study explores how to adapt the TESI model into ‘environmental chemistry’ elective course.

Theoretical Framework Underpinning TESI Model

The TESI model has two different traits: (a) interactions among three hallmarks of scientific inquiry (scientific conceptualization, scientific investigation, and scientific communication) and (b) the use of varied educational technologies to conceptualize, investigate, and communicate in the process of scientific inquiry (see Fig. 1).

Cognitive, behavioral, and social characteristics/indicators of the TESI model are as follows. *Technology-Embedded Scientific Conceptualization* enables the students to use subject matter knowledge to frame a problem of inquiry. Such technologies as probes and sensors may be used to test and clarify conceptual ideas. For example, students may be able to conceptualize the conductivity of mobile charged ions (anions and cations) and the concept of solubility using Texas Instrument-84 (TI-84), calculator-based laboratory (CBL), and conductivity sensor. Embedding InT into scientific conceptualization makes abstract chemical concepts concrete. *Technology-Embedded Scientific Investigation* uses digital tools and software applications to collect, display, and share data. For example, the amount of salt needed to lower the freezing point of ice can be measured using TI-84, CBL, conductivity sensor, and GPS to support or reject hypothesis. *Technology-Embedded Scientific Communication* uses virtual platforms to engage the students in actively taking part in dialogic discourse on research processes, results, claims, and arguments (Ebenezer et al. 2011). For example, the students will be able to share their gained results and ideas in previous hallmarks of the TESI model with peers, experts, and teachers through social networks (Facebook, MSN, twitter, discussion board, etc.) on the Internet.

Because the TESI model, alike an umbrella, embraces the InT, scientific inquiry, scientific investigation, scientific conceptualization, and scientific communication (Calik 2013), the current study employs the TESI model as a driving factor and deploys the ‘environmental chemistry’ elective course as a context. For this reason, any improvement in the current study is directly attributed to the TESI model that shapes and informs it. For example, senior science student teachers (SSSTs) are able to comprehend the environmental chemistry concepts/issues via InT in the first hallmark (Technology-Embedded Scientific Conceptualization) of the TESI model. Later, they are able to investigate environmental issues with InT by acting like scientists (e.g., identifying research questions/hypothesis, sampling, data collection, submission of report) in second hallmark (Technology-Embedded Scientific Investigation) of the TESI model. Also, TESI Web site, designed for the third hallmark (Technology-Embedded Scientific Communication) of the TESI model, gives a chance for the SSSTs under investigation to share their gained views and results with peers and project team. In brief, the current study is underpinned by each hallmark of the TESI model.

TESI Empirical Studies

The TESI model has been the subject of some preliminary studies at the international level (e.g., Calik 2013; Çalık et al. 2012; Ebenezer et al. 2011, 2012). Ebenezer et al. (2011) measured 125 grades 9–12 students’ perceptions of fluency with InT and levels of scientific inquiry ability. They concluded that the students improved their overall technologies by engaging into InT-embedded scientific practices since their scientific inquiry abilities were at the proficient level for 7 out of 11 criteria. Further, Ebenezer et al. (2012) probed a secondary science teacher’s experience of his professional development in InT when he attended the summer institutes organized by the US National Science Foundation. They reported that two mechanisms influenced the science teacher’s growth and his students’ perceptions of their InT fluency: (a) a personal commitment to developing his own and his students’ InT abilities in the context of doing environmental research projects and (b) an increase in class time devoted to science education due to schooltime scheduling policy. Believing that professional learning ought to begin at teacher preparation, Çalık et al. (2012) presented the effect of scientific investigation on the SSSTs’ scientific inquiry skills by means of preliminary data from project known as *Technological-Embedded Scientific Inquiry* (*TESI*): *Modeling and Measuring Pre-Service Teacher Knowledge and Practice*. They reported that the SSSTs’ environmental research papers generally showed various levels of scientific inquiry abilities. As an outcome of the same project, Calik (2013) investigated the effect of the ‘environmental chemistry’ elective course via the TESI model on the SSSTs’ self-efficacy. He indicated that the proposed TESI model was feasible for the related context and resulted in increasing the SSSTs’ self-efficacy. For a further study in a Turkish University, the researchers used a methodological framework guided by the theory underpinning *technological pedagogical content knowledge* (*TPACK*) (Mishra and Koehler 2006) to measure the SSSTs’ pedagogical content knowledge (PCK).

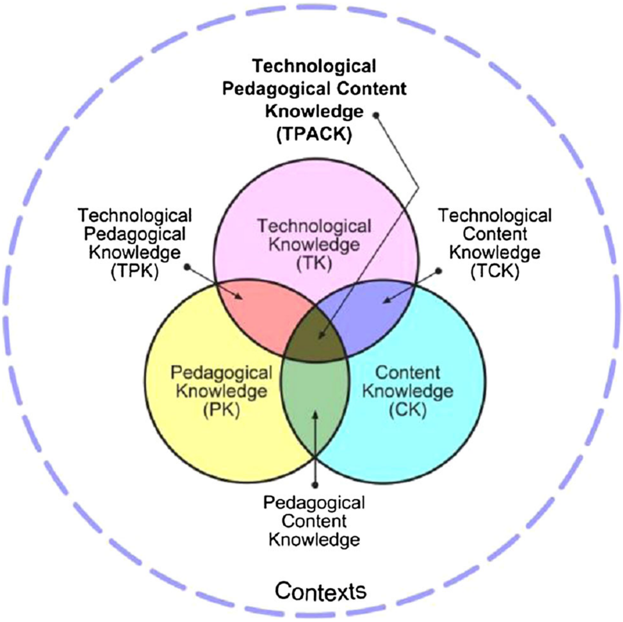


Fig. 2 Technological pedagogical content knowledge (Koehler and Mishra 2008, p. 12)

Theory Underpinning TPACK

Because TPACK points out the complex, multifaceted, and situated nature of teacher knowledge (Koehler and Mishra 2008), the researchers have stressed the relationships among technology, content, and pedagogy using different labels: information, communication, and technology (ICT)-related PCK (e.g., Angeli and Valanides 2005); technological content knowledge, electronic PCK, or e-PCK (e.g., Irving 2006). In this article, we have retained the original term TPACK with reference to the relationships among content, pedagogy, and technology suggested by Hughes (2004), Niess (2005), Mishra and Koehler (2006). Also, the TPACK term seems more reasonable in that the TESI model includes several InT, i.e., online discussion boards, TESI Web site, sensors, probes, Logger Pro software.

Similar to the TESI model, the TPACK is anchored in a theoretical framework that advocates the integration of technologies into classroom instruction (Mishra and Koehler 2006; Thompson and Mishra 2007–2008). This framework links students' content-related learning needs with particular content-based learning activities and related educational technologies (e.g., Harris and Hofer 2006).

Figure 2 visually represents complex interplay of three primary forms; content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). For example, the SSSTs know the InT used in the current study as technological knowledge. Further, they are able to learn sufficient knowledge of the environmental chemistry concepts as content knowledge. Also, they grasp a wide range of teaching approaches (as pedagogical knowledge) in the 'environmental chemistry' and 'teaching practicum' classroom settings.

The intersections of three primary forms of knowledge arise to pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). The TCK adapts technology to facilitate comprehension of subject matter by diverse students and learning styles. The PCK indicates how subject matter can be organized, adapted, facilitated, and presented. The TPK is about knowledge of the existence of technologies and ability to integrate them into teaching and learning. For the 'environmental chemistry' elective course, the SSSTs acquire the PCK on how to select effective teaching approaches (i.e., TESI model) to guide student thinking and science learning. Also, they figure out the TCK to employ InT into teaching practicum. Further, the TPK shows how the SSSTs think more deeply about effect of the InT on the teaching approaches used in the 'environmental chemistry' classroom setting. Overall, the 'environmental chemistry' elective course stimulates the SSSTs' TPACK level by illustrating how to appropriately combine science, technologies, and teaching approaches.

This visual organizational structure of the TPACK may be used for identifying what teachers or student teachers need to efficiently integrate technology into their classes (Archambault and Crippen 2009). To develop the SSSTs' TCK level, the current study used probes, sensors, GPS, photometer, and Logger Pro software for graphing and piloting data in the disciplines 'environmental chemistry and/or science and technology.' To improve their TPK level, generic communication learning technologies, i.e., online discussion boards, TESI Web site, animations and simulations, and InT (Ebenezer et al. 2011), e.g., measurement tools (probes and sensors) and Logger Pro software, were exploited.

The three hallmarks of the TESI model somewhat overlap the components of the TPACK. For example, the TCK may be considered equivalent to the first hallmark (Technology-Embedded Scientific Conceptualization) of the TESI model. Also, even though technology plays a significant role in both the TESI model and TPACK, previous studies have not explored the effects of the 'environmental chemistry' elective course via the TESI model on the SSSTs' attitudes toward chemistry and their TPACK levels. In order to assess the feasibility of the TESI model, further studies should be undertaken on different variables. Our study at hand focuses on the SSSTs' conceptions, attitudes, and TPACK levels.

Literature Review on Environmental Chemistry Studies

This section critically analyzes the characteristics of the environmental chemistry studies which implemented inquiry- or context-based approaches with pre-service teachers or secondary students. Students' understanding of the environmental chemistry issue/content has been investigated by Mandler et al. (2012), Amarasiriwardena (2007), Nugultham and Shiowatana (2010) and Robelia et al. (2010). Developing a unit 'I Have Chemistry with the Environment,' Mandler et al.'s (2012) students underwent a significant change in their awareness of environmental issues and especially appreciated the feeling that they could discover things by themselves. Similarly, a project-based laboratory approach teaching analytical atomic spectroscopy advances in an environmental chemistry class (Amarasiriwardena 2007) offered the undergraduate students with an opportunity to work on a local agricultural and environmental issue using the theoretical knowledge gained from the class. As a matter of fact, Amarasiriwardena's (2007) students were not only exposed to an authentic environmental analytical chemistry issue, but also experienced the analytical chemical challenges associated with working on 'real-world' samples. Similarly, inquiry-based learning via experimental kits by Nugultham and Shiowatana (2010) enabled the students to learn essential concepts of water quality. In contrast, adding environmental perspectives to a developmental chemistry course, Robelia et al. (2010) reported that environmental chemistry assessments showed no significant difference between the comparison (which used everyday chemistry examples, e.g., pH of household substances) and treatment (which employed environmental chemistry perspective, i.e., pH of acid rain from different places in the local environment) groups. Studies on students' changes in attitudes, behaviors, awareness, and motivation toward science/chemistry were conducted by Karpudewan et al. (2011), Mandler et al. (2012), and Robelia et al. (2010). Karpudewan et al. (2011) addressed that the green chemistry experiments (i.e., heating and cooling with lauric acid, production of biodiesel, visualize the impact of global warming), as a potential source, improved the pre-service teachers' self-determined motivations. Similarly, involving an environmental context in the chemistry curriculum, Mandler et al. (2012) modified the students' perceptions of chemistry and made them become more aware of the relationships between chemistry and society. Likewise, Nugultham and Shiowatana (2010) pointed the effect of the inquiry-based learning on discussing science more within a novel environment. On the contrary, Robelia et al.'s (2010) students in the comparison and treatment groups did not significantly change their awareness/concern for the environment during the semester.

Existing environmental research studies on pre-service teacher is sparse but does provide a context to situate this study. That is, they indicate that the 'environmental chemistry' context/course enables the students to take several (societal) issues/concepts (e.g., drinking water quality and the greenhouse effect—Mandler et al. 2012) into account to conduct scientific investigation via the InT. Hence, it can drive the students to acquire the scientific inquiry abilities. Further, experimental kits or technological tools have a potential to enhance the student teachers' self-determined motivation (e.g., Karpudewan et al. 2011) that is a prerequisite for a 'need to know' basis to teach (environmental) chemistry (e.g., Ültay and Çalık 2012). In brief, these studies also call upon a study that will concentrate on how the 'environmental chemistry' elective course via the TESI model may influence the SSSTs' conceptions, attitudes, and TPACK levels. Such a study will provide more evidence on discrepant issues in the aforementioned studies and shed more light on integration of the InT into teaching science/chemistry. This study, therefore, purposes to examine the effects of the 'environmental chemistry' elective course via TESI model on the SSSTs' conceptions of environmental chemistry concepts/issues, attitudes toward chemistry, and TPACK levels. The following research questions guide the study:

1. Is there any significant difference between pre- and post-test mean scores of the SSSTs' TPACK levels?
2. Is there any significant difference between pre- and post-test mean scores of the SSSTs' conceptions based on the Environmental Chemistry Conceptual Understanding Questionnaire (ECCUQ)?
3. Is there any significant difference between pre- and post-test mean scores of the SSSTs' attitudes toward chemistry based on the Chemistry Attitudes and Experience Questionnaire (CAEQ)?

Methodology

Because the current study evaluated the SSST's conceptions, attitudes, and TPACK levels by means of pre- and post-test scores, the research design is thus simple causal design (Trochim 1999). The term 'Causal design' means to find the cause(s) and effect(s) or relationships between two or more variables. In the context of our study, this term addresses effects of the 'environmental chemistry' elective course via the TESI model (as an independent variable) on dependent variables (conception, attitudes, and TPACK levels). Given an educational consensus about control–experimental comparisons (e.g., Zhang 2013), a lack of random assignments and control group may be viewed as more validity threat to this research design. Indeed, random assignment for a short period of the treatment is not always possible and feasible in an educational context because of some administrative issues/procedures. However, Trochim (1999) sees the main validity threat as being involved in an 'experiment.' That is, the teaching intervention described in our study may result in an apparent improvement in conception, attitude, and TPACK levels because the experimental group is exposed to the teaching intervention within a significant amount of time. It is, therefore, obvious that the students in the experimental group are bound to perform better than those in the control group as compared with the post-test scores (e.g., Calik 2013; Çalık et al. 2010; Karslı and Çalık 2012; Sadler 2009). Further, using assessments of content directly aligned with the enacted curriculum may result in higher post-test scores (Sadler 2009). Moreover, it is worth arguing that such a control–experimental research design cannot fully meet the needs for studying a multifaceted technology design, alike the current study, which involves in dozen elements and features of the learning environment (e.g., Zhang 2013). For these reasons, the researchers employed only one experimental group design without control one and tried to exploit the underlying science content of the 'environmental chemistry' key concepts/issues in ECCUQ but not directly align with the curriculum.

Participants and Their Backgrounds

The participants comprised of 117 SSSTs (68 females and 49 males—aged 21–23 years) enrolled in the 'environmental chemistry' elective course in the spring semester of 2011–2012 academic-years. Thus, the intervention lasted 14 weeks. The SSSTs were in the final semester of their final (senior) year. However, three of the SSSTs were dropped from this study because of their absence in either the pre-test or the post-test. Before this study began, the SSSTs were required to fill consent forms that emphasized assurances of confidentiality.

Science teacher education includes three integrated major disciplines (chemistry, biology, and physics). For this reason, the 'environmental chemistry' elective course is viewed as a part of chemistry in the science teacher education. Prior to the 'environmental chemistry' elective course, the SSSTs had attended 'special topics in chemistry' compulsory course in their third-year program covering such topics as *structure of the atmosphere*, *air pollution*, *nuclear power generation*, *water pollution*, *pollutants from industry and agriculture*, *chemistry and food*, *chemistry industry*, *and relationship between chemistry and environment*. Further, they took 'instructional technologies and material design' course in their third-year program, consisting of such topics as *instructional technology concepts*, *characteristics of various instructional technologies*, *technology needs of the school*, *developing two- and/or three-dimensional materials* (*e.g.*, *transparencies and PowerPoint*) *and teaching materials* (*i.e.*, *worksheet*), via *instructional technologies*, *identifying qualities of computer-based materials—animations*, *simulations*, *VCD and DVD—using Internet and other instructional technologies in Turkey*.

In their final year, the SSSTs mandatorily attends 'teaching practicum' course; however, the integration of technologies in teaching practicum is not always a requirement for all SSSTs. If the content of the 'science and technology' course in lower secondary school lends itself for technology integration, the SSSTs are usually expected to prepare PowerPoint presentations for starting a discussion environment and to use animations and simulations to enhance student learning of science. However, the SSSTs do not necessarily put forth conscientious effort to integrate technologies into science curriculum and pedagogy.

Development of Instruments and Data Collection

To measure the SSSTs' conceptions of the environmental chemistry issues, an 8-item questionnaire (called Environmental Chemistry Conceptual Understanding Questionnaire—ECCUQ) was developed and used (see Appendix 1 at Supplementary Material). To identify the SSSTs' TPACK levels, TPACK survey (see Appendix 2 at Supplementary Material) developed by Schmidt et al. (2009) was initially translated from English into Turkish and adapted into the 'environmental chemistry' and 'teaching practicum' course contexts by the project team (two science educators with PhD degrees and five graduate students). During this procedure, they checked the translation and ensured validity of constructs and readability. In fact, the original TPACK survey with 39 items (6 items for TK, 3 items for CK, 7 items for PK, one item for PCK, one item for TCK, 9 items for TPK, one item for TPACK, 8 items for Models of TPACK—Faculty, mentor teachers, and 3 items for Models of TPACK) was modified into its adapted version with 32 items. For instance, Item 7 (*I have sufficient knowledge about science*) and Item 10 (*I know how to assess student performance in a classroom*) in the original TPACK survey were changed in the adapted version with the statements '*I have sufficient knowledge about environmental chemistry*' and '*I know how to assess student performance in a classroom in* '*teaching practicum*' *course*,' respectively. Also, Items 29–35 in the original TPACK survey (*My mathematics education/literacy education/science education/social studies education/instructional technology/educational foundation/outside of education professors appropriately modeled combining* *content*, *technologies*, *and teaching approaches in their teaching*) were combined in Item 29 (*My professor teaching* '*environmental chemistry*' *course appropriately modeled combining content*, *technologies*, *and teaching approaches in his teaching*). Similarly, Items 37–38 in the original survey (*In general*, *approximately what percentage of your teacher education professors/your professors outside of teacher education have provided an effective model of combining content*, *technologies*, *and teaching approaches in their teaching*?) were combined with Item 31 (*In general*, *approximately what percentage of your professor teaching* '*environmental chemistry*' *course has provided an effective model of combining content*, *technologies*, *and teaching approaches in his teaching*?).

Because the 'environmental chemistry' elective course acts as a part of chemistry in science teacher education, any attitude and experience with this course directly rely on the chemistry. Hence, the above procedure was also pursued for the Chemistry Attitudes and Experiences Questionnaire (CAEQ) (see Appendix 3 at Supplementary Material), which was improved by Dalgety et al. (2003, p. 663). In fact, the original CAEQ consisted of 21 items in different subscales (8 items for chemists, 4 items for chemistry research, one item for science documentaries, one item for chemistry Web sites, 5 items for chemistry jobs, one item for talking to my friends about chemistry, and one item for science fiction movies). To investigate comprehensibility and applicability of ECCUQ and TPACK, they were pilot-tested with 71 SSSTs in the spring semesters of 2010–2011 academic-years. Similarly, the adapted version of the CAEQ was pilot-studied with 290 student teachers (Ültay and Çalık 2011) and data were subjected to the confirmatory factor analysis. Three factors loaded: chemists for Items 1–6 and Item 8, chemistry research for Items 9–12, and chemistry jobs for Items 16–19. Therefore, 'science documentaries, chemistry Web sites, talking to my friends about chemistry, and science fiction movies' subscales were removed from the adapted version of the CAEQ. Item 15 (*from easy to challenging*) in the 'chemistry jobs' subscale (in the original CAEQ) was also eliminated. Likewise, the confirmatory factor analysis of the adapted TPACK appeared the same factors of the original TPACK: Technological knowledge for Items 1–6, environmental chemistry content knowledge for Items 7–9, pedagogical knowledge for Items 11–16, PCK for Item 17, technological content knowledge for Item 18, technological pedagogical knowledge for Items 19–27, technological pedagogical content knowledge for Item 28, Models of TPACK (Faculty, mentor teachers) for Items 29–30, and Models of TPACK for Items 31–32 (see Appendix 2 at Supplementary Material).

Table 1 Cronbach's alpha values for the data collection instruments in the pilot and real studies

Data collection instrument	Pilot study Cronbach's Alpha	Number of items	Real study Cronbach's Alpha
TPACK	0.95	32	0.96
ECCUQ	0.65	8	0.83
CAEQ			
General	0.82	15	0.92
Chemists	0.62	7	0.84
Chemistry research	0.76	4	0.90
Chemistry jobs	0.77	4	0.90

Table 2 Revisions in the ECCUQ after the pilot study

	The pilot study version of the items	Revised version of the items after the pilot study
Item 2	What types of the biochemical cycling are? How is this cycling relevant with environmental chemistry	Please address how types of the biochemical cycling are related to environmental chemistry
Item 6	Please state what should be carried out to reduce air pollution?	How are people able to reduce air pollution?
Item 7	Please explain causes and sources of soil pollution?	Please explain causes of soil pollution and their effects on the environment
Item 8	Please address effect of radioactive waste on environment	Please address how radioactive waste affects the environment

As indicated in Table 1, Cronbach's alpha values for the instruments in the actual study were higher than the acceptable value addressed by Hair et al. (2006). After the pilot study, some typographical revisions were made for the TPACK and the CAEQ. Moreover, some revisions were made in the ECCUQ for increasing its comprehensibility and fluency (see Table 2).

Although both Items 4 and 7 asked causes and sources of the environmental issues, the SSSTs in the pilot study tended to use the same statements for the causes and the sources. For this reason, the real study removed the term 'sources' from the foregoing items. An increase in Cronbach's alpha value for the ECCUQ pointed to the efficiency of the revised versions. The instruments described above were administered as a pre-test on the first week of the spring semester. After a 14-week teaching intervention, the instrument was employed as a post-test one week after the intervention was over.

Data were collected by handing out hard copies of the instruments to the SSSTs. They responded to the ECCUQ in their class, which took about one hour. To encourage the SSSTs to answer all questions, they were required to submit their responses to the TPACK and the CAEQ a few days later. Following this procedure provided the SSSTs ample time to reflect and elaborate their ideas (Calik 2011; Niaz 2008). In other words, the SSSTs responded to the instruments in their own time.

Data analysis

SPSS 15.0^{TM} was used to conduct paired-sample t test, Cronbach's alpha, and descriptive statistics. An adapted version of Abraham et al. (1994)'s criteria was used to label the SSSTs' responses to each item in the ECCUQ (see Appendix 1 at Supplementary Material). The criteria are as follows: *Sound Understanding* (*SU*) includes all the components of the validated response, *Partial Understanding* (*PU*) includes at least one of the components of validated response, but not all the components, and *No Understanding* (*NU*) includes irrelevant or unclear response or left blank. The researchers scored the data independently to confirm interrater consistency. Disagreement was resolved through negotiation. Possible responses to the TPACK survey (see Appendix 2 at Supplementary Material) used a five-point Likert scale: do not understand (zero point), strongly disagree (1 point), disagree (2 points), neither agree or disagree (3 points), agree (4 points), and strongly agree (5 points). In addition, the last two items of the survey (Items 31–32) used a four-point Likert scale to portray the Models of TPACK as follows: 25 % or less (1 point), 26–50 % (2 points), 51–75 % (3 points), and 76–100 % (4 points). A similar procedure was followed for the CAEQ (see Appendix 3 at Supplementary Material) composed of a seven-point Likert scale.

Intervention

The course lecturer (first author) taught the 14-week-long (2 h per week) 'environmental chemistry' elective course via the TESI model. This approach was new and different from the way the same course was taught in the Department of Science Education. The intervention embedded the InT and the TESI model in two contexts: the 'environmental chemistry' elective course and 'teaching practicum' course. In Turkey, all elective courses, as well as compulsory courses, are counted as whole-year course credits. That is, the 'environmental chemistry' elective course was counted as the course credits toward the whole-year study. In the final semester of the teacher preparation program, the SSSTs were required to choose either 'environmental chemistry' or 'scientific research methods-II' elective courses. The latter enables the SSSTs to carry out their research proposals they prepared in the 'scientific research methods,' which is a compulsory course in the third year of the program. This means that the SSSTs are grouped into the two elective courses. However, because of the popularity of our pilot study, 117 SSSTs enrolled in the 'environmental chemistry' elective course and 63 SSSTs in 'scientific research methods-II' elective course.

The SSSTs enrolled in the environmental chemistry elective course were asked to group themselves into small groups of two or three so that they could work collaboratively. The SSSTs were accustomed to work in small groups in such courses as general chemistry laboratory, general physics laboratory, general biology laboratory, laboratory applications in science and science teaching methods. Subsequently, each member of the small groups of the SSSTs was given access to the materials posted on the TESI Web site. Each week, the lecturer discussed environmental chemistry topics (see topics in Table 3) and demonstrated how to integrate the InT into teaching and learning science. Then, he requested the SSSTs to get help from the research project's scholars when they attempted to work with the InT. Based on the TESI project's research agenda (i.e., design technology, environmental education, pedagogical content knowledge, integration of technology in science education, chemistry attitudes, and experiences) five scholars, one from chemistry education and four from science education, were selected to help the SSSTs. For example, a scholar, who was interested in designing technology, served as the TESI Web site Webmaster.

The SSSTs were encouraged to use the TESI Web site to communicate with their peers, lecturer, and the scholars. They were also asked to share their ideas and course-related documents with their peers using the TESI Web site. For example, for each environmental chemistry topic, the course lecturer (first author) posted a question to prompt dialogue. He also monitored the SSSTs' views and required them to answer the question from the communication page prior to the lecture (see Fig. 3).

During the lecture, the lecturer used SSSTs' views posted on the discussion board to teach the environmental chemistry topic related to the question. Also, the SSSTs and the research project scholars were granted the freedom to initiate and contribute to discussion of the environmental chemistry issues or news relevant to the course on the discussion board. When the SSSTs were online, they were able to negotiate and communicate with their peers, lecturer, and scholars in chat rooms. When the SSSTs were off-line, they were able to send messages through the discussion board. The TESI Web site automatically sent the message as an alert e-mail to the respective SSSTs. Some dialogues in the TESI Web site embrace the subsequent types: sharing information, information seeking, feedback solicitation, negotiation, inquiry, providing information,

Table 3 Schedule for the 'environmental chemistry' elective course

Week	Face-to-face session	Innovative technologies introduced
Week 1	Introduced project team, project aims, and innovative technologies involved, the TESI Web site (www.ktutedba.ning.com), and its function in the project. Later, summarized content of the 'environmental chemistry' elective course and handed the TESI guide out	Introduced the innovative technologies
Week 2	Created a discussion environment on environmental education in Turkey (Çalık and Eames 2012), environmental chemistry, environmental pollution, and basic biochemical cycles (carbon, sulfur, nitrogen, phosphorus, oxygen) and discussed these issues with the SSSTs	Introduced and used some innovative technologies, i.e., calculator-based laboratory instrument, Texas Instrument, relative humidity sensor, global positioning system (GPS), and Logger Pro software
Week 3	Discussed the issues of air pollutants, ozone layer, and dispersion of the rays from the sun in space with the SSSTs	Introduced and used some innovative technologies, i.e., dissolved oxygen sensor, soil moisture sensor, and light sensor
Week 4	Taught and discussed global warming using news from mass media magazines	Practices with the innovative technologies
Week 5	Presented and discussed the issues of chemical reactions in the atmosphere and ozone layer depletion	Introduced and used some innovative technologies—temperature, turbidity, and pH sensors
Week 6	Taught and discussed the issues of greenhouse effect and acid rain	Introduced and used an innovative technology—photometry
Week 7	Mentored the SSSTs to use the innovative technologies in practice	Practices with the innovative technologies
Week 8	Presented and discussed the issues of photochemical smog, particles in air, and organic and inorganic particles. Instructed the SSSTs to devise a project topic by defining a scientific problem, generating hypotheses, and identifying methodology with appropriate sensors and probes	Introduced and used some innovative technologies, i.e., conductivity and flow rate sensors
Week 9	Discussed the issue of air pollution and its resources with the SSSTs	Introduced CO_2 sensor
Week 10	Presented and discussed the issues of soil pollution, water pollution, and cleaning up drinking water and underground water. Required the SSSTs to determine data collection and sampling procedure for their projects	Independent study for their projects
Week 11	Taught and argued the socioscientific issue of nuclear power and the effect of nuclear waste on the environment using news from mass media	Independent study for their projects
Week 12	Analyzed data they obtained and shared them with peers, lecturer, and scholars using the TESI Web site	Independent study for their projects
Week 13	Prepared their research reports	Independent study for their projects
Week 14	Submission of projects	–

In weeks 2–6, 9–11, the SSSTs were especially asked to communicate with peers, lecturer, and scholars using the TESI Web site

prompting deadlines for deadlines, giving feedback for refining work, launching a discussion, appreciating performance, etc. (see Çalık et al. 2013a for further information).

As part of the environmental chemistry elective course, the SSSTs were required to identify a topic for their research project and outline an appropriate procedure for data collection and sampling. In their small groups, the SSSTs collected and analyzed their data and prepared their research papers. Half of the research projects required them to travel to local sites to collect samples for analysis (i.e., *Investigating drinkable water qualities of Ankara and Trabzon*, *Determination of water quality in different regions*, *Determination of water quality in a local stream*

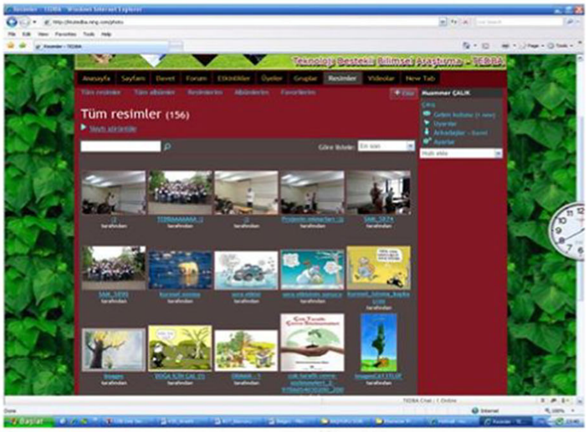
MAIN PAGE

LECTURER'S PAGE

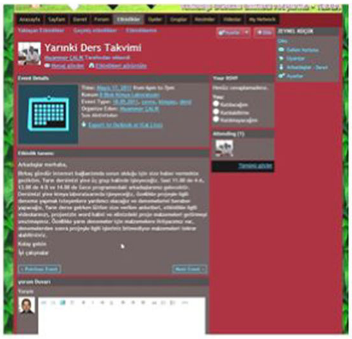
INVITATION PAGE FOR PEERS AND RELATED PEOPLE

SCHEDULED ACTIVITY PAGE

GROUPS AND THEIR MEMBERS



UPLOADED PICTURES AND PHOTOS



PROMPTED QUESTIONS FOR COMING LECTURING

DISCUSSION BOARD

Fig. 3 Some screens for the TESI Web site

Table 4 Descriptive statistic results of the TPACK domains

TPACK Knowledge Domains	Pre-test		Post-test	
	Mean	SD	Mean	SD
Technology Knowledge	3.41	1.09	4.10	0.74
Content Knowledge	3.02	0.91	4.22	0.64
Pedagogical Knowledge	3.74	1.00	4.32	0.59
Pedagogical Content Knowledge	3.62	0.95	4.21	0.52
Technological Content Knowledge	3.46	0.98	4.18	0.47
Technological Pedagogical Knowledge	3.50	1.02	4.27	0.61
Technological Pedagogical Content Knowledge (TPACK)	3.58	0.95	4.40	0.53
Models of TPACK (Faculty, mentor teachers)	2.86	1.42	4.34	0.58
Models of TPACK	2.19	0.95	3.37	0.73
General mean	3.26	1.03	4.17	0.60

Table 5 Descriptive statistic results of the ECCUQ

Items	Pre-test		Post-test	
	Mean	SD	Mean	SD
1. Please explain what environmental pollution and its types are	0.83	0.61	1.39	0.49
2. Please address how types of the biochemical cycling are related to environmental chemistry	0.67	0.65	1.10	0.38
3. Please depict how the relationship between quality of water and water purification is	0.68	0.55	1.18	0.38
4. Please discuss reasons of water pollution	0.99	0.62	1.72	0.45
5. Please note reasons of air pollution and their effects to environment	1.04	0.62	1.40	0.49
6. How are people able to reduce air pollution?	0.92	0.60	1.41	0.49
7. Please explain reasons of soil pollution and their effects on the environment	0.91	0.59	1.04	0.18
8. Please address how radioactive waste affects the environment	0.50	0.63	1.01	0.16
General mean	0.79	0.61	1.28	0.38

(*Kalenima*) *in Akcaabat*, *Effect of deep sea discharge system on local environment*, *Effect of sewages from public* (*e.g.*, *hospital*, *school*) *and private* (*i.e.*, *shopping center*) *organizations on closer environment*). At the beginning of the 'environmental chemistry' elective course, a TESI guide, put together by the project, was distributed to all SSSTs. The TESI guide provided instructions on how to use the project-related InT. It also consisted of sample projects with critiques. The critique explicitly stated the advantages, disadvantages, and limitations of each sample project. Also, some constructive comments were offered in the TESI guide in order to improve the sample projects.

Unlike the SSSTs in previous years, the SSSTs in our research project had the opportunity to deliberately integrate the InT into the curriculum and pedagogy during their practicum. For example, the SSSTs embedded TI-84, CBL, CO_2 sensor, and Logger Pro software in lesson plans pertaining to the topic of 'Respiration.' Whenever they figured out that some topics were useful to teach with the InT, they posed several questions: 'Which topics call for the use of the InT? How can the lesson plans with the InT designed? Which the InT is needed in order to implement lesson plans?' These InT-related curriculum and pedagogical questions served as the bases for negotiation among the SSSTs, the researchers, and the scholars. In fact, through our extensive project, the research team observed and scored the SSSTs' performance of lesson implementation with the InT using indicators, the results of which are reserved for another paper.

Findings

Findings will hereby be presented in regard to the order of the research questions. That is, the results from the TPACK, then the ECCUQ, and finally the CAEQ will be provided.

Technological Pedagogical Content Knowledge (TPACK) Survey

Table 4 indicates that the mean scores of pre- and post-tests and standard deviations of the TPACK domains varied. Mean range for the pre-test was between 2.19 (Models of TPACK) and 3.74 (PK), while the mean range for the post-test was between 3.37 (Models of TPACK) and 4.40 (TPACK). General means of the TPACK domains were 3.26 for the pre-test and 4.17 for the post-test. Also, the standard deviation general values ranged from 1.03 in the pre-test to 0.60 in the post-test. This means that the standard deviation values were narrower for the post-test than the pre-test of the TPACK.

Concerning the mean scores of the SSSTs' responses to the TPACK survey, the following categories were employed: do not understand (zero point), strongly disagree (0.01–1.00), disagree (1.01–2.00), neither agree or disagree (2.01–3.00), agree (3.01–4.00), and strongly agree (4.01–5.00). As observed in Table 4, the mean scores for TK, PK, PCK and TCK, and TPK and TPACK were categorized under 'agree' for the pre-test and 'strongly agree' for the post-test. Moreover, the mean scores of 'environmental chemistry content knowledge,' 'Models of TPACK (Faculty, mentor teachers),' and 'TPACK models' domains were labeled under 'disagree' for the pre-test and

Table 6 Percentages of the SSSTs' responses and their sample responses to the ECCUQ in respect to understanding categories

Item no	Pre-test			Post-test			Some sample SU responses given by the SSSTs
	NU	PU	SU	NU	PU	SU	
Item 1	27	62	11	–	61	39	Environmental pollution adversely affects physical, chemical, and biological structures of air, water, and soil that constitute our environment components. Any increase in environmental pollution threatens the health of living things. If we elaborate these notions, physical pollution means any change and deformation in physical structure of air, water, and soil, i.e., litter on the soil, leaking water from garbage, fume, dust. Also, chemical pollution engenders a negatively change in natural chemical cycle such as acid rain, photochemical smog. Further, biological pollution causes proliferation of malignant microorganism in the seas. Then, the more the increase in phosphor occurs, the more the algae grows up; hence, this harms and destroys sea life
Item 2	63	28	9	3	85	12	Environmental chemistry investigates allomerism of soil, water, and air, while biochemical cycle examines life cycle, cycles of carbon, oxygen, phosphor, nitrogen, etc. Therefore, environmental chemistry explores any change in biochemical cycles by taking allomerism of soil, water, and air into consideration. Further, it identifies effects of the biochemical cycles on the environmental issues, their possible reasons, and interactions between the environmental chemistry and biochemical cycle
Item 3	34	61	5	–	82	18	Purified water improves quality of water. For example, purifying turbid water, we can increase quality of water via a series of processes, i.e., determining turbidity, pH, color, dissolved oxygen, heavy metal, solid matter, organic matter amount, conductivity, and odor
Item 4	20	64	16	–	29	71	Acid rain, industrial waste, chemical detergents, living pathogens in the water, and radioactive element bring about water pollution. Some of the effects of water pollution on the environmental issues are as follows: (a) an increase in stream (lake) phosphate appears eutrophication that destroys the aquatic organisms and (b) radioactive metals and other wastes adversely influence the aquatic organisms, i.e., fish, algae, plankton. Similarly, acid rain causes acidification of water that threatens plants and aquatic organisms
Item 5	18	62	20	–	61	39	Causes of air pollution are natural phenomena (i.e., volcanic eruption), industrial activities, exhaust gases, factory chimneys without filter that give off gases. Thus, it results in respiratory diseases, greenhouse effect, global warming, melting of icebergs, and ozone layer depletion
Item 6	20	68	12	–	58	42	We are able to reduce air pollution via several methods or issues: planned urbanization, catalytic converter, absorbing gas emission from factory chimneys, use of unleaded fuel, and filter for exhaust gases, use of renewable sources (e.g., solar system and wind power) and protecting forests to restore nature
Item 7	19	67	14	–	96	4	Causes of soil pollution are heavy toxic metals, pesticides, fertilizers, untreated sewage, radioactive matters, and so forth. For example, chemical pesticides are used to struggle with agricultural harmful insects, but this process also spoils soil quality. Overall, it damages flora and fauna environments. Indeed, due to chemical structure of pesticides, they remain stable without recycling, thereon; increasing amount of the chemicals causes the soil pollution. For instance, heavy toxic metals react with soil components and change its structure in which plants have little chance to grow up
Item 8	57	36	7	–	97	3	Because radioactive half-life is generally too long, they affect environment for a long-term period. Existing radioactive wastes in the soil at a period of long years may engender to the carcinogenic effect. Exposing to more radiation may result in genetic mutation. Since radioactive wastes penetrate into soil and water, they may spread a very large area. Because of the radioactive half-life and constant structure, radioactive wastes influence the current and future environments

'strongly agree' for the post-test. Overall, the TPACK general mean value was classified under 'agree' for the pre-test and 'strongly agree' for the post-test.

Environmental Chemistry Conceptual Understanding Questionnaire (ECCUQ)

The mean scores of the SSSTs' conceptions of the 'environmental chemistry' issues for each item were taken into account using the following categories: No Understanding (NU) (0–0.66), Partial Understanding (PU) (0.67–1.33), and Sound Understanding (SU) (1.34–2.00). As noted in Table 5, except for Item 8 that was classified under 'NU,' all other items fell into 'PU' category for the pre-test. For the post-test, Items 2, 3, 7, and 8 were categorized under 'PU' and Items 1, 4–6 under 'SU.' Items 7 and 8 showed a reduction in SU from the pre-test to the post-test but indicated a large increase in PU from the pre-test to the post-test. General mean scores of the SSSTs' responses to the ECCUQ were classified under 'PU' for the pre-test (0.79) and the post-test (1.28). Also, the standard deviation general value was 0.61 in the pre-test and 0.38 in the post-test. This means that the standard deviation values were narrower for the post-test than the pre-test of the ECCUQ.

Table 6 represents the percentage variations of the SSSTs' responses to the pre-test and the post-test of the ECCUQ. For instance, the percentages of the SSSTs' responses classified under 'NU' were between 18 % for Item 5 and 63 % for Item 2 in the pre-test, while those for Item 2 was 3 % in the post-test. Likewise, the percentages of the SSSTs' responses labeled under 'PU' were between 28 % for Item 2 and 68 % for Item 6 for the pre-test and between 29 % for Item 4 and 97 % for Item 8 for the post-test. Likewise, the percentages of the SSSTs' responses, which fell into 'SU,' were between 5 % for Item 3 and 20 % for Item 5 for the pre-test and between 3 % for Item 8 and 71 % for Item 4 for the post-test. This percentage distribution indicates that the SSSTs' responses for Items 1–8, except for 3 % for Item 2, totally changed from 'NU' to 'PU.' Moreover, the highest changes for 'SU' in the pre- and post-test procedure were for Items 1, 4, and 6.

Table 7 Descriptive statistic results of the CAEQ

Item number	Pre-test		Post-test	
	Mean	SD	Mean	SD
Item 1	4.19	1.58	4.87	1.48
Item 2	5.33	1.37	5.78	1.13
Item 3	5.86	1.35	6.36	0.99
Item 4	5.23	1.29	5.83	1.28
Item 5	4.95	1.39	5.62	1.18
Item 6	5.07	1.39	5.84	1.07
Item 7	5.58	1.25	5.96	1.33
General mean for chemists	5.17	1.38	5.75	1.21
Item 8	5.49	1.29	5.93	1.17
Item 9	5.50	1.35	6.06	0.98
Item 10	5.28	1.40	5.97	1.07
Item 11	5.79	1.39	6.17	1.07
General mean for chemistry research	5.52	1.36	6.03	1.07
Item 12	5.18	1.48	5.82	1.24
Item 13	5.18	1.54	5.77	1.25
Item 14	5.18	1.39	5.64	1.15
Item 15	5.07	1.44	5.74	1.30
General mean for chemistry jobs	5.15	1.46	5.74	1.23
Overall mean	5.28	1.40	5.84	1.17

Chemistry Attitudes and Experience Questionnaire (CAEQ)

As shown in Table 7, the mean scores of the CAEQ improved from pre-test to post-test. For example, the mean scores of subscales (chemists, chemistry research, and chemistry jobs) were 5.15, 5.15, and 5.15 in the pre-test, while those for the post-test were 5.75, 6.03, and 5.74, respectively. Further, overall mean score of the CAEQ changed from 5.28 (in the pre-test) to 5.84 (in the post-test). Also, the standard deviation general value decreased from 1.40 (in the pre-test) to 1.17 (in the post-test). This means that the standard deviation values were narrower for the post-test than the pre-test of the CAEQ.

As shown in Table 8, results of paired-sample t-test showed statistically significant differences between the pre- and post-test mean scores of the TPACK, the ECCUQ, and the CAEQ in favor of the post-test scores ($t_{(113)} = -11.38$, $p < 0.001$ for the TPACK; $t_{(113)} = -12.58$, $p < 0.05$ for the ECCUQ; $t_{(113)} = -5.86$, $p < 0.05$ for the CAEQ). Also, the same case was valid for pairs 1, 2, and 3 of the CAEQ in favor of the post-test scores ($p < 0.05$).

Discussion

Because there were statistically significant differences between the pre- and post-test mean scores of the TPACK, the ECCUQ, and the CAEQ in favor of the post-test scores, it can be inferred that the 'environmental chemistry' elective course via the TESI model improved the SSSTs' TPACK levels, conceptions, and attitudes toward

Table 8 Paired-sample *t* test results of TPACK, ECCUQ, and CAEQ

Instruments	Mean difference between the pre-test and the post-test	Standard deviation	Std. error means	*t*	*df*	*p*
TPACK	−2.64	24.72	2.32	−11.38	113	0.000**
ECCUQ	−3.88	3.29	0.31	−12.58		0.000*
CAEQ						
Pair 1—chemists	−3.68	12.60	1.18	−3.12	113	0.002*
Pair 2—chemistry research	−2.07	4.89	0.46	−4.52		0.000*
Pair 3—chemistry jobs	−2.36	5.04	0.47	−4.99		0.000*
CAEQ general mean	−6.90	12.55	1.18	−5.86		0.000*

* Mean difference was significant at the level of 0.05

** Mean difference was significant at the level of 0.001

chemistry. These impacts may result from interactive framework of the TESI model and the SSSTs' firsthand use of the InT. That is, it was the first time they engaged these InT in their schooling backgrounds within the dual-situated framework (meaning to balance theoretical knowledge with practical one). In other words, it can be deduced that bridging the gap between theoretical and practical knowledge (e.g., Duit 2007; Xie and Reider 2013) intimately stimulated their attitudes toward chemistry and made related knowledge more meaningful for the SSSTs. Hence, it can be concluded that the 'environmental chemistry' elective course via the TESI model has a great potential to meet NRC's statement (2011) of 'knowledge and practice' elements. Moreover, the current intervention, which links scientific (e.g., science content structure for instruction—environmental chemistry), technological (e.g., probes, sensors, TESI Web site, Logger Pro software, GPS), and practical modes (transforming process) for science education research, seems to have dealt with the various difficulties of improving science teaching and learning. This conclusion supports Psillos' (2001, p. 11) claim '*that it is necessary to link the major concerns of all three modes* (*i.e., practical, technological and scientific modes*) *in order to meet the various difficulties of improving science teaching and learning.*' Now, we will especially discuss the results for each instrument in the following paragraphs.

TPACK levels

An improvement in 'pedagogical knowledge (PK)' domain may stem from the dual-situated framework of the project (see Table 3). For example, transforming their content knowledge of the 'environmental chemistry' concepts/issues into their pedagogical knowledge during teaching practicum may be viewed as the dual-situated framework/learning. That is, transferring their gained experiences of the InT into practicum may have resulted in enhancing the 'pedagogical knowledge (PK)' domain. Another possible reason may result from the sample implementations in the 'environmental chemistry' elective course conducted by the lecturer. Therefore, this procedure may have improved their pedagogical knowledge by help of '*how, at which level, why, by what and when*' questions and evolved their content knowledge domain. Similarly, developing and implementing their research projects concerning societal problems helped the SSSTs to link 'technological knowledge (TK)' domain with 'pedagogical knowledge (PK)' one. Such a procedure may have influenced increases in these knowledge domains due to interrelations among the TPACK domains. Also, it may stem from interdisciplinary framework of the 'environmental chemistry' elective course that overlaps the interrelations among the TPACK and the TESI model. Further, this may result from complex relationships among content knowledge, pedagogy knowledge, and technology knowledge. That is, for the 'environmental chemistry' elective course, the SSSTs' content-related learning needs were directly linked with content-based learning activities and related InT, which fit for the TESI model and the TPACK levels (e.g., Harris and Hofer 2006).

A category change for 'technological knowledge (TK)' domain (from 'agree' to 'strongly agree' through the pre- and post-test—see Table 4) may stem from the SSSTs' practical experiences with the InT. Indeed, Turkish Ministry of National Education (TMNE) encourages the teachers to integrate the InT into school courses. For this reason, given our informal discussions at the consultation days and observations on the SSSTs' project performances, they seem to have been very willing to learn the InT. Phrased differently, TMNE's new demands concerning the teacher competencies may have triggered the SSSTs' learning curiosity of TK.

A category change for 'content knowledge (CK)' (from 'neither agree nor disagree' to 'strongly agree' through the pre- and post-test) may come from the TESI guide or teaching style of the lecture. Likewise, the SSSTs' engagement with the TESI Web site (see Fig. 3) and their actions (discussing and sharing their views of the environmental chemistry or socioscientific issues with peers and experts) may have caused to an improvement in their content knowledge (e.g., Çalık et al. 2013a; Liang et al. 2010; Ebenezer and Puvirajah 2005). Needless to say that their performances of the environmental research projects may have influenced their content knowledge in that they practically used this 'content knowledge' domain of the 'environmental chemistry' elective course. In some cases, content of the research project forced them to learn new notions or concepts or principles. The balance between theoretical and practical knowledge (e.g., She 2002, 2004) in the TESI model may have resulted in long-term learning and conceptual understanding. Indeed, an improvement in the ECCUQ results from the pre-test to the post-test (see Table 7) advocates the gains at 'content knowledge (CK)' in the TPACK survey. Similarly, increases in PCK and TCK domains (from 'agree' to 'strongly agree' through the pre- and post-test—see Table 4) may result from a transmission of their learning outcomes into the teaching practicum (e.g., Çalık and Aytar 2013). Indeed, this dual-situated procedure required them to think about student level and appropriate teaching approach/model/techniques. Hence, this may have improved their pedagogical content knowledge. This also denotes an increase in their capacities to transform the content knowledge they possessed into forms that are pedagogically powerful (e.g., Kind 2009). This is in a harmony with Shulman's (1986, 1987) emphasis on transformative knowledge. Moreover, the TESI guide and consultation days on the use of the InT may have influenced their technological content knowledge.

For the TPK, TPACK, and 'Models of TPACK (Faculty, mentor teachers)' domains, a category change was identified from 'agree' to 'strongly agree' throughout the pre- and post-test (see Table 4). This demonstrates that the 'environmental chemistry' elective course via the TESI model afforded the SSSTs to think in-depth about how to integrate InT into practicum. In a parallel case, using a proper combination of science, technology, and pedagogical content knowledge may have resulted in the SSSTs' professional developments through their teaching practicum and the 'environmental chemistry' elective course. Because the first author pedagogically illustrated how to adapt the InT (i.e., TI-84, CBL, pH sensor, CO_2) into the 'environmental chemistry' elective course, the SSSTs may have practically grasped how to blend and link their technological, pedagogical, and content knowledge with one another. Indeed, implementing their lesson plans with the InT (embedded within the TESI model) into the teaching practicum may also be one of the reasons in an increase in the foregoing knowledge. In brief, since the TPACK indicates the complex, multifaceted, and situated nature of teacher knowledge (Koehler and Mishra 2008), the TESI model may have shed more lights on complex relationships among the TPACK levels and afforded them to identify their needs (of content, pedagogy, and technology) on how to efficiently integrate technology into their classes (Archambault and Crippen 2009). Meanwhile, someone may think that the TPACK survey is a self-assessment instrument and not enough for interpreting the SSSTs' TPACK levels. In fact, through the extensive project, such additional confirmatory measures as interviews, observation protocols in the teaching practicum course, self-efficacy survey of the TESI model (Calik 2013), and their dialogues on the TESI Web site (see Çalık et al. 2013b) were employed, but not presented here. This may be viewed as a limitation of this paper.

Conceptions

As seen in Table 7, the SSSTs attained the significant changes for the environmental chemistry issues/topics to make sense of their new learning. This confirms that learning is an interaction between the prior and new knowledge (e.g., Bakırcı and Çalık 2013; Brooks and Brooks 1999; Fensham 1992; Kolomuç and Çalık 2012). An increase in the SSSTs' conceptions of the environmental topics from 'NU' to 'PU' through the pre- and post-test may have stemmed from their content (subject matter) knowledge through the InT. For instance, while teaching the topic of 'air pollution,' the lecturer helped the SSSTs to measure time-dependent CO_2 gas change by means of CO_2 gas sensor, connected to a CBL, TI-84. Also, the lecturer projected the Logger Pro software generated graph onto a large screen so that the SSSTs could analyze and interpret the graphical results. Such measurement through the InT and visual representation of the results transformed the abstract concept to the concrete one so that the concepts may have been better understood (e.g., Ebenezer et al. 2011; Nugultham and Shiowatana 2010). In a similar vein, this may result from 'data representation and data analysis' features in the teaching intervention that are significant predictors of scientific knowledge (e.g., Zhang 2013). For example, a meta-analysis of technology-based learning tools (Zhang 2013) confirms this possible reason: 'When the other variables are held constant, with a data representation feature, the probability of having science knowledge gains is about 15 times greater than without this feature (p. 5).'

Environmental-issue-related documents and news from mass media were uploaded to the TESI Web site in order to stimulated SSSTs' discussion. Given the idea 'With discussion functions, the probability of achieving gains in scientific explanations is about 7 times greater than without this feature (Zhang 2013, p. 8),' it can be concluded that discussion function in the TESI Web site and the course may have acted as a significant role in achieving the conceptual understanding of the environmental chemistry concepts/issues. Incorporating the TESI model, inquiry learning, and dual-contextual learning in the organizational structure of the 'environmental chemistry' elective course may have improved the SSSTs' conceptions. This result corroborates Nugultham and Shiowatana's (2010) claim that the inquiry-based learning via the experimental kits enabled their project students to learn the essential concepts of water quality.

Researching into environmental issues and discussing these issues with peers, the lecturer, and project scholars may also attribute to a significant change in their conceptions. This idea is consistent with Zhang's (2013) result that a situated environment with scientific communication and collaboration has 20 times higher probability of achieving gains. Our claim is substantiated by Mandler et al. (2012), who emphasized that the students in their study significantly improved their awareness of the environmental issues and especially appreciated the feeling that they themselves were able to make knowledge claims. In contrast to Mandler et al.'s study and our study, Robelia et al. (2010) reported that assessments of the environmental chemistry concepts showed no significant difference between the comparison and treatment groups.

In summary, the 'environmental chemistry' elective course demanded the SSSTs to conduct and report their environmental research projects, integrate the InT into the science curriculum during their practicum, and communicate online and off-line with peers, the lecturer, and the project scholars. Adapting a 'need to know' pedagogical approach (Demircioğlu et al. 2009; Ültay and Çalık 2012) may be acknowledged as a principal incentive and reason for the SSSTs' conceptual learning. The 'environmental chemistry' elective course may have changed the SSSTs' views/beliefs about scientific inquiry and their pedagogical approach during the practicum. The results in our study are inconsistent with those of Saad and BouJaoude (2012), who found that most teachers had restricted views of nature of science and unfavorable beliefs and attitudes about inquiry.

A dismal case in the 'SU' category of the ECCUQ may come from the competitive nature of the Turkish teacher education programs. Phrased differently, the SSSTs ultimately concentrate on the subject-specific national examination to be employed in public schools (Çalık et al. 2012) rather than the elective courses such as the environmental chemistry offered by the teacher education programs. The SSSTs during the informal interviews pointed out that the 'environmental chemistry' elective course should have been offered in the beginning of science teacher education program.

Attitudes

Statistically meaningful differences were found between the pre- and post-test mean scores of the CAEQ and its subcategories. The differences in attitudes toward chemistry may have been attributed to the environmental chemistry elective course via the TESI model. Based on Karpudewan et al.'s (2011) work on the green chemistry experiments, we can confidently claim that the 'environmental chemistry' elective course has the potential to improve the SSSTs' attitudes/motivations toward chemistry.

The 14-week-long environmental chemistry elective course may have had an impact on the attitudinal change toward chemistry. Much research clearly points out that a short-term intervention does not do any good impact for attitudinal or behavioral change (e.g., Güven and Sülün 2012; Mandler et al. 2012; Taşlıdere and Eryılmaz 2012; Ültay and Çalık 2011).The SSSTs' perspectives changed for the 'chemists' subcategory in the CAEQ. This change in the positive direction could have been because the SSSTs behaved like chemists when conducting their environmental research projects. The SSSTs taking the role of the chemists may have affected their perspectives on the chemists. Also, the feeling that they had developed in the 'environmental chemistry' elective course like the chemists (Mandler et al. 2012) may have influenced their awareness of the role of the chemists. Similarly, for the 'chemistry research' subcategory, an improvement in the SSSTs' attitudes toward chemistry research was noted. This result is truly a reflection of their own environmental research projects with the InT. The 'environmental chemistry' elective course that required the SSSTs to conduct their environmental projects seems to have helped them develop the attitudes of the chemistry research. Likewise, for the 'chemistry jobs' subcategory, the SSSTs efforts on their environmental projects may have provided them to become increasingly aware of the chemistry-related jobs. In other words, the development of consciousness of jobs in the field of chemistry may have positively changed their attitudes toward chemistry jobs. Overall, the 'environmental chemistry' course via the TESI model, which was employed in the InT as incentives to stimulate the SSSTs' attitudes and experiences toward chemistry, achieved this goal. This means that the InT played a significant complimentary role to prompt the interests (e.g., Xie and Reider 2013) in chemistry, especially chemists, chemistry research, and chemistry jobs.

Conclusions and Implications for Practice

Our study concludes that the 'environmental chemistry' elective course via the TESI model improved the SSSTs' conceptions of the 'environmental chemistry' topics, TPACK levels, and attitudes toward chemistry. We believe that positive results were achieved because the SSSTs learned how to use the InT in the contexts of the environmental chemistry elective course and practicum. The functional interaction between theoretical and practical knowledge within the 'environmental chemistry' elective course seems to have increased feasibility and applicability of the TESI model. Given the complex relationships among content knowledge, pedagogy knowledge, and technology knowledge, the 'environmental chemistry' elective course seems to have directly connected the SSSTs' content-related learning needs to the content-based learning activities and relevant InT. It is thus deduced that the TESI model is likely to have influenced the SSSTs' TPACK levels (e.g., Harris and Hofer 2006).

Taking into account the SSSTs' responses to the ECCUQ (see Table 6), it can be inferred that the 'environmental chemistry' elective course via the TESI model developed the SSSTs' prior conceptions of the environmental chemistry issues/topics into sound and partial understanding levels. Also, it can be concluded that the role and responsibilities of the SSSTs in the 'environmental chemistry' elective course stimulated their attitudes toward chemistry.

The most important barrier restricting implementation of the 'environmental chemistry' elective course via the TESI model was the nation-wide summative exam. Unfortunately, this exam excludes subject-specific courses, e.g., environmental chemistry, offered by the Faculty of Education (e.g., Çalık et al. 2012). Therefore, such an innovative teaching intervention to reduce exam anxiety ought to be carried out at earlier years of teacher education program. After such an intensive professional development course as environmental chemistry elective course, a follow-up study (including interviews and self-assessment of their experiences) to elicit the TESI model's long-term effect should be conducted with some of the SSSTs recruited in public or private schools. Similarly, a longitudinal study, similar to Ebenezer et al. (2012), should be conducted with science student teachers as they move from teacher preparation to professional learning and development during their early career. This study was limited with a Turkish university in which one area of chemistry (environmental chemistry) was specifically taught by the TESI model. Therefore, a cross-cultural study from different countries (i.e., developed, developing, and undeveloped countries) to investigate and/or extend its feasibility should be undertaken. In that time, it may be concluded that the TESI approach would be useful for science teacher education and teacher professional development. Further, the TESI model could be extended to other chemistry topics (e.g., medicinal chemistry, forensic chemistry) and to other areas of science (e.g., biology and physics). Hence, its applicability and its interactive framework may be transformed to a multidisciplinary environment.

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