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Improving Science Student Teachers' Self-perceptions of Fluency with Innovative Technologies and Scientific Inquiry Abilities

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Abstract The aim of this study was to investigate the effects of "Environmental Chemistry" elective course via Technology-Embedded Scientific Inquiry (TESI) model on senior science student teachers' (SSSTs) self-perceptions of fluency with innovative technologies (InT) and scientific inquiry abilities. The study was conducted with 117 SSSTs (68 females and 49 males—aged 21–23 years) enrolled in the "Environmental Chemistry" elective course in spring semester of 2011–2012 academic year in a Turkish University. Within a simple (causal) experimental design, Innovative Technology Fluency Survey and the SSSTs' environmental research papers were employed to collect data. The results indicate that the "Environmental Chemistry" elective course via the TESI model improved the SSSTs' self-perceptions of fluency with InT and the scientific inquiry abilities. In light of the results, it is recommended that an undergraduate course for improving the SSSTs' higher-order scientific inquiry abilities and preparing academically papers should be devised and added into the science teacher-training programmes.

Keywords Technology-Embedded Scientific Inquiry · Science student teachers · Innovative technologies · Teacher preparation

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Introduction

The use of innovative technologies (InT) at home and in workplace not only facilitates human work/life but also plays a significant role in educational innovations (O'Brien et al. 2011; Rogers and Twidle 2013). For example, various educational innovations (e.g., technological devices, tools, software and hardware) have been deployed to develop student learning and to bring pragmatic solutions for learning problems (Adegbija 2011; Gülbahar 2007; Kim and Hannafin 2011). Of course, their functional features have emerged different technological terms, for example, information technology (IT) (e.g., Xie and Reider 2014), information communication technology (ICT) (e.g., Linn 2003; Rogers and Twidle 2013), learning technology (e.g., Atwater 2000; 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 2014). For the current study, "Innovative Technology (InT)" term denotes the technologies (e.g., online discussion boards, TESI Web site, sensors, probes, Logger Pro software, GPS) that student teachers under investigation initially encountered in the "Environmental Chemistry" elective course rather than a broader sense of the innovation (e.g., Çalik et al. 2014).

Recognizing the value of InT for student learning, many governments have globally made investments for increasing InT facilities in elementary and secondary schools (e.g., Barron et al. 2003; Kutluca 2012; Özsevgeç 2011). For instance, an important initiative of the Turkish Ministry of National Education is to integrate InT into school subjects. Hence, prevalent introduction of InT in education has asked for re-designing teacher-training programmes in many countries (Kozma 2009; Rogers and Twidle 2013). However, despite a great effort of in-service and pre-service education, teachers have still encountered barriers in integrating InT into their own classes (Chen 2008; Gorder 2008; Hermans et al. 2008). These barriers result from the influence of external factors (Chen 2008), teacher's limited or improper theoretical understanding (Chen 2008; Hermans et al. 2008) and teacher's other conflicting beliefs (Chen 2008; Hermans et al. 2008), and teacher's inability to practice, reflect and share his teaching practices of InT (Gorder 2008; Rogers and Twidle 2013).

The importance of InT for student learning and teacher professional learning suggests that this capacity building ought to rightly begin with teacher preparation (O'Brien et al. 2011). Phrased differently, unless student teachers build InT competencies as early as teacher preparation, there is no guarantee that InT will be used in the classroom. For this reason, educating students to face the technological world requires teacher commitment to develop their competencies in InT and associated learning demands. That is, if student teachers develop their capacity to integrate InT in their practicum classrooms, they will possibly be willing to transfer their gained experiences into their future teaching careers (Friedrichsen et al. 2006; Liu 2011). A positive experience with InT during the practicum or school-based courses fosters professional abilities and shapes pedagogical practices (Çalık and Aytar 2013; Kutluca and Ekici 2010; Liu 2011), but a few studies have shown that pre-service teacher education has still possessed some deficiencies in effective use of technology (Angeli and Valanides 2008; Liu 2001). For example, these deficiencies stem from a lack of skill-based courses that prepare student teachers to capture how to link technology with a pedagogical context (e.g., Angeli and Valanides 2008) and from inconsistency between the courses in the teacher education programme (i.e., technology training and method) and real classroom practice in "Teaching Practicum" course (Liu 2001). For this reason, such severe deficiencies call for alternative ways to prepare the student teachers on how to integrate or link the technology with the instruction (e.g., Liu 2001).

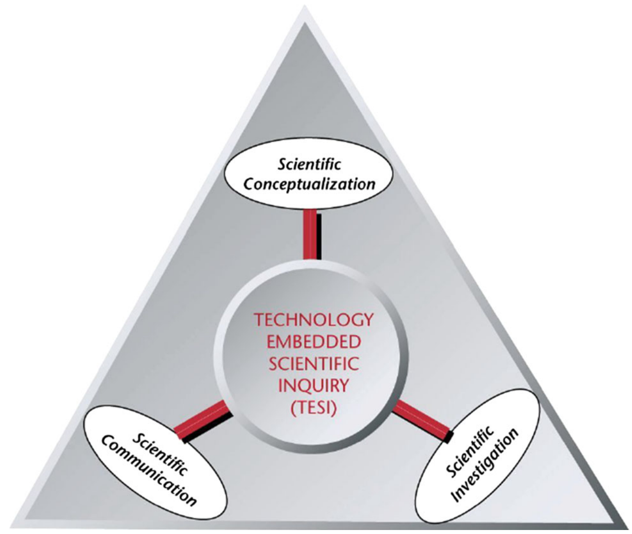

Fig. 1 TESI model suggested by Ebenezer et al. (2011, p. 97)

To sum up, new technological tools that require new technical knowledge make a profound impact on learning pedagogy (Newton and Rogers 2001; Rogers and Twidle 2013); thereby, they call new models and/or intervention upon training the (student) teachers. Given the foregoing issues to develop science student teachers' InT integration competency, such models as Technology-Embedded Scientific Inquiry (TESI) (Ebenezer et al. 2011) model (see Fig. 1) have been proposed. Now, we will outline theoretical framework of the TESI model and then illuminate earlier studies of the TESI model and environmental chemistry.

Theoretical Framework of the TESI Model

The TESI model is in a harmony with National Science Education Standards that promote students to use InT (i.e., hand tools, measuring instruments, calculators, electronic devices, computers for the data collection, data analysis and display of data) in conducting scientific inquiry (NRC 1996, 2000, 2012). The TESI model is also in line with a technology performance indicator promoted by International Society for Technology Education (ISTE), depicting what students are supposed to achieve "research and information fluency" (ISTE 2008). These science and technology standards, in turn, illustrate how the (student) teachers can integrate various technologies in their classrooms.

The TESI model involves in three hallmarks: *Technology-Embedded Scientific Conceptualization* that incorporates understanding subject matter knowledge, testing and clarifying conceptual ideas; *Technology-Embedded Scientific*

Investigation that focuses on developing students' critical abilities in scientific inquiry through their engagement with socio-scientific issues; and *Technology-Embedded Scientific Communication* that contains communicating research process, research results and knowledge claims via classroom discourse and/or online/offline dialogues (Ebenezer et al. 2011).

Earlier Studies of the TESI Model and Environmental Chemistry

Our preliminary studies have tested the TESI model to integrate InT into science teaching and learning (e.g., Calik 2013; Çalik et al. 2013, 2014; Ebenezer et al. 2011, 2012) and reported promising conclusions about feasibility of the TESI model. For example, Ebenezer et al. (2011) deduced that grades 9–12 students' fluency with InT and their scientific inquiry ability levels improved throughout a 3-year *Translating Information Technologies into Classroom* project funded by the USA National Science Foundation. Similarly, as an outcome of the same project, Ebenezer et al. (2012) reported that the secondary science teacher's growth and his students' perceptions of InT fluency were affected by two mechanisms: (a) a personal commitment to develop 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. Likewise, in perspective of adapting the TESI model into pre-service education (professional learning at teacher preparation), Calik (2013), Çalık et al. (2013) and Çalik et al. (2014), who examined the effects of the "Environmental Chemistry" elective course via the TESI model on some variables, addressed significant increases in the SSSTs' performances of variables under investigation (e.g., self-efficacy—Calik 2013; conceptions of environmental chemistry concepts/issues, attitudes toward chemistry and Technological Pedagogical Content Knowledge (TPACK) levels—Çalik et al. (2014); online and offline dialogues—Çalik et al. 2013). Likewise, Xie and Reider (2014), who analyzed the outcomes of an *Innovative Technology Experience* (e.g., geographic information system and information assurance) *For Students And Teachers (ITEST)* project, Mayor's Youth Technology Corps (MYTCs) in Detroit, MI, implied that the MYTC students demonstrated growth in nearly every area covered in the surveys, including dispositions about STEM career and learning. Rogers and Twidle (2013), who carried out the *ICT for Innovative Science Teachers* Project to develop training materials, emphasized a teacher's pedagogical change, which empowers students to work more independently.

Of environmental chemistry studies, Mandler et al. (2012) indicated that teaching analytical chemistry along with environmental chemistry enabled grade 12 students to undergo a significant change in their awareness of environmental issues and to especially praise the feeling of inquiry. Robelia et al. (2010) showed that a developmental chemistry course with environmental perspectives resulted in a slight significant difference between experimental and control groups' assessments of general chemistry knowledge, but no significant difference between their environmental chemistry assessments. Karpudewan et al. (2011) reported that green chemistry principles (called a laboratory-based pedagogy) into chemistry curriculum not only intrinsically motivated the student teachers in committing pro-environmental actions but also positively changed their environmental values/attitudes. Nugultham and Shiowatana (2010) pointed out that the inquiry-based learning via experimental kits enhanced secondary school students' understanding of chemistry concepts and their enthusiasm toward the use of the experimental kits.

The TESI studies shed more lights on needs of the use of InT to (a) support teachers'/student teachers' scientific inquiry abilities (e.g., Ebenezer et al. 2011), (b) achieve contemporary reforms and standards through technology-supported/technology-based learning environments (e.g., Ebenezer et al. 2012; Xie and Reider 2014), (c) link real-world experimentation with theoretical knowledge/subject matter knowledge (e.g., Calik 2013; Calik et al. 2014), (d) capture functional role of an intensive in-service (e.g., Ebenezer et al. 2012; Rogers and Twidle 2013; Xie and Reider 2014) or pre-service education (Calik 2013; Calik et al. 2014), (e) design a pre-service course, for example, "Environmental Chemistry" elective course, that practically includes the use of InT in pedagogical and subject matter knowledge through Expert–Lecturer–Student Teacher Learning Reciprocity (e.g., Ebenezer et al. 2012; Rogers and Twidle 2013), (f) activate an online/offline communication for sharing teachers'/student teachers' reflective experiences and inquiring through environmental research projects (e.g., Çalik et al. 2013; Ebenezer et al. 2012).

In a similar vein, the environmental chemistry studies reveal several environmental (societal) issues and concepts for scientific investigation. Thus, this context to help the students obtain the scientific inquiry abilities can be used as a driving factor. Further, experimental kits or technological tools can be employed as an attitudinal organizer in that they have a potential to stimulate the student teachers' self-determined motivation/enthusiasm (e.g., Karpudewan et al. 2011). Also, societal and/or socio-scientific issues in environmental chemistry (e.g., drinking water quality and the greenhouse effect—Mandler et al. 2012) illuminate to teach (environmental) chemistry within a "need to know" basis (e.g., Ültay and Çalık 2012). Overall, because the student teachers' self-perceptions of technology integration have a pivotal role in shaping and scaffolding their professional growth of the use of InT, there is a need for studies to explore and improve their self-perceptions of fluency with InT and the scientific inquiry abilities. Further, the environmental chemistry studies call a study upon investigating the effects of "Environmental Chemistry" elective course via the TESI model on the SSSTs' self-perceptions of fluency with InT and the scientific inquiry abilities.

At that point, we hypothesize that fluency with InT acquired through the "Environmental Chemistry" elective course in authentic learning contexts will play a significant role in enabling the SSSTs to confidently exploit InT in their environmental research papers. We hereby addressed "*Fluency with InT*" term as the necessary perception to properly transform InT applications into empirical science or real-life problems/projects. The aim of this study was to investigate the effects of the "Environmental Chemistry" elective course via the TESI model on the SSSTs' self-perceptions of fluency with InT and the scientific inquiry abilities. The following questions guide the study:

(a) Is there any significant difference between pretest and posttest mean scores of the SSSTs' self-perceptions of fluency with InT through the "Environmental Chemistry" elective course via the TESI model?
(b) At which level do the SSSTs' environmental research papers attain the scientific inquiry abilities?

Methodology

Because the current study evaluates the effects of the "Environmental Chemistry" elective course via the TESI model on the SSSTs' self-perceptions of fluency with InT and the scientific inquiry abilities, it follows simple (causal) design by means of pretest and posttest mean scores (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 the effects of the "Environmental Chemistry" elective course via the TESI model (as an independent variable) on dependent variables (self-perceptions of fluency with InT and the scientific inquiry abilities). Because the treatment group is exposed to teaching intervention within a significant amount of time, significant gains in self-perceptions of fluency with InT and the scientific inquiry abilities may highly appear. That is, the students at the treatment group likely perform better than do those in the control one after the treatment (e.g., Bakirci and Calik 2013; Çalık et al. 2010; Demircioğlu et al. 2013; Sadler 2009). Furthermore, a control experimental research design cannot completely involve the needs for studying a multifaceted technology design with a dozen elements and features of the learning environment, alike the present study (e.g., Zhang 2014). For these reasons, the authors preferred employing only one treatment group design and deployed the pretest as a starting point to monitor the SSSTs' growth of fluency with InT and the scientific inquiry abilities.

Sample of the Study

The sample comprised of a total of 117 SSSTs (68 females and 49 males—aged 21–23 years) enrolled in the "Environmental Chemistry" elective course in spring semester of 2011–2012 academic year in a Turkish University. Because of the absence in either pretest or posttest, three of them were eliminated. The researchers required the SSSTs to fill consent forms and emphasized assurances of confidentiality.

In Turkey, all elective courses, as well as compulsory courses, are counted as whole year's course credits. In the final semester of teacher-training programme, the SSSTs were asked to choose either "Environmental Chemistry" or "Scientific Research Methods-II" elective courses. The "Scientific Research Methods-II" elective course promotes the SSSTs to implement their research proposals which are prepared in the "Scientific Research Methods" compulsory course in the third year of the programme. Overall, the SSSTs are divided into two elective courses in regard to their interests. However, because of the popularity of our pilot study in 2010–2011 academic year, 117 SSSTs enrolled in the "Environmental Chemistry" elective course and 63 SSSTs in "Scientific Research Methods-II" elective course.

Prior to the "Environmental Chemistry" elective course in final semester of the SSSTs, they had attended "Special Topics in Chemistry" compulsory course in their third-year programme embracing 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 programme covering such topics as "*instructional technology concepts, characteristics of various instructional technologies, technology needs of the school, developing 2- and/or 3-dimensional materials (e.g., transparencies and PowerPoint) and teaching materials (i.e., worksheet), identifying qualities of computer-based materials—animations, simulations, VCD and DVD—using internet and other instructional technologies in Turkey.*" In brief, InT and the TESI model were quite new experiences for the SSSTs, but they were accustomed to work through collaborative groups in such courses as General Chemistry Laboratory, General Physics Laboratory, General Biology Laboratory, Laboratory Applications in Science and Science Teaching Methods.

Data Collection

To collect data, Innovative Technology Fluency Survey (ITFS) and the SSSTs' environmental research papers were employed. A 44-item ITFS (originally developed and validated by Ebenezer et al. 2011) measured the SSSTs' self-perceptions of fluency with InT. The ITFS was conformed and adapted into Turkish context in regard to the project scope. In this procedure, items on GIS and Hach's portable spectrophotometer in the original ITFS, e.g., "*Use the Geographic Information Systems (GIS) software,*" "*Measure distance and area on a GIS map,*" "*Pan and zoom within GIS,*" "*Edit the legend of a theme in GIS,*" "*Use GIS to add, activate or change the drawing order of a theme,*" "*Use Hach's portable spectrophotometer,*" "*Create a web page,*" "*Use of Hach's portable spectrophotometer in doing water analysis,*" were dropped out because they were out of the project scope. Also, Item 12 in Part A and Item 8 in Part B in the original ITFS (*Use of Logger Pro in interfacing with the graphing calculator*) were the same; hence, one of them was removed. Further, open-ended questions in Parts A and B in the original form, "*How good are you at using technology? Describe with examples*" and "*With examples describe how good you are at using technologies that appear in the questions above?*" were combined into one open-ended question in the current study; "*How good are you at using technologies mentioned above items? Describe with examples.*" Moreover, items referring EasyData in the original form of the ITFS, i.e., "*Follow knowledge of EasyData menu structure,*" were changed with Logger Pro, i.e., "*Follow knowledge of Logger Pro menu structure.*" Further, Parts A and C were combined within Part A (see Appendixes A and B for Turkish and English versions of the ITFS). Two science educators and five graduate students (who were bilingual) checked its translated version to confirm content validity and readability. Finally, the translated version of the ITFS consisted of 23 items within two subscales (21 items for Part A and two items for Part B) and two open-ended questions (*How good are you at using technologies mentioned the above items? Describe with examples; How good are you at using Global Positioning System (GPS)? Describe with examples*).

The ITFS was pilot-tested with 71 SSSTs in spring semester of 2010–2011 academic year. The SSSTs marked the ITFS ranging from *Not Applicable (zero point)* to *Very Fluent (five points)*. Its Cronbach alpha value in the pilot study was found to be 0.82. After some typographical errors were tidied up, this value for the real study was counted to be 0.91. Moreover, the SSSTs, in their small groups of 3–4, engaged in conducting their own environmental research papers using InT (i.e., pH sensor, CO_2 sensor, Texas Instrument 84 Plus Silver Edition—TI-84, calculator-based laboratory instrument—CBL, Global Positioning System—GPS) and submitted 32 environmental research papers as their group works. Half of the environmental research papers called the SSSTs to travel to local areas for collecting and sampling data. Because it was the first time they had prepared their research papers, the environmental research papers were viewed as the main indicators of the scientific inquiry abilities. In other words, their limited experiences of research paper preparation directed the authors to neglect a pre-measure of the scientific inquiry abilities. This may be seen as a limitation of the current study.

Data were collected by handing out hardcopies of the ITFS to the SSSTs. The SSSTs answered the instruments in their own time that afforded them ample time to reflect and elaborate their ideas (Calik 2011; Niaz 2008). Phrased differently, they submitted their responses to the ITFS a few days before and after the teaching intervention and handed in their environmental papers at the end of the semester.

Intervention

The first author taught the "Environmental Chemistry" elective course using the TESI model in respect to a 14-week syllabus (2 h per week). The SSSTs were initially called to create their small groups of 3–4. Later on, they enrolled to the TESI Web site and surfed through this Web site. In each week, the first author discussed the environmental chemistry topics *(i.e., Turkish environmental education, environmental chemistry, environmental pollution, basic biochemical cycles, air pollutants, ozone layer, global warming, chemical reactions in atmosphere, ozone layer depletion, greenhouse effect, acid rains, photochemical smog, particles in air, organic and inorganic particles)* and illustrated how to integrate InT (i.e., calculator-based laboratory instrument, Texas instrument, temperature sensor, turbidity sensor, pH sensor, photometry, conductivity sensor, flow rate sensor, GPS, Logger Pro software) into teaching chemistry/science *(as Technology-Embedded Scientific Conceptualization)*. Then, he asked the SSSTs to practically utilize the introduced InT for enhancing their InT fluency. Further, they were not only promoted to communicate with peers, lecturer and scholars but also to share their ideas or documents with peers using the TESI Web site *(as Technology-Embedded Scientific Communication)*. Then, the SSSTs were required to

Table 1 Descriptive statistics for the ITFS

	Pretest		Posttest	
	Means	Standard deviation	Means	Standard deviation
A. Please indicate your level of fluency with each of the following innovative technology skills				
1. Use the Internet	3.91	1.19	4.50	0.64
2. Transfer data into a computer database	3.87	1.25	4.49	0.60
3. Communicate with others over the Internet	4.11	1.18	4.54	0.73
4. Use PowerPoint for presenting research	3.96	1.16	4.66	0.55
5. Communicate with others using electronic discussion boards	3.48	1.44	4.33	0.88
6. Integrate data into a computer database	3.59	1.24	4.34	0.80
7. Use a graphing calculator/CBL2	1.63	1.15	3.45	1.39
8. Use the image processing and analysis (IPA)	1.75	1.30	3.55	1.25
9. Use the Global Positioning System (GPS) units	1.33	0.99	3.72	0.99
10. Use the Logger Pro in interfacing with the graphing calculator	1.06	0.66	4.02	0.84
11. Use the digital titrator	1.08	0.64	3.32	1.39
12. Use probes and sensors	1.10	0.75	4.21	0.76
13. Follow knowledge of Logger Pro menu structure	1.03	0.62	4.11	0.87
14. Collect data efficiently and effectively with Logger Pro	1.03	0.64	4.12	0.82
15. Analyze data efficiently and effectively with Logger Pro	1.04	0.67	4.11	0.78
16. Interpret data collected with Logger Pro	1.04	0.70	4.18	0.81
17. Transfer data and other output from the Logger Pro to a desktop computer	1.03	0.59	4.23	0.74
18. Use most of the features of Logger Pro	1.04	0.57	3.91	0.96
19. Design laboratory activities that incorporate the use of Logger Pro	1.07	0.67	3.86	1.01
20. Use of Logger Pro in interfacing with the LabPro	1.04	0.63	3.71	1.17
21. Use of the digital titrator in doing water analysis	1.07	0.66	3.23	1.38
B. Please indicate your level of fluency with Global Positioning System (GPS) skills				
	Means	Std. deviation	Means	Std. deviation
1. Use a GPS unit to pinpoint a location	1.22	0.93	3.16	1.31
2. Use a GPS unit to navigate to a given set of coordinates	1.23	0.99	3.06	1.29
General mean value	1.86	0.90	3.95	0.95

identify environmental project topics involved in data collection, sampling procedure and data analysis. Thereby, they prepared their environmental research papers (*as Technology-Embedded Scientific Investigation*). Also, the SSSTs, as trainees, were encouraged to transfer their gained experiences with InT in “Teaching Practicum” course at lower secondary schools. In fact, the integration of technologies in teaching practicum is not 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 expected to prepare PowerPoint presentations and to use animations and simulations to enhance student learning of science. However, the SSSTs in our research project had the opportunity to intimately integrate 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.” In the development of lesson plans in “Teaching Practicum,” the SSSTs, the researchers and the scholars collaboratively negotiated with each other to answer pedagogical questions, i.e., “Which topics call for the use of InT? How can a lesson plan with InT be designed?” In fact, as a part of our project, the research team observed and scored the SSSTs’ performance of lesson plan with InT using indicators, but its results are reserved for another paper.

Given some deficiencies identified in the pilot study, a TESI guide (including theoretical knowledge of the “Environmental Chemistry” elective course, introduction of the TESI model, how to use InT—sensors, probes, photometry, etc.—and the TESI Web site, some sample environmental research papers with critics, expected duties and assignments) was originally improved and passed the SSSTs out. Also, the project team declared consultation days to help the SSSTs about the use of InT and the environmental research papers if necessary.

Data Analysis

For possible responses to the ITFS (from *zero point—Not Applicable t*o five points—*Very Fluent)*, the data were imported into SPSS 15.0™ to run statistical analysis (paired-samples *t* test, Cronbach's alpha, descriptive statistics). Further, content analysis was employed for the open-ended questions to emerge categories and frequencies. In analyzing the SSST's environmental research papers, the authors used "Scientific Inquiry Rubrics" with eleven criteria developed by Ebenezer et al. (2011). The criteria were scored as follows: missing (zero point) that indicates no scientific inquiry ability, beginning (one point) that shows weak or incoherent or improper or incorrect level of the scientific inquiry ability, developing (two points) that points to partial level of the scientific inquiry ability, proficient (three points) that denotes competent/qualified level of the scientific inquiry ability (see Appendixes C and D for Turkish and English version of Scientific Inquiry Rubrics). During this process, the authors scored the environmental research papers separately in order to scrutinize inter-rater consistency and all disagreement points were resolved through a process of negotiation.

Results from the Innovative Technology Fluency Survey (ITFS)

Mean scores of each criterion in the ITFS were taken into account using the following categories: *Not Applicable* (zero point), *Do not Understand* (0.01–1.00), *Not Fluent* (1.01–2.00), *Somewhat Fluent* (2.01–3.00), *Fluent* (3.01–4.00), *Very Fluent* (4.01–5.00). As observed in Table 1, the mean scores of the SSSTs' to the ITFS were varied in the pretest and posttest. For instance, the mean scores of the SSSTs' responses to Items 1, 2, 4–6 in Part A were classified under "Fluent" for the pretest and "Very Fluent" for the posttest. Likewise, the mean scores of the SSSTs' responses to Items 7–11 progressed from "Not Fluent" in the pretest to "Fluent" in the posttest. Further, the mean scores of the SSSTs' responses to Item 12 fell into "Fluent" in the pretest and "Very Fluent" in the posttest. Moreover, the mean scores of the SSSTs' responses to Items 13–17 ranged from "Not Fluent" in the pretest to "Very Fluent" in the posttest, while those for Items 18–21 evolved from "Not Fluent" in the pretest through "Fluent" in the posttest. Likewise, only one item (Item 3) was at the same category, "Very Fluent," in both the pretest and the posttest. For Part B, mean scores of the SSSTs' responses to Items 1–2 were categorized under "Not Fluent" in the pretest. For the posttest, Item 1 and Item 2 were labeled under "Fluent" and "Somewhat Fluent," respectively. In brief, general mean scores of the SSSTs' responses to the ITFS changed from "Not Fluent" in the pretest to "Fluent" in the posttest (see Table 1).

Table 2 Paired-sample *t* test results of the ITFS (as a total of Parts A and B) and its parts

Scores		Means	Std. deviation	*t*	*df*	*p*
ITFS	Posttest–pretest	4. 77	16.04	31.74	113	0.000*
Part A	Posttest–pretest	4.33	17.10	27.02	113	0.000*
Part B	Posttest–pretest	5.69	12.75	4.77	113	0.000*

* Mean difference was significant at the level of 0.001

As seen in Table 2, results of paired-sample *t* test showed statistically significant differences between the pretest and posttest mean scores of the ITFS (as a total of Part A and Part B) and its parts (Part A and Part B) in favor of the posttest ones (for the ITFS $t_{(113)} = -31.74$, $p < 0.001$; for Part A $t_{(113)} = -27.02$, $p < 0.001$; for Part B $t_{(113)} = -4.77$, $p < 0.001$).

Frequencies and categories of the SSSTs' responses to the open-ended questions in the ITFS for the pretest and posttest are presented in Table 3.

As can be seen in Table 3, the SSSTs' responses to the open-ended questions were not at satisfactory level and tended to give blank for the pretest. For the question *"How good are you at using technologies mentioned the above items? Describe with examples,"* over half of the SSSTs addressed themselves as *fluent* for using technology in the posttest. Also, most of them exploited sensors and computers to learn and/or teach the content. Likewise, for the question *"How good are you at using Global Positioning System (GPS)? Describe with examples,"* almost half of them viewed themselves as *fluent* for the posttest and revealed a location pinpoint for the content.

Results from the Environmental Research Papers

Mean scores of each criterion in the Scientific Inquiry Rubrics to categorize the SSSTs' environmental research papers were taken into account using the following categories: missing (0–0.74), beginning (0.75–1.49), developing (1.50–2.24) and proficient (2.25–3.00).

As can be seen in Table 4, the mean scores of the descriptive statistics for the Scientific Inquiry Rubrics showed that the environmental research papers attained "proficient level" for nine out of 11 criteria (criteria 1–6 and 8–10). The environmental research papers also accomplished "developing level" for criteria seven and 11. Further, overall mean score of the environmental research papers for the Scientific Inquiry Rubrics (mean = 2.54 and standard deviation = 0.59) pointed to "proficient level." A

Table 3 Frequencies and categories of the SSSTs' responses to the open-ended questions in the pretest and posttest

Questions	Categories	Pretest (*f*)	Posttest (*f*)	Sample response
How good are you at using technologies mentioned the above items? Describe with examples.	*Fluent level*			
	Blank	101	43	I used lots of sensors at sufficient level in my environmental research project and "Teaching Practicum" course
	Not Fluent	5	1	
	Somewhat Fluent	1	6	
	Fluent	7	64	
	Total	114	114	
	Content			
	Sensors	–	69	I taught "air pollution" subject via TI-84, CBL and CO_2 sensor duration my teaching practicum. I am really fluent at utilizing sensors and the innovative technologies
	Computer	7	35	
	Transferring data	–	28	
	Internet	10	27	
	Office	7	15	
	Videos and graph	–	12	
	Total	24	186	
How good are you at using Global Positioning System (GPS)? Describe with examples.	*Fluent level*			
	Blank	107	29	I employed GPS in my teaching practicum in order to pinpoint a location (altitude, latitude and longitude). Use of this tool is quite easy
	Not Fluent	7	17	
	Somewhat Fluent	–	20	
	Fluent	–	48	
	Total	114	114	
	Content			
	A location pinpoint	–	32	I easily found a location pinpoint with GPS

total of 32 environmental research papers with InT and their scores are represented in Table 5.

As seen in Fig. 2, the environmental research papers generally showed two levels (developing and proficient levels) of the scientific inquiry abilities attained by the SSSTs.

Discussion

As seen in Tables 1 and 3, an improvement from "Not Fluent" in the pretest to "Fluent" in the posttest appeared and was supported with statistically significant differences between the pretest and posttest mean scores of the ITFS (as a total of Part A and Part B) and its parts (see Table 2). This means that the "Environmental Chemistry" elective course via the TESI model improved the SSSTs' self-perceptions of fluency with InT and the scientific inquiry abilities (e.g., Ebenezer et al. 2011). This may result from a dual-situated learning framework of the "Environmental Chemistry" elective course that balanced theoretical knowledge with practical one. Phrased differently, bridging the gap between theoretical and practical knowledge (e.g., Duit 2007; Rogers and Twidle 2013; Xie and Reider 2014; Yakar and Baykara 2014) deliberately enhanced their self-perceptions of fluency with InT and the scientific inquiry abilities. Thereby, the "Environmental Chemistry" elective course via the TESI model seems to have aroused importance of National Research Council's (2011) statement of "knowledge and practice" elements of science. Hence, the SSSTs had an opportunity to transfer their gained experiences and/or self-perceptions into teaching practicum and the environmental research papers. In other words, such an authentic learning context may have played a significant role in enabling the SSSTs to confidently exploit InT in practicum. Likewise, activity-based training (i.e., hands-on and minds-on activities in the "Environmental Chemistry" elective course) and independent studies (i.e., environmental research papers) seem to have empowered them to work more confidently on InT and to develop the scientific inquiry abilities. As a matter of fact, overall mean score of their environmental research papers (see Table 4) can be seen as an indicator of the authentic learning context. In fact, this may stem from relationships among scientific (e.g., environmental chemistry issues/concepts), technological (e.g., probes, sensors, TESI Web site, Logger Pro software, GPS) and practical modes (transforming process, for example, environmental research papers) that deal with various difficulties of improving science teaching and learning (Psillos, 2001).

The mean scores of the SSSTs' responses to Items 1, 2, 4–6 (Part A in the ITFS) were classified under "Fluent" in

Table 4 Descriptive statistics of the SSSTs' environmental research papers in regard to the Scientific Inquiry Rubrics

	Criterion	Means	Standard deviation
1.	Define a scientific problem based on personal or societal relevance with need and/or source	2.34	0.75
2.	Formulate a statement of purpose and/or scientific question	2.91	0.30
3.	Formulate a testable hypothesis and propose explanation(s)	2.69	0.74
4.	Demonstrate logical connections between scientific concepts guiding a hypothesis and research design	2.50	0.57
5.	Design and conduct scientific investigations related to the hypothesis—methods and procedures are logically outlined; proper measuring equipment is used; safety precautions are heeded; and sufficient repeated trials are taken to validate the results	2.41	0.67
6.	Collect and analyze data systematically and rigorously with appropriate tools	2.75	0.51
7.	Make logical connection between evidence and scientific explanation	2.22	0.83
8.	Use a variety of technologies for investigation	3.00	0.00
9.	"Use mathematical tools and statistical software" means students should use these for collecting, analyzing and displaying data in charts and graphs and for doing statistical analysis	2.56	0.50
10.	Communicate through scientific paper for replication and enhancement	2.31	0.93
11.	Defend scientific arguments connected with investigation, evidence and scientific explanation	2.22	0.66
	Mean for all criteria	2.54	0.59

the pretest and "Very Fluent" in the posttest (see Table 1). This may result from their earlier technology skills (e.g., use of internet and PowerPoint for presenting research). In other words, the "Environmental Chemistry" elective course via the TESI model positively afforded them to convey their pre-existing skills (*Fluent*) to satisfactory level (*Very Fluent*) in that they frequently surfed through the TESI Web site and communicated with peers, lecturers and scholars using discussion boards. Likewise, the SSSTs' responses to Items 7–11 progressed from "Not Fluent" in the pretest to "Fluent" in the posttest. This may result from use of InT (e.g., CBL2, GPS, digital titrator) in the "Environmental Chemistry" elective course. Moreover, changes in Items 13–17 and 18–21 ranged from "Not Fluent" in the pretest to "Very Fluent" and "Fluent" in the posttest, respectively. This means that the teaching

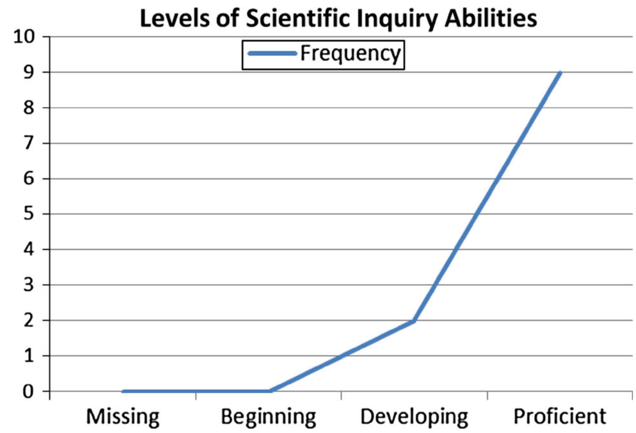

Fig. 2 Frequencies of levels of the scientific inquiry abilities for the environmental research papers

intervention enhanced the SSSTs' self-perceptions of use of Logger Pro. In brief, given practically use of InT in the environmental research papers and "Teaching Practicum" course, such an enriched learning environment seems to have resulted in an increase in fluency with InT. In a similar vein, this may result from "data representation and data analysis" features in the environmental research papers that are significant predictors of scientific knowledge (e.g., Zhang 2014). As a matter of fact, Zhang's (2014) meta-analysis of technology-based learning tools displays that a data representation feature possesses 15 times greater probability of having science knowledge gains. In fact, this is an expected result because this was the first time the SSSTs had initially encountered with the related InT and the TESI model. For instance, frequencies of the SSSTs' responses to the first open-ended question changed seven in the pretest to 64 in the posttest (see Table 3). The SSSTs' responses to the second open-ended question were only fluent at operating the GPS. Phrased differently, fluency with the GPS seems to have highly depended on structure of the environmental research paper (eight out of 32 environmental research papers—see Table 3).

As seen in Table 4, general mean value of the environmental research papers pointed to "proficient level." This may stem from scaffold of the TESI guide that helped the SSSTs to properly conduct their own environmental research papers. In fact, whenever they needed any assistance, the research team assisted them in solving related issues through a face-to-face or online/offline communication environment (via the TESI Web site). Further, a situated environment (i.e., environmental research papers and "Environmental Chemistry" elective course) with scientific communication (face-to-face, online/offline in the TESI Web site) and small-group collaboration may have evolved their levels of the scientific inquiry abilities. This

Table 5 Environmental research papers with InT and their scores

Title	InT used	Score
Effects of smoking and air pollution at different regions on human health	TI-84, CBL, CO_2 sensor	26
Factors that affect to grow up agricultural products	TI-84, CBL, CO_2, temperature, humidity sensors	29
Effect of carbon dioxide gas on soil fertility	TI-84, CBL, pH, CO_2 sensor, GPS	28
Conscious use of chemical fertilizers	TI-84,CBL, pH sensor, photometer	26
Acidity rate of rainwater and its effect on soil	TI-84,CBL, pH sensor, photometer,	26
Effects of pH values of public water and components in the shampoos on hair loss	TI-84,CBL, pH sensor, photometer,	24
Compliancy of drinkable water to common standards	TI-84, CBL, conductivity, pH, dissolved oxygen sensors, GPS	29
Effect of tea diversity on mineral structure of water	Photometer	28
Investigating drinkable water qualities of Ankara and Trabzon	TI-84, CBL, pH, temperature, turbidity sensors, photometer	24
Measuring pH and mineral values of mineral waters	TI-84, CBL, pH sensor, photometer,	24
Examining and investigating proper places and conditions for growing up trout	TI-84, CBL, conductivity, turbidity, pH, dissolved oxygen sensor, Photometer, GPS	30
Determination of water quality in different regions	TI-84, CBL, conductivity, turbidity, pH, dissolved oxygen sensor, photometer, GPS	26
Effect of different light colors on greenhouse plants	TI-84, CBL, CO_2, temperature, humidity sensors	29
Effect of off-shore cleaning materials on health and environment	TI-84, CBL, pH sensor, photometer	28
Determination of water quality in a local stream (Kalenima) in Akcaabat	TI-84, CBL, pH, dissolved oxygen, conductivity, turbidity sensors	32
Importance of fertilizer in enhancing tea crop	TI-84, CBL, pH sensor, photometer	28
Determining physical and chemical parameters (i.e., pH, turbidity and dissolved oxygen) of five different pickle brands comparing them with each other	TI-84, CBL, turbidity, pH, dissolved oxygen sensors	32
Measuring pH values of different type shampoos	TI-84, CBL, pH sensor,	26
Effect of deep sea discharge system on local environment	TI-84, CBL, conductivity, turbidity, pH, dissolved oxygen sensors, photometer, GPS	33
Effect of urbanization, industrialization and environmental waste on chemical and physical structure of water	TI-84, CBL, conductivity, turbidity, pH, dissolved oxygen sensors, photometer, GPS	30
A comparison of soils parameters (i.e., pH, humidity and O_2) from different provinces in East Black Sea region	TI-84,CBL, pH, dissolved oxygen, humidity sensors	22
Measuring pH values and ingredients of different type juices	TI-84, CBL, pH sensor, photometer	32
Water quality of Trabzon	TI-84, CBL, turbidity, pH, dissolved oxygen sensors, photometer	23
An investigation of effect of sewage water on sea environment	TI-84, CBL, pH, dissolved oxygen, turbidity, temperature sensors, GPS	29
An examination of parameters (i.e., pH, dissolved oxygen, nitrate, sulfate) in different type carbonate drinks	TI-84, CBL, pH, dissolved oxygen sensors, photometer	21
Investigating exhaust gas emissions in old and new vehicles	TI-84, CBL, $C0_2$ sensor	32
Measurement of CO_2 emissions in different home plants	TI-84, CBL, $C0_2$ sensor	32
Effect of chemical fertilizer use in tea garden on spring water	TI-84, CBL, conductivity, turbidity, pH, dissolved oxygen sensors, photometer, GPS	29
Effect of sewages from public (e.g., hospital, school) and private (i.e., shopping center) organizations on closer environment	TI-84, CBL, conductivity, turbidity, dissolved oxygen, pH sensors, photometer	31
A comparison of industrial yoghurt, fruity yoghurt and homemade yoghurt in terms of pH, calcium and iron	TI-84, CBL, pH sensor, photometer	29
Investigating parameters (e.g., pH, dissolved oxygen, anions and cations) of Zemzem water	TI-84, CBL, conductivity, dissolved oxygen, pH sensors	27
Identifying types of detergents causing eutrophication	TI-84, CBL, pH, conductivity sensor, photometer	28

Mean: 27.91; standard deviation: 3.15; range: 12 (maximum score was 33 points) is in parallel with Zhang's (2014) result depicting that a situated environment with scientific communication and collaboration has 20 times higher probability of achieving gains. Also, the fact that independent study structure of the environmental research papers drove them to concentrate on their perceived environmental issues seems to have contributed development of their scientific inquiry abilities. That is, they had an opportunity to use their own community/local resources (i.e., streams, Black Sea) as a platform for learning. This idea is consistent with Xie and Reider's (2014) principal idea of MYTC project and Nabhan and Trimble's (1994) view—"a set of building blocks from which to construct a life (p. 131)". Moreover, "proficient level" in criteria 1–4 in the Scientific Inquiry Rubrics (see Fig. 2) showed that the SSSTs paid more attention to define a scientific problem, to formulate a statement purpose and a testable hypothesis and to demonstrate logical connections between scientific concepts. In other words, they may have viewed these first four criteria as a pre-request for efficiency of the environmental research papers. Furthermore, the highest level for criterion eight in the Scientific Inquiry Rubrics may stem from use of a variety of technologies (i.e., TI-84, CBL, sensor, probes, Logger Pro software, digital titrator, GPS, the TESI Web site) in the environmental research papers and the "Environmental Chemistry" elective course. The fact that criteria seven and 11 were categorized under "developing" may result from a lack of contemporary higher-order scientific inquiry abilities for making a logical inference and defending scientific arguments (e.g., Ebenezer et al. 2011). Needless to say that the higher-order scientific inquiry abilities may require much more time to progress or evolve. In a similar vein, "developing" level in Criteria seven and 11 may come from the SSSTs' limited experiences at preparing academically papers (e.g., Ebenezer et al. 2011). For this reason, it is recommended that an undergraduate course for improving the SSSTs' higher-order scientific inquiry abilities and preparing academically papers should be devised and added into the science teacher-training programmes. Thereby, (science) teacher-training programmes may act as a catalysis for educational reforms that spark (student) teachers' imaginations for improving connections across academic disciplines and classroom boundaries (i.e., Means 1998). Also, such undergraduate courses as the "Environmental Chemistry" elective course should involve in sustainable projects to produce genuine benefits for student teacher–lecturer partnerships (i.e., Means 1998). Further, a follow-up study with novice (beginning) teachers should be carried out to track InT integration into their real classes. Also, given an increase in the amount of independent studies of innovative (educational) technologies, systematically reviews ought to be regularly conducted to synthesize and evaluate their matches and mismatches (Çalık and Sözbilir 2014; Zhang 2014). Moreover, future studies may explore how societal framework of the environmental chemistry (named socio-scientific issues) influences the student teachers' scientific habits of mind (e.g., Çalik and Coll 2012; Çalık et al. 2014) and understanding of the relationships among science, technology, society and environment (e.g., Pedretti 2003; Zhou et al. 2014).

To sum up, the "Environmental Chemistry" elective course via the TESI model resulted in significant gains in the SSSTs' self-perceptions of fluency with InT and the scientific inquiry abilities. Given the Turkish Ministry of National Education's (TMNE) demands and efforts of InT integration into school courses, the TESI model seems to be promising for equipping the SSSTs with the contemporary teacher competencies. Hence, it can be concluded that the "Environmental Chemistry" elective course, as a teacher-training course, meets a supply–demand balance/standard for Turkish context by building bridges between theory and practice.

Because this paper is an outcome of the extensive research project, it covers several variables and data collection instruments *(Environmental Chemistry Conceptual Understanding Questionnaire, Technological Pedagogical Content Knowledge Survey, Chemistry Attitudes and Experiences Questionnaire, TESI Classroom Protocol, Interview Protocol, ITFS, Environmental Research Papers and dialogues undertaken on TESI Web site)*. Due to page length limitation, presenting only some parts of the results (the ITFS and the environmental research papers in the current paper) may be viewed as a limitation of the study. For example, the current paper has not presented the results of the SSSTs' performances (observed and marked by the project team) in "Teaching Practicum" course even though it sometimes referred to these performances.

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