International Journal of Science Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsed20

The Sources of Science Teaching Self-efficacy among Elementary School Teachers: A mediational model approach

Ya-Ling Wang[a], Chin-Chung Tsai[a] & Shih-Hsuan Wei[b]

[a] Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taipei, Taiwan

[b] Department of Mathematics Education, National Taichung University of Education, Taichung, Taiwan

Published online: 20 Aug 2015.

International Journal of Science Education, 2015
http://dx.doi.org/10.1080/09500693.2015.1075077

Routledge
Taylor & Francis Group

The Sources of Science Teaching Self-efficacy among Elementary School Teachers: A mediational model approach

Ya-Ling Wang[a], Chin-Chung Tsai[a*] and Shih-Hsuan Wei[b]
[a]*Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taipei, Taiwan;* [b]*Department of Mathematics Education, National Taichung University of Education, Taichung, Taiwan*

This study aimed to investigate the factors accounting for science teaching self-efficacy and to examine the relationships among Taiwanese teachers' science teaching self-efficacy, teaching and learning conceptions, technological–pedagogical content knowledge for the Internet (TPACK-I), and attitudes toward Internet-based instruction (Attitudes) using a mediational model approach. A total of 233 science teachers from 41 elementary schools in Taiwan were invited to take part in the study. After ensuring the validity and reliability of each questionnaire, the results indicated that each measure had satisfactory validity and reliability. Furthermore, through mediational models, the results revealed that TPACK-I and Attitudes mediated the relationship between teaching and learning conceptions and science teaching self-efficacy, suggesting that (1) knowledge of and attitudes toward Internet-based instruction (KATII) mediated the positive relationship between constructivist conceptions of teaching and learning and outcome expectancy, and that (2) KATII mediated the negative correlations between traditional conceptions of teaching and learning and teaching efficacy.

Keywords: *Science teaching self-efficacy; Teaching and learning conceptions; Technological pedagogical content knowledge; Knowledge of and attitudes toward Internet-based instruction*

Introduction

A strong sense of teaching efficacy could influence effective teaching and student achievement in the field of education (Henson, Kogan, & Vacha-Haase, 2001). However, it is probably more difficult to prepare the science course units for

*Corresponding author. Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, #43, Sec. 4, Keelung Rd., Taipei 106, Taiwan. Email: cctsai@mail.ntust.edu.tw

elementary school teachers because they are required to be responsible for teaching the majority of subjects, including both their majors and non-majors, thus leading to a lower sense of self-efficacy related to teaching science (Joseph, 2010; RameyGassert, Shroyer, & Staver, 1996). Therefore, it is likely that a lower degree of self-efficacy may exist when it comes to science teaching in elementary schools. In this regard, exploring the sources of science teaching self-efficacy among elementary teachers demands immediate attention.

In an attempt to improve this situation, the current research aimed to investigate factors in explaining the sources of science teaching self-efficacy. First, since Bandura (1977) suggested that the major factors in accounting for self-efficacy are various kinds of personal experiences, teaching and learning conceptions, which are regarded as factors constructed from previous experience, should be taken into account. Furthermore, with the advance and innovation of technology, Internet-based instruction has gained increasing attention among science educators and researchers in the field of educational technology (Anderson, Barham, & Northcote, 2013; Benson & Ward, 2013; Lee & Tsai, 2008). Researchers have asserted that Internet-based instruction can meet learners' needs for interactive and individualized learning (Lee & Tsai, 2008; McCarthy, Light, & McNaughton, 2007; Nuffer & Duke, 2013) Accordingly, Internet-based instruction is likely to promote effective teaching, which in turn contributes to teacher self-efficacy.

Given this, the current study aimed to investigate the factors accounting for the sources of science teaching self-efficacy, exploring the relationships among teachers' science teaching self-efficacy, teaching and learning conceptions, technological pedagogical content knowledge (TPCK) for the Internet, and attitudes toward Internet-based instruction.

Science Teaching Self-efficacy

Self-efficacy, developed by Bandura (1977, 1981), refers to the specific beliefs people have in their ability to complete tasks or achieve goals (personal efficacy), and their expectations that certain behaviors will produce desirable outcomes (outcome expectancy). It has been acknowledged as a critical theory in accounting for people's learning behavior. Influenced by Bandura's (1977) conceptualization of self-efficacy, many researchers have applied this theory to the research of teacher effectiveness (Gibson & Dembo, 1984; Riggs & Enochs, 1990; Roberts & Henson, 2000). In line with these studies, teacher efficacy has been identified as a variable accounting for individual differences in teaching effectiveness, and refers to the extent to which teachers believe that they have the capability to influence student achievement (Henson et al., 2001; Riggs & Enochs, 1990).

Furthermore, according to Bandura's (1977, 1981) definition of self-efficacy belief as a situation specific rather than global construct, researchers have recently applied this concept to specific teaching subjects such as science teaching, and have also developed relevant instruments investigating this idea in the field of science teaching (Aydin & Boz, 2010; Joseph, 2010; Roberts & Henson, 2000; Yılmaz & Çavaş, 2008). For instance, Riggs and Enochs (1990) developed the Science Teaching Efficacy Beliefs Instrument (STEBI), which aimed to keep the two constructs, teacher self-efficacy and outcome expectancy, distinct, and was also specific to elementary teachers' efficacy beliefs in science teaching. Furthermore, building on previous research on STEBI, Roberts and Henson (2000) introduced a new self-efficacy instrument—the Self-efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST), which included two constructs: teaching efficacy and knowledge efficacy. Based on the previous instruments, in this current research, the science teaching self-efficacy scale was modeled after the STEBI and the SETAKIST.

Precursor Factors of Science Teaching Self-efficacy

Teaching and Learning Conceptions

The traditional or constructivist conceptions of teaching and learning (Chan & Elliott, 2004), referring to the beliefs held by teachers regarding their preferred ways of teaching and learning, are associated with two models: traditional and constructivist. The traditional model regards teachers as the source of knowledge, and focuses on teachers' authority and the certainty of knowledge; the constructivist model, on the other hand, highlights the creation of student-centered environments that allow students to engage in critical thinking, discovery, and collaboration. Furthermore, Tsai (2002) interviewed Taiwanese science teachers and developed a framework for teachers' beliefs of teaching science. The findings suggested that traditional teachers hold a belief that students are passive recipients of knowledge and should learn from teachers and textbooks, and are probably less concerned about students' learning status and needs, or know less about how to improve students' learning performance. On the other hand, constructivist teachers tend to encourage students to think critically and to raise questions, and are open to challenges based on students' prior individual knowledge so that they may view themselves as effective teachers in terms of being flexible and liberal.

Knowledge of and Attitudes Toward Internet-Based Instruction

The framework of Pedagogical Content Knowledge (PCK), which was introduced by Shulman (1986), refers to the content knowledge (CK) that involves the teaching process. He further suggested Pedagogical Knowledge (PK), CK, and PCK as different concepts of teaching. To be more specific, PK is knowledge regarding how to teach, CK refers to knowledge about the subject matter, and PCK means knowledge of teaching the subject matter. There is, of course, some interplay among these three concepts.

Derived from PCK, TPCK was developed by Mishra and Koehler (2006) to illustrate the knowledge regarding how teachers integrate technology into their pedagogy. According to a systematic literature review as proposed by Voogt, Fisser, Roblin, Tondeur, and van Braak (2013), three views on TPCK have evolved over time. At first, TPCK was regarded as an enhancement of PCK. Niess (2005) investigated how a technology integration program impacted teachers' use of technology in teaching. She described TPCK as 'the integration of the development of knowledge of subject matter with the development of technology and of knowledge of teaching and learning' (p. 510).

More or less at the same time with Niess (2005), Koehler and Mishra (2005) viewed TPCK as growth in the three knowledge domains (content, pedagogy, and technology) and their intersections (PCK, Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), TPCK). Furthermore, they added 'context' to the seven knowledge domains as an imperative part of the TPACK framework (Koehler & Mishra, 2008). Along this line of thought, Thompson and Mishra (2007–2008) suggested a new name, TPACK (formerly referred to as TPCK), by which they emphasize three kinds of knowledge—Technology (T), Pedagogy (P), And Content (C), integrating them into a concise framework (henceforth referred to as TPACK in the current study). Thus, TPACK goes beyond seeing these three kinds of knowledge element in isolation. Instead, it focuses on the connections and interplay relationships among them, defining three new areas of knowledge: the PCK, the TCK, and the TPK.

However, Angeli and Valanides (2009) proposed a transformative view on TPACK and argued that the conceptualization of TPACK needs to be further clarified in the sense that the current form of TPACK fails to make explicit connections among content, pedagogy, and technology. They also indicated that the current form of TPACK lacks precision and does not deal with the role of tool affordances in learning. To enhance the framework of TPACK, Jimoyiannis (2010) further proposed an adaptation of the framework for science education, Technology Pedagogical Science Knowledge (TPASK), which was developed in the context of a teacher preparation program in Greece. In Jimoyiannis' (2010) research, he clarified the components and made explicit the connections among content, pedagogy, and technology. He further offered a detailed description of the TPASK dimensions in a realistic education setting. Also, he shifted the focus from CK to the knowledge of pedagogy that is applicable to the instruction of specific content. In general, the integrated TPASK framework elaborated the components of TPACK and enhanced the knowledge about the weak sides of TPACK model.

In view of the above adaptation of TPACK framework, the current research aimed to focus on its realistic application so that we added a specific context, that is, the Internet-based instruction as assistance for science education. The Internet is undoubtedly a highly important technology for contemporary education. With the Internet, this framework is more applicable to various education settings such as science teaching. Chou and Tsai (2002) have claimed that the Internet opens new avenues for the development, distribution of, and access to, learning materials. Therefore, when it comes to teaching with the Internet, TPACK may be insufficient for providing adequate information to assist teacher preparation and professional development. Given this, educators may require more comprehensive knowledge than TPACK when integrating the Internet into pedagogy (Lee & Tsai, 2008).

To deal with this insufficiency in the theoretical framework and practice, Lee and Tsai (2008) further specified that the Internet could be a specific form of technology, and introduced a framework of Technology Pedagogical Content Knowledge for the Internet (TPACK-I). They also developed a new questionnaire with satisfactory validity and reliability to explore teacher knowledge of Internet-based instruction.

In this current research, we integrated teachers' 'attitudes toward Internet-based instruction' into TPACK-I, along with the research of Lee and Tsai (2008), to create what we will henceforth refer to as the Knowledge of and Attitudes toward Internet-based Instruction (KATII).

A Mediational Model Approach

The Relationship Between Teaching and Learning Conceptions and Science Teaching Self-efficacy

Previous research has widely investigated the predictors of self-efficacy (e.g. Chiou & Liang, 2012; Phan, 2007; Tsai, Ho, Liang, & Lin, 2011). For example, Chiou and Liang (2012) investigated the relationships among Taiwanese high school students' science self-efficacy, conceptions of learning science, and approaches to learning science by using a structural equation modeling method. The results displayed that the students' conceptions of learning science significantly predicted their science self-efficacy, so they concluded that students' conceptions of learning in science could serve as one of the major components in their belief system of science self-efficacy. On top of that, research has also obtained consistent findings in science teaching. For instance, Sang, Valcke, Braak, and Tondeur (2010) examined the effect of student teachers' thinking processes on prospective information and communications technology (ICT) integration in education. Their findings revealed that constructivist teaching was significantly related to teacher self-efficacy.

Therefore, arguing that the beliefs or the conceptions of teaching and learning may serve as one possible component in explaining science self-efficacy, in the current study, we hypothesize that a positive relationship between constructivist conceptions of teaching and learning and science teaching self-efficacy and a negative relationship between traditional conceptions of teaching and learning and science teaching self-efficacy may emerge (shown as Path C in Figure 1). Subsequently, the present research examines whether TPACK-I is a potential mediator contributing to the relationship between teaching and learning conceptions and science teaching self-efficacy.

The Mechanism: KATII

To shed light on the relationship between teaching and learning conceptions and science teaching self-efficacy, we argue that teaching and learning conceptions and KATII are essential variables in explaining the sources of science teaching self-efficacy, and KATII could be seen as the mechanism behind why teaching and learning

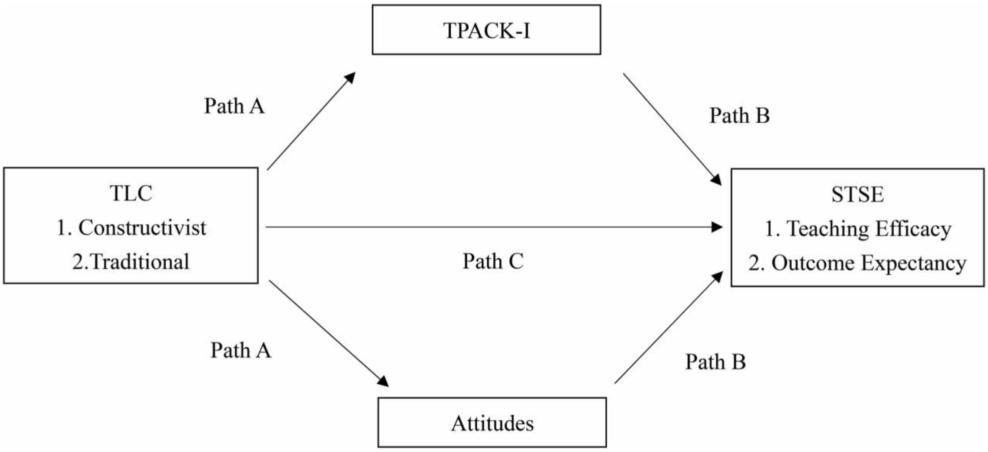

Figure 1. The mediational effects of KATII between teaching and learning conceptions and science teaching self-efficacy

conceptions influence science teaching self-efficacy (shown as Figure 1) based on the following theoretical foundations.

First, Bandura (1977) suggested that the major factors in accounting for self-efficacy are various kinds of personal experiences. In the current study, teaching and learning conceptions and KATII are both factors constructed from previous teaching experiences, thus representing precursor factors for explaining science teaching self-efficacy.

Second, according to Bandura's (1977) theory, self-efficacy is influenced by both an individual's pre-task personal factors and during-task learning behaviors. In this current research, teaching and learning conceptions refer to the beliefs that teachers hold regarding science teaching, so could be regarded as one of the individual's pre-task personal factors. Also, KATII was proposed to explore teachers' KATII, representing their during-task behaviors. Accordingly, both teaching and learning conceptions and KATII are essential in accounting for the sources of science teaching self-efficacy.

Last but not least, the positive relationship between constructivist teaching and teaching efficacy was confirmed (Sang et al., 2010), implying that Path C in Figure 1 may exist. Also, Koh, Chai, and Tsai (2014) indicated that pedagogical approaches such as inquiry-based learning and problem-based learning were developed from the conceptions of constructivism. To illustrate, constructivist approaches were incorporated as a general question on teaching pedagogies in several TPACK surveys (e.g. Archambault & Barnett, 2010; Schmidt et al., 2009), implying that Path A in Figure 1 may emerge. We accordingly predicted that teaching and learning conceptions may lead to KATII (see Path A in Figure 1), and constructivist teaching conceptions may foster science teaching self-efficacy (refer to Path C in Figure 1).

Together, based on what we inferred above, we thus hypothesized that KATII may mediate the relationship between Teaching and Learning Conceptions and Science Teaching Self-Efficacy, involving the mediational models as follows:

(1) A higher level of constructivist conceptions of teaching and learning may predict better KATII, which would then lead to a higher degree of self-efficacy belief in science teaching.
(2) A lower level of traditional conceptions of teaching and learning may predict better KATII, which would then result in a higher degree of self-efficacy belief in science teaching.

Overview of the Current Research

The purpose of the present research was to shed light on the sources of science teaching self-efficacy by investigating the relationships among teachers' teaching and learning conceptions, KATII, and science teaching self-efficacy in the discipline of science education using a mediational model technique. First, the current research adopted Bandura's (1977, 1981) and Riggs and Enochs's (1990) theory to distinguish the science teaching self-efficacy into two identified dimensions (teaching efficacy and outcome expectancy). Additionally, we employed Chan and Elliott's (2004) framework in which teachers' beliefs about teaching and learning are grouped as either traditional or constructivist. Finally, we used two subscales of Lee and Tsai's (2008) KATII (TPACK-I and Attitudes) as mediators of our models.

In an attempt to find the possible factors accounting for science teaching self-efficacy, we integrated teaching and learning conceptions and KATII into our models, and hypothesized that KATII may mediate the relationships between teaching and learning conceptions and science teaching self-efficacy. In order to examine the hypothesis of mediational effects in the current research, we followed Baron and Kenny's (1986) suggestions, and conducted regression analyses in which several regression analyses were tested and the significance of the coefficients was examined in each step.

Method

Participants

A total of 233 science teachers (55.4% females) were solicited from 41 elementary schools in Taiwan. Of these teachers, 5.2% were less than 30 years old, 43.3% were 30–40 years old, 43.8 were 40–50 years old, 5.6% were 50–60 years old, 0.9% were more than 60 years old, and 1.3% did not report their age. Their teaching experience ranged from 1 to 41 years, with an average of approximately 15 years. Also, 45.5% of the participants had a Bachelor's degree, 52.4% had a Master's degree, 1.3% had a Ph. D., and 0.9% did not report their degree. Although this sample could not be viewed as a national sample, the surveyed teachers came from a variety of schools in Taiwan, across different demographic areas and backgrounds, which may be said to be representative in Taiwan.

Measures

Science teaching self-efficacy. The Science Teaching Self-Efficacy scale measures the extent to which science teachers believe they have the capability to positively influence students' science learning and performance. The science teaching self-efficacy scale was mainly modeled after the STEBI developed by Riggs and Enochs (1990), by also integrating some items from the SETAKIST developed by Roberts and Henson (2000). To streamline and simplify our models, we adopted the two factors of STEBI, teaching efficacy and outcome expectancy, as the constructs of science teaching self-efficacy.

Three experts in science education and three elementary school teachers validated the scale items, and suggested some minor wording revisions. After the procedure of item development, the content validity of the science teaching self-efficacy scale was established. The 12-item version consists of 2 factors: (1) Personal Science Teaching Efficacy, which means the belief that teachers have confidence in their own teaching abilities (e.g. 'I know the steps necessary to teach science concepts effectively'; 1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*); (2) Science Teaching Outcome Expectancy, which refers to the belief that students' science learning can be influenced by effective teaching (e.g. 'When a low achieving child progresses in science, it is usually due to extra attention given by the teacher'; 1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*).

The traditional or constructivist conceptions of teaching and learning. The Teaching and Learning Conceptions Questionnaire, which was revised and translated from the scale developed by Chan and Elliott (2004), measures two different conceptions of teaching/learning: Traditional and Constructivist.

The 14-item version consists of 2 constructs: (1) Traditional, which means the belief that teaching is seen as a transmission of knowledge (e.g. 'Learning means remembering what the teacher has taught'; 1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*); (2) Constructivist, which refers to the belief that teaching is a provision and facilitation of the learning process rather than transmission of knowledge (e.g. 'Learning means students have ample opportunities to explore, discuss and express their ideas'; 1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*).

Knowledge of and attitudes toward Internet-based instruction. The KATII survey, which was developed by Lee and Tsai (2008), was proposed to explore teacher KATII. To streamline and simplify our models, we only used two subscales from Lee and Tsai (2008) for the current study: Technological Pedagogical Content Knowledge—for the Internet (TPACK-I) and Attitudes toward Internet-based instruction (Attitudes).

The 15-item survey thus consists of two constructs: (1) Technological Pedagogical Content Knowledge—Internet (TPACK-I), which measures the extent to which teachers have confidence in their knowledge of how to implement appropriate online learning activities to achieve the purpose of a particular course (e.g. 'I know how to apply teaching modules on the Internet to courses'; 1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*); (2) Attitudes toward Internet-based instruction (Attitudes), which operationalizes teachers' agreement regarding the usage of Internet-based instruction (e.g. 'Internet technology can actually be used in the practice of teaching'; 1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*).

Data Analysis and Procedures

The procedure of this study involved two phases: exploratory factor analysis (EFA), which was used to reduce the number of items and to ensure the structures of each measure, and mediational models, which were employed to test the relationships among teaching and learning conceptions, science teaching self-efficacy, and KATII.

In the EFA, we followed two criteria to decide whether an item should be retained. First, only those items with a factor loading of at least 0.50 within their own factor were retained in the measure (Costello & Osborne, 2005; Hair, Black, Babin, Anderson, & Tatham, 2006). Second, items with factor loadings of multiple cross-loadings were excluded in the process (Bentler, 1990). Accordingly, the construct validity of the three measures we used in our study was established. Also, the Cronbach's alpha coefficient for each dimension of the science teaching self-efficacy instrument, the teaching and learning conceptions questionnaire, and KATII were calculated to ensure the reliability (internal consistency) of each factor.

In addition, in order to examine our hypothesis of mediational effect, we also conducted regression analyses in which several regression analyses were conducted and the significance of the coefficients was examined in each step (Baron & Kenny, 1986).

Results

Validity and Reliability of the Measures

Since oblique rotations provide a more accurate representation of how constructs are likely to be related to one another (Gorsuch, 1983; Hendrickson & White, 1964), and one of the oblique rotations, the Promax rotation, was recommended due to its accessibility, we conducted an EFA with a Promax rotation to clarify the constructs of science teaching self-efficacy questionnaire. As a result, the teachers' responses were grouped into Teaching Efficacy and Outcome Expectancy as expected. The eigenvalues of the two factors from the principle axis factoring were all larger than one. Items with a factor loading of less than 0.50 and with many cross-loadings were omitted from this measure (Costello & Osborne, 2005). A total of 12 items were retained in the final version of the science teaching self-efficacy instrument (see Table 1 for the instrument), and the total variance explained was 56.51%. Also, the reliability (Cronbach's alpha) coefficients for Teaching Efficacy and Outcome Expectancy were 0.88 and 0.78, respectively, indicating that they had high internal consistency for assessing the teachers' self-efficacy for teaching science.

Furthermore, Table 2 shows the EFA results for teaching and learning conceptions questionnaire. It is noted that the same criteria were adopted for all instruments used

Table 1. Final retained items and rotated factor loadings of the science teaching self-efficacy instrument

Questionnaire items	Factor 1 Teaching efficacy	Factor 2 Outcome expectancy
1. I know the steps necessary to teach science concepts effectively.	0.73	
2. I am very effective in monitoring science experiments.	0.82	
3. I am typically able to answer students' science questions.	0.74	
4. I wonder if I have the necessary skills to teach science.	0.73	
5. I know what to do to turn students on to science.	0.66	
6. After I have taught a science concept once, I feel confident teaching it again.	0.62	
7. I know how to make students interested in science.	0.67	
8. The high science achievement of some students is generally caused by their teachers.		0.71
9. When a low achieving child progresses in science, it is usually due to extra attention given by the teacher.		0.54
10. The teacher is generally responsible for the achievement of students in science.		0.65
11. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.		0.73
12. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher.		0.60

in the current study. Accordingly, the 14 items were all included in teaching and learning conceptions questionnaire, with a total of 56.61% of variation explained. The alpha reliability coefficients were 0.88 for the Constructivist factor and 0.86 for the Traditional factor, suggesting satisfactory internal consistency of assessing teachers' conceptions of teaching and learning.

In order to validate KATII, of which we only used two constructs—TPACK-I and Attitudes—in this study, we also conducted an EFA with a Promax rotation to clarify the two constructs. The results indicated that the 15 items could all be retained and could be grouped into two factors, as expected (see Table 3 for the measure). The total variance explained was 61.03%. In addition, the reliability coefficients were 0.90 for TPACK-I and 0.89 for Attitudes, suggesting that this instrument is reliable for evaluating teachers' TPACK-I and Attitudes.

Tests of Hypotheses

Preliminary Analysis

Table 4 contains means, standard deviations and correlations for the major variables. As can been seen in Table 4, constructivist conceptions and the two constructs of

Table 2. Final retained items and rotated factor loadings of the teaching and learning conceptions questionnaire

Questionnaire items	Factor 1 Constructivist	Factor 2 Traditional
1. It is important that a teacher understands the feelings of the students.	0.57	
2. Good teachers always encourage students to think for answers themselves.	0.63	
3. Learning means students have ample opportunities to explore, discuss and express their ideas.	0.78	
4. Effective teaching encourages more discussion and hands on activities for students.	0.75	
5. The focus of teaching is to help students construct knowledge from their learning experience instead of knowledge communication.	0.66	
6. Students should be given many opportunities to express their ideas.	0.72	
7. The ideas of students are important and should be carefully considered.	0.77	
8. Learning means remembering what the teacher has taught.		0.74
9. The traditional/lecture method for teaching is best because it covers more information/knowledge.		0.76
10. Learning mainly involves absorbing as much information as possible.		0.75
11. Teaching is to provide students with accurate and complete knowledge rather than encourage them to discover it.		0.77
12. A teacher's task is to correct learning misconceptions of students right away instead of letting the students verify them for themselves.		0.65
13. Learning to teach simply means practicing the ideas from lecturers without questioning them.		0.59
14. The major role of a teacher is to transmit knowledge to students.		0.58

science teaching self-efficacy were positively correlated ($r = .42$, $p < .01$ for teaching efficacy; $r = .18$, $p < .01$ for outcome expectancy), indicating that teachers with higher agreement with constructivist teaching conceptions displayed stronger teaching efficacy beliefs and outcome expectancy in science teaching. Also, traditional conceptions and teaching efficacy were negatively correlated ($r = -.13$, $p < .05$), indicating that teachers with more traditional teaching conceptions displayed lower teaching efficacy beliefs in science teaching.

Teaching and Learning Conceptions Predicting Mediators

To test the mediational effect, we regressed teaching and learning conceptions on the mediators: TPACK-I and Attitudes. The results are shown in Table 5.

The analyses predicting TPACK-I and attitudes revealed the expected and significant effect of constructivist conceptions ($\beta = .42$, $p < .001$ for TPACK-I; $\beta = .38$, p

Table 3. Final retained items and rotated factor loadings of the KATII

Questionnaire items	Factor 1 TPACK-I	Factor 2 Attitudes
1. Be able to select proper existing Internet-based courses to assist teaching.	0.52	
2. Be able to use Internet technology to enhance teaching.	0.56	
3. Be able to apply Internet technology to use multiple teaching strategies in a particular course unit.	0.75	
4. Be able to search for information using Internet technology, thereby assisting the instruction of a science course unit.	0.52	
5. Be able to guide students to use Internet resources to study a certain course unit.	0.73	
6. Be able to guide students to engage in science curriculum activities with Internet technology.	0.67	
7. Be able to use Internet technology to support teaching for the content of a particular course unit.	0.59	
8. Be able to guide students to complete take-home assignments with Internet technology and related resources.	0.72	
9. Be able to design supplementary materials for students in science courses with Internet technology and related resources.	0.80	
10. Internet technology can actually be used in the practice of teaching.		0.64
11. The characteristics of the Internet can help instruction.		0.81
12. Internet technology can enhance teaching skills.		0.86
13. Internet-related resources can enrich course content.		0.77
14. Internet-based teaching can enhance students' learning motivation.		0.82
15. Internet-based teaching is a future trend in education.		0.74

Table 4. Descriptive statistics and correlations

Descriptive statistics			Correlations					
	Mean	SD	1	2	3	4	5	6
TLC								
1. Constructivist	4.62	0.40	1.00					
2. Traditional	2.39	0.60	−0.29	1.00				
STSE								
3. Teaching efficacy	4.06	0.46	0.42**	−0.13*	1.00			
4. Outcome expectancy	3.70	0.49	0.18**	0.11	0.36**	1.00		
KATII								
5. TPACK-I	4.20	0.46	0.36**	−0.22**	0.62**	0.29**	1.00	
6. Attitudes	4.41	0.47	0.32**	−0.19**	0.40**	0.25**	0.66**	1.00

Note: TLC, teaching and learning conceptions; STSE, science teaching self-efficacy.

*$p < .05$.

**$p < .01$.

Table 5. Teaching and learning conceptions predicting the mediators

Variables	TPACK-I *B* (SD)	Attitudes *B* (SD)
Constructivist	0.42*** (0.07)	0.38*** (0.07)
Traditional	−0.17** (0.05)	−0.15** (0.05)

$^{**}p < .01$.

$^{***}p < .001$.

< .001 for attitudes). Additionally, the effects of traditional conceptions predicting TPACK-I and attitudes were also significant ($\beta = -.17$, $p < .01$ for TPACK-I; $\beta = -.15$, $p < .01$ for attitudes). The results indicated that constructivist teachers showed more Internet-based PCK and had more positive attitudes toward Internet-based instruction; on the other hand, traditional teachers displayed less Internet-based PCK and also had less positive attitudes toward Internet-based instruction.

Mediational Effects of KATII Between Teaching and Learning Conceptions and Science Teaching Self-efficacy

To test the mediational effect, we regressed teaching and learning conceptions and the mediators on science teaching self-efficacy. The results listed in Table 6 and in Figures 2 and 3 support the mediational effects. The coefficient for the direct relationship between constructivist and outcome expectancy dropped from a significant .22 ($p < .01$) to 0.10 (ns) after accounting for the effects of TPACK-I ($\beta = .27$, $p < .001$); also, the coefficient dropped from a significant .22 ($p < .01$) to 0.14 (ns) after accounting for the effects of attitudes ($\beta = .22$, $p < .01$). As for the relationship

Table 6. Teaching and learning conceptions and mediators (KATII) predicting science teaching self-efficacy

	Outcome expectancy			Teaching efficacy		
Variables	Model 1a	Model 1b	Model 1c	Model 2a	Model 2b	Model 2c
Constructivist	0.22** (0.08)	0.10 (0.08)	0.14 (0.08)			
Traditional				−0.10** (0.05)	0.00 (0.04)	−0.04 (0.05)
TPACK_I		0.27*** (0.07)			0.61*** (0.05)	
Attitudes			0.22** (0.07)			0.37*** (0.06)

$^{**}p < .01$.

$^{***}p < .001$.

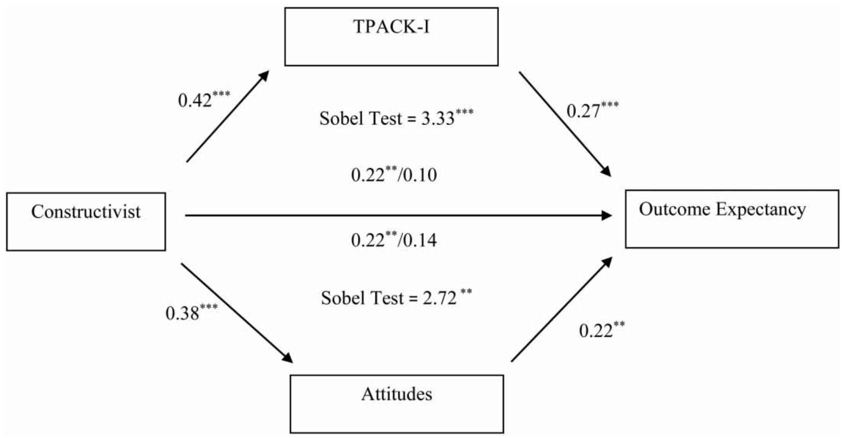

Figure 2. The mediational effects of TPACK-I and attitudes between constructivist teaching conceptions and outcome expectancy

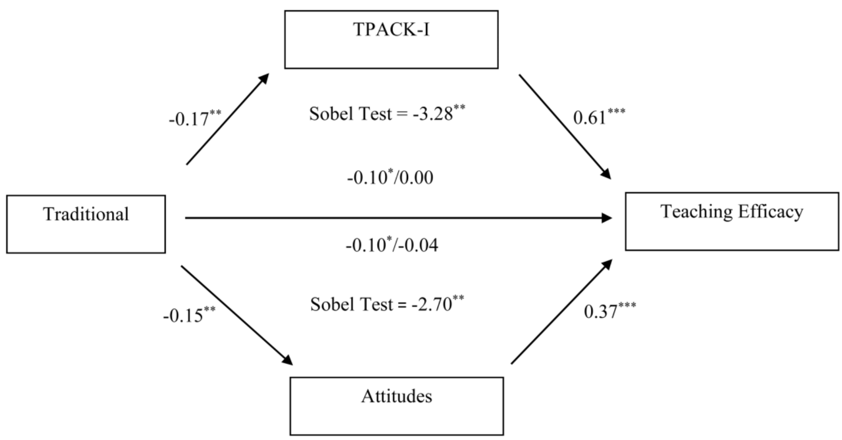

Figure 3. The mediational effects of TPACK-I and attitudes between traditional teaching conceptions and teaching efficacy

between traditional beliefs and teaching efficacy, the coefficient dropped from a significant −.10 ($p < .05$) to 0.00 (ns) after accounting for the effects of TPACK-I ($\beta = .61$, $p < .001$), and from a significant −.10 ($p < .05$) to −.04 (ns) after accounting for the effects of attitudes ($\beta = .37$, $p < .001$).

Discussion

This study was conducted to investigate the factors accounting for science teaching self-efficacy, and hypothesized the mediational relationship among Taiwanese teachers' science teaching self-efficacy, teaching and learning conceptions, and KATII.

First, the study modified STEBI, which was developed by Riggs and Enochs (1990), and SETAKIST, which was developed by Roberts and Henson (2000), to assess teacher self-efficacy in science teaching. The EFA results showed two constructs, Teaching Efficacy and Outcome Expectancy, consistent with Bandura's (1977, 1981) definition of self-efficacy beliefs. Next, the study adopted Chan and Elliott's (2004) teaching and learning conceptions questionnaire to measure the teachers' conceptions of teaching and learning. The EFA results revealed two constructs, Traditional and Constructivist, which are aligned with Chan and Elliott's theory. Finally, this study utilized two subscales of the KATII survey (Lee & Tsai, 2008) to assess teacher knowledge and attitudes toward Internet-based instruction. The results of good construct validity and high reliability of the subscales are consistent with Lee and Tsai's study.

Also, the mediational relationships among science teaching self-efficacy, KATII, and teaching and learning conceptions were supported in the current study using regression analyses. The results indicated that TPACK-I and Attitudes mediated the effects of teaching and learning conceptions on science teaching self-efficacy. Based on the findings of the current study, it is suggested that teachers' knowledge of and attitudes toward Internet-based instruction are crucial in explaining the mechanism behind why teaching and learning conceptions would predict teaching efficacy and outcome expectancy.

The results in the current research are consistent with the previous findings. For example, Sang et al. (2010) examined the effect of student teachers' thinking processes on prospective ICT integration in education, and their findings revealed that constructivist teaching beliefs were significantly related to teacher self- efficacy. Similar findings in the study of Temiz and Topcu (2013) were analogous to our finding that teaching and learning conceptions positively affected science teaching self-efficacy. Also, Voogt et al. (2013) systematically reviewed 55 peer-reviewed articles regarding TPACK. Their findings showed that six studies examined how a teacher's TPACK was related to teacher beliefs, one study of which demonstrated that teachers' TK was a stable predictor of teachers' self-efficacy in terms of technology. Although their findings were consistent with those of the current study, they did not integrate these relationships into a more comprehensive framework. In this regard, the current research is one of the pioneering studies to investigate the sources of science teaching self-efficacy adopting a mediational model approach.

Similarly, Chiou and Liang (2012) investigated the relationships among Taiwanese high school students' Conceptions of Learning Science, Approaches to Learning Science, and Science Self-efficacy. The results revealed that students' conceptions of learning science directly influenced their approaches to learning science, which in turn contributed to their science self-efficacy. Although Chiou and Liang proposed a structural model accounting for the sources of students' science self-efficacy, consistent with the approach we adopted in the current research, the current study aimed to target the science teacher population and to explore the sources of science teaching self-efficacy instead, as one of the contributions this study was devoted to making.

However, it is worth noting that, of all the possible models, the mediational effects of TPACK-I and Attitudes only emerged in the relationships between constructivist conceptions and outcome expectancy, and in traditional conceptions and teaching efficacy. That is, TPACK-I and Attitudes did not significantly mediate the relationship between traditional conceptions and outcome expectancy, or the relationship between constructivist conceptions and teaching efficacy.

We provide two possible explanations for these unexpected findings. First, as can been seen in Table 4, Pearson correlation analysis showed no significant relationship between traditional conceptions and outcome expectancy. For this result, it is likely that teachers with a traditional conception tend to regard teaching as a way of transmitting knowledge, and learning as remembering what the teacher has taught (Chan & Elliott, 2004; Cheng, Chan, Tang, & Cheng, 2009). Accordingly, in terms of learning achievement, they probably place more emphasis on student learning effort, rather than on what teachers do. However, outcome expectancy refers to the belief that effective teaching can influence students' science learning. Therefore, it is likely that the traditional conception was not significantly related to outcome expectancy because traditional teachers may attribute student learning achievement to student effort, rather than effective teaching. Second, as for the relationship between constructivist conceptions and teaching efficacy, the results showed that teachers with constructivist conceptions of teaching and learning had higher levels of teaching efficacy in science teaching. However, TPACK-I and Attitudes did not significantly mediate this relationship in terms of the mechanism behind why constructivist conceptions could predict teaching efficacy. It is possible that since teachers who have a higher level of constructivist conceptions tend to believe in their own ability to teach effectively, they may prepare their courses and activities based on individual differences in the students' prior knowledge and experience (Chan & Elliott, 2004; Cheng et al., 2009). Also, they are more flexible when it comes to using all kinds of pedagogy based on the needs of the students (Chan & Elliott, 2004; Cheng et al., 2009). In addition to the various pedagogies based on students' need, it is also likely that constructivist teachers tend to hand over more responsibilities to learners for their own learning. Teachers may design different pedagogical activities to encourage students to being responsible for their own learning. Accordingly, teachers do not rely on a specific teaching strategy because of the requirements of a student-centered environment. Together, knowledge of and attitudes toward Internet-based instruction are probably not salient in explaining the effects of teaching and learning conceptions on science teaching self-efficacy. However, these possible explanations are tentative; the clarification of this issue will be left to future research.

Implications, Future Directions, and Conclusions

This study is one of the pioneering studies to investigate the sources of science teaching self-efficacy adopting a mediational model approach. The sources of self-efficacy have been widely investigated in previous studies (e.g. Bandura, 1977; Chiou & Liang, 2012; Kiran & Sungur, 2012a, 2012b). However, few studies have focused on the sources of science teaching self-efficacy using a mediational model approach, so the findings of this current research could have implications for science education and future research.

The educational and testing systems in Taiwan may impede students' creativity and intrinsic motivation to utilize deep approaches to learning science, decreasing their self-efficacy for learning science (Lin & Tsai, 2013). One way to improve this situation is to build a mature science learning environment with successful science teachers. Successful science teachers are acknowledged as being those who are equipped with adequate knowledge and who are capable of developing appropriate pedagogical strategies to accomplish teaching based on various levels of student prior knowledge (Lin, Tsai, Chai, & Lee, 2012). These strategies certainly include a better usage of ICTs (Mishra & Koehler, 2006). The findings from the mediational models in this study could provide two suggestions for science teachers to promote teaching efficacy. First, constructivist conceptions of teaching and learning, rather than traditional conceptions, should be developed. For example, teachers could learn to encourage students to express their ideas, and to design course activities based on student feedback or alternative conceptions. Furthermore, based on our previous suggestion, the effects of TPACK-I and attitudes toward Internet-based instruction are cumulative. To illustrate, in addition to developing constructivist conceptions, teachers could also appropriately use the Internet technology to support teaching, while having a positive attitude toward Internet-based instruction, which will facilitate this effect.

As for its implications for future research, although this study spared no effort to explore the effects described above, the results should be interpreted with caution. We list the limitations with corresponding future research directions as follows.

First, there may be other mechanisms (i.e. other mediators or moderators) that can explain the effects of teaching and learning conceptions on science teaching self-efficacy. It is likely that the relationship between teaching and learning conceptions and science teaching self-efficacy does not exist in some specific situations, and given that, exploring these boundary conditions is inevitably crucial for future research. It is our intention that the mediational effects of TPACK-I and Attitudes proposed in this study will stimulate future research that investigates ways to shed further light on the mechanisms behind why teaching and learning conceptions may affect science teaching self-efficacy.

Second, because this study examined participants using a single questionnaire design, its conclusions should be limited to this particular situation. From the perspectives of theoretical replication and practical application, future research should collect data from natural environments, experimental tasks, and actual interactions using longitudinal methods. For example, researchers could sequentially examine the degree of teachers' teaching and learning conceptions, KATII, and science teaching self-efficacy from different waves of investigations, thereby establishing the causal relationships.

Finally, regarding the finding that TPACK-I and Attitudes did not significantly mediate this relationship in terms of the mechanism behind why constructivist conceptions could predict teaching efficacy, the possible explanations we provided, however, are tentative. Further research exploring these issues could adopt interviews with teachers, which could obtain more information regarding how constructivist teachers prepare their courses and activities.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Ministry of Science and Technology in Taiwan [MOST 102-2511-S-011-002-MY3].

References

Anderson, A., Barham, N., & Northcote, M. (2013). Using the TPACK framework to unite disciplines in online learning. *Australasian Journal of Educational Technology*, *29*(4), 549–565.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, *52*(1), 154–168. doi:10.1016/j.compedu.2008.07.006

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, *55*(4), 1656–1662. doi:10.1016/j.compedu.2010.07.009

Aydin, S., & Boz, Y. (2010). Pre-service elementary science teachers' science teaching efficacy beliefs and their sources. *Elementary Education Online*, *9*(2), 694–704.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

Bandura, A. (1981). Self-referent thought: A developmental analysis of self-efficacy. In J. H. Flavell & L. Ross (Eds.), *Social cognitive development frontiers and possible futures* (pp. 200–239). Cambridge: Cambridge University Press.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173–1182.

Benson, S. N. K., & Ward, C. L. (2013). Teaching with technology: Using TPACK to understand teaching expertise in online higher education. *Journal of Educational Computing Research*, *48*(2), 153–172. doi:10.2190/Ec.48.2.C

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*, 238–246.

Chan, K.-W., & Elliott, R. G. (2004). Relational analysis of personal epistemology and conceptions about teaching and learning. *Teaching and Teacher Education*, *20*(8), 817–831. doi:10.1016/j.tate.2004.09.002

Cheng, M. M. H., Chan, K.-W., Tang, S. Y. F., & Cheng, A. Y. N. (2009). Pre-service teacher education students' epistemological beliefs and their conceptions of teaching. *Teaching and Teacher Education*, *25*(2), 319–327. doi:10.1016/j.tate.2008.09.018

Chiou, G. L., & Liang, J. C. (2012). Exploring the structure of science self-efficacy: A model built on high school students' conceptions of learning and approaches to learning in science. *Asia-Pacific Education Researcher*, *21*(1), 83–91.

Chou, C., & Tsai, C.-C. (2002). Developing web-based curricula: Issues and challenges. *Journal of Curriculum Studies*, *34*(6), 623–636. doi:10.1080/00220270210141909

Costello, A. B., & Osborne, J. W. (2005). Best practice in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation*, *10*(7), 1–9.

Gibson, S., & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology*, *76*(4), 569–582.

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis*. Upper Saddle River, NJ: Prentice-Hall.

Hendrickson, A. E., & White, P. O. (1964). Promax: A quick method for rotation to oblique simple structure. *British Journal of Statistical Psychology*, *17*, 65–70.

Henson, R. K., Kogan, L. R., & Vacha-Haase, T. (2001). A reliability generalization study of the teacher efficacy scale and related instruments. *Educational and Psychological Measurement*, *61*(3), 404–420. doi:10.1177/00131640121971284

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education*, *55*(3), 1259–1269. doi:10.1016/j.compedu.2010.05.022

Joseph, J. (2010). Does intention matter? Assessing the science teaching efficacy beliefs of pre-service teachers as compared to the general student population. *Electronic Journal of Science Education*, *14*(1), 1–14.

Kiran, D., & Sungur, S. (2012a). Middle school students' science self-efficacy and its sources: Examination of gender difference. *Journal of Science Education and Technology*, *21*(5), 619–630. doi:10.1007/s10956-011-9351-y

Kiran, D., & Sungur, S. (2012b). Sources and consequences of Turkish middle school students' science self-efficacy. *Asia-Pacific Education Researcher*, *21*(1), 172–180.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of Technological Pedagogical Content Knowledge. *Journal of Educational Computing Research*, *32*(2), 131–152.

Koehler, M. J., & Mishra, P. (2008). Introducing TPCK. In The AACTE Committee on Innovation and Technology (Ed.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3–29). New York, NY: Routledge.

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2014). Demographic factors, TPACK constructs, and teachers' perceptions of constructivist-oriented TPACK. *Educational Technology & Society*, *17*(1), 185–196.

Lee, M.-H., & Tsai, C.-C. (2008). Exploring teachers' perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the world wide web. *Instructional Science*, *38*(1), 1–21. doi:10.1007/s11251-008-9075-4

Lin, T.-J., & Tsai, C.-C. (2013). A multi-dimensional instrument for evaluating Taiwanese high school students' science learning self-efficacy in relation to their approaches to learning science. *International Journal of Science and Mathematics Education*, *11*(6), 1275–1301. doi:10.1007/s10763-012-9376-6

Lin, T.-C., Tsai, C.-C., Chai, C. S., & Lee, M.-H. (2012). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*(3), 325–336. doi:10.1007/s10956-012-9396-6

McCarthy, J., Light, J., & McNaughton, D. (2007). The effects of Internet-based instruction on the social problem solving of young adults who use augmentative and alternative communication. *Augmentative and Alternative Communication*, *23*(2), 100–112. doi:10.1080/07434610600720426

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. doi:10.1111/j.1467-9620.2006.00684.x

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. doi:10.1016/j.tate.2005.03.006

Nuffer, W., & Duke, J. (2013). A comparison of live classroom instruction and internet-based lessons for a preparatory training course delivered to 4th year pharmacy students. *Journal of Science Education and Technology*, *22*(4), 522–528. doi:10.1007/s10956-012-9411-y

Phan, H. P. (2007). An examination of reflective thinking, learning approaches, and self-efficacy beliefs at the university of the South Pacific: A path analysis approach. *Educational Psychology*, *27*(6), 789–806. doi:10.1080/01443410701349809

RameyGassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education*, *80*(3), 283–315. doi:10.1002/(Sici)1098-237x(199606)80:3<283::Aid-Sce2>3.0.Co;2-A

Riggs, M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy. *Science Education*, *74*(6), 625–637.

Roberts, J. K., & Henson, R. K. (2000). *Self-efficacy teaching and knowledge instrument for science teachers (SETAKIST): A proposal for a new efficacy instrument*. Paper presented at the annual meeting of the Mid-South Educational Research Association, Bowling Green, KY.

Sang, G., Valcke, M., Braak, J. v., & Tondeur, J. (2010). Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors with educational technology. *Computers & Education*, *54*(1), 103–112. doi:10.1016/j.compedu.2009.07.010

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technology pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123–149.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

Temiz, T., & Topcu, M. S. (2013). Preservice teachers' teacher efficacy beliefs and constructivist-based teaching practice. *European Journal of Psychology of Education*, *28*(4), 1435–1452. doi:10.1007/s10212-013-0174-5

Thompson, A. D., & Mishra, P. (2007–2008). Breaking news: TPCK becomes TPACK! *Journal of Computing in Teacher Education*, *24*(2), 38–64.

Tsai, C.-C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*, *24*(8), 771–783. doi:10.1080/09500690110049132

Tsai, C.-C., Ho, H.-N. J., Liang, J.-C., & Lin, H.-M. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction*, *21*(6), 757–769. doi:10.1016/j.learninstruc.2011.05.002

Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge—a review of the literature. *Journal of Computer Assisted Learning*, *29*(2), 109–121. doi:10.1111/j.1365-2729.2012.00487.x

Yılmaz, H., & Çavaş, P. H. (2008). The effect of the teaching practice on pre-service elementary teachers' science teaching efficacy and classroom management beliefs. *Eurasia Journal of Mathematics, Science & Technology Education*, *4*(4), 45–54.