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A mixed research-based model for pre-service science teachers' digital literacy: Responses to "which beliefs" and "how and why they interact" questions

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ABSTRACT

This study constructs a science teaching belief system to examine pre-service science teachers' scientific epistemological beliefs (SEBs) and conceptions of teaching and learning (COTL). The aim of the study was to investigate the structural relations among pre-service science teachers' SEBs, COTL and digital literacy skills and to determine the reasons for these relations. First, quantitative research was conducted to examine the structural relations among the variables, using structural equation modeling analysis on the data gathered from 979 pre-service science teachers. Next, qualitative research investigated the reasons for these relations. Thus, the study has a sequential explanatory research design. The findings of the study showed that pre-service science teachers' SEBs affected their constructivist conceptions positively. On the other hand, their SEBs were related to their traditional conceptions negatively. In addition, pre-service teachers' COTL contribute more positively to their digital literacy skills if they hold constructivist conceptions. The previous experiences of pre-service science teachers were also found to affect their beliefs and digital literacy skills. The findings contribute to the educational literature by focusing on the relationships among pre-service science teachers' SEBs, COLT and digital literacy, which is one of the most important 21st century skills, in the context of pre-service science teachers' belief systems.

1. Introduction

A plethora of scientific research has empirically shown that integrating digital technologies into science-learning media supports student comprehension (Abdullahi, 2014; Chang, Tsai, & Jang, 2014; Maharaj-Sharma & Sharma, 2017; Shively & Yerrick, 2014). Considering coherence among evidential support presented in the literature, Turkish education policymakers initiated the FATIH (Turkish acronym for Movement of Enhancing Opportunities and Improving Technology) project in 2010 to empower digital technologies in all levels of state schools. LCD touchable smart boards, together with internet connection and personal tablets for students and teachers, were distributed across the country, and in-service training for teachers was provided by the Ministry of National Education. The country allocated a large budget for this project. In November 2016, President Erdoğan stated, "We overcame the physical problems but could not enhance the minds at the same level." Several days later, PISA 2015 results were presented, indicating that Turkish students' science literacy scores were ranked 52nd among 70 countries (OECD, 2016). A plethora of scientific research point out challenges, barriers and other issues to be considered about integrating digital technologies in education (Al-

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Bataineh, Anderson, Toledo, & Wellinski, 2008; Ertmer & Ottenbreit-Leftwich, 2010; Frederick, Schweizer, & Lowe, 2006; Honan, 2008; Hutchison & Reinking, 2011; Lim, 2007). For example Ertmer and Ottenbreit-Leftwich (2010) focused on a lack of pedagogical support. Furthermore, Frederick et al. (2006) studied on insufficient skills of teachers. In brief, issues related to digital literacy remain on the agenda of many countries.

In this study, we address the issue from a psychological perspective, together with contributions from the lens of educational technology researchers. Specifically, we focus on pre-service science teachers' barriers regarding technology integration. Ertmer (1999, 2005) explains that there are two forms of barriers: first-order and second-order. First-order barriers relate to the accessibility of hardware and software equipment and to pre-/in-service teacher training on how to use the equipment. As described above, this barrier was already addressed in Turkey. Second-order barriers involve intrinsic factors such as teachers' beliefs, knowledge and attitudes regarding technology integration. Turkish students' performance on international exams indicates that the problem relates to second-order barriers (Erdemir, Bakırcı, & Eyduran, 2009; Karaca, Can, & Yıldırım, 2013; Pamuk, Çakır, Ergun, Yılmaz, & Ayas, 2013). Therefore, we must empower pre-service science teachers with regard to technology integration.

Science education literature underscores the effects of pre-service science teachers' beliefs on their current and future teaching practices (Fives & Buehl, 2012; Pajares, 1992). Notably, there exists a hierarchy of beliefs because of the abundance of teachers' belief types (Fishbein & Ajzen, 1975; Rokeach, 1968). Pre-service science teachers' epistemological beliefs and conceptions of teaching and learning are reflected in their teaching behaviors (Bahcivan, 2014a,b; Bahçivan, 2016; Bahcivan & Kapucu, 2014; Hofer & Pintrich, 1997). Therefore, we suggest that these beliefs may affect pre-service science teachers' adoption of digital technologies in producing, learning and teaching science.

Regarding second-order barriers, another important issue is pre-service science teachers' digital literacy, which is considered a 21st century competency (Dede, 2010; Mishra & Kereluik, 2011; Voogt & Pareja Roblin, 2012). Digital literacy may be an indicator of pre-service science teachers' effective use of digital technologies in science learning environments (Martinovic & Zhang, 2012; Zhao, Pugh, Sheldon, & Byers, 2002) and may be related to the hierarchy of other beliefs. Therefore, these possible hierarchies of beliefs and their relation to digital literacy qualifications can help determine how teachers should be educated in undergraduate programs. In addition, knowing the reasons why and how these beliefs are linked to digital literacy will improve teacher education. In this regard, the purpose of this study is twofold: 1) to construct a science teaching belief system to address pre-service science teachers' epistemological beliefs and conceptions of teaching and learning, investigating the relations between these beliefs and digital literacy; and 2) to examine how and why these beliefs affect their digital literacy.

2. Background

2.1. Science teacher belief systems

Beliefs are defined as people's subjective judgments about themselves and their environment (Fishbein & Ajzen, 1975) or predispositions to actions (Rokeach, 1968). These definitions have led science teacher educators into thinking that teachers' beliefs affect their decisions and teaching practices (Bahçivan, 2016; Bahcivan & Cobern, 2016) by filtering context-based knowledge and providing direction via attitudes and behaviors (Ajzen, 1991; Fives & Buehl, 2012; Pajares, 1992). However, science teacher educators have presented evidence regarding the resistance of beliefs to change and thus believe that addressing pre-/in-service science teachers' beliefs is the most effective way of producing science-literate people (Bahcivan & Cobern, 2016). However, they also observe that teachers' beliefs may not be coherent with their practices (Kane, Sandretto, & Heath, 2002). At this point, a psychological lens may support the progress of science teacher education. Prominent psychologists (e.g., Fishbein & Ajzen, 1975; Rokeach, 1968) note that because people hold countless beliefs, it is difficult to make healthy decisions without a hierarchy among these beliefs. Therefore, pre-service science teachers' beliefs should have an impact on their teaching behavior in a systematic manner referred to as a belief system (Rokeach, 1968).

According to Rokeach (1968), people's beliefs expand on a central-peripheral continuum such that central beliefs have more connections to other beliefs in comparison to peripheral beliefs. Therefore, changing a central belief is more difficult than changing a peripheral belief, because if a central belief is changed, the peripheral beliefs connected to this central belief also must change. Rokeach (1968) defines 5 types of beliefs from central to peripheral: Type A, B, C, D and E beliefs. Types A and B include the beliefs about the nature of self so that these beliefs involve personal responses to "Who am I?" question. Moreover, there is a social consensus on Type A beliefs, whereas there is not a social consensus on Type B beliefs. Both of these beliefs are incontrovertible, and therefore, nearly infeasible to change. Type C beliefs, also called authority beliefs, assist people in forming a realistic picture of the world through sources of knowledge and knowing. Type D beliefs include ideological beliefs derived from Type C beliefs. Finally, Type E beliefs relate to matters of taste. According to Rokeach (1968), Type C beliefs are more central in comparison to Type D beliefs because the latter is derived from the former. In addition, Type E beliefs are the most peripheral ones because they have almost no connection to other beliefs. Numerous studies, including Bahcivan (2014a), Bahçivan (2016), Bahcivan and Cobern (2016), Bahcivan and Kapucu (2014), Güneş and Bahçivan (2016), present empirical findings that such a belief system can be adapted to pre-/in-service science teachers' teaching beliefs. In this study, Type A and B beliefs are not included in the system because of the infeasibility of changing them. Type E beliefs are also excluded because according to Rokeach (1968), these beliefs are mostly found in the study area of advertising.

2.1.1. Type C: epistemological beliefs

Epistemological beliefs concern the structure of knowledge and the way in which people gain knowledge (Hofer & Pintrich, 1997).

There are 3 different research traditions in this area. The first, developmental (unidimensional) tradition, began with the introduction of Perry's (1970) seminal work. According to Perry, people's epistemological beliefs expand through the 4 following stages: dualistic, multiplicity, relativism and commitment within relativism, respectively. To illustrate, whereas a dualistic person believes that knowledge should be categorized as right or wrong, a person at the commitment within relativism stage believes that knowledge has a relativistic structure but is still possible through justification. Perry (1970) states that biological developments, together with social interactions as in the Piagetian approach, shift people's epistemological beliefs. In the second tradition, a group of researchers led by Schommer (1994) suggest that epistemological beliefs have a multidimensional structure involving five dimensions: certainty, source, simplicity, quick learning and innate ability. The last two dimensions have been criticized by developmentalists because these dimensions relate to learning rather than epistemological beliefs. Addressing these concerns, Schommer-Aikins (2004) notes that the first three dimensions relate to the last two. Sophisticated beliefs involve judgments when knowledge is not certain (certainty) and not authoritarian (source) and has an interrelated complex structure (simplicity), whereas naïve beliefs correspond to commitments that knowledge is certain, authority-based and has disconnected portions and a simple structure. Researchers have verified not only the existence of different types of epistemological beliefs but also the independence of these dimensions. That is, an individual may have sophisticated beliefs regarding the source of knowledge and naïve beliefs regarding the certainty and simplicity of knowledge (Schommer, 1994).

The last tradition relates to the domain and/or context dependency of epistemological beliefs (Sinatra, Kienhues, & Hofer, 2014). Researchers following this tradition suggest that people have general epistemological beliefs which can be particularized if they are measured in regard to specific domains (Buehl, Alexander, & Murphy, 2002) or contexts (Elby & Hammer, 2001). For example, college students may believe that knowledge related to natural sciences is more certain than knowledge related to humanities (Palmer & Marra, 2008). To illustrate context dependency, a high school student may behave as if physics knowledge were certain, although s/he has more sophisticated beliefs to obtain higher scores on exams (Elby & Hammer, 2001).

The importance of pre-service science teachers' epistemological beliefs can be explained in two ways. First, these beliefs are accepted as central to learning/teaching behaviors and beliefs (Brownlee, Boulton-Lewis, & Purdie, 2002; Hofer & Pintrich, 1997). Within samples of Turkish pre-service science teachers, Bahcivan (2014a), Bahçivan (2016), and Güneş and Bahçivan (2016) provide empirical evidence of this concept. In a similar way, Chan and Elliott (2004) provide empirical support showing that pre-service teachers' epistemological beliefs predict their conceptions of teaching and learning. In other words, pre-service science teachers' epistemological beliefs are usually linked to their constructivist conceptions of teaching and learning. However, the same researchers note that cultural differentiations between western and eastern civilizations were responsible for the unexpected results. Hofer (2008) recommends that researchers should investigate cultural differentiations to construct more comprehensive models for epistemological beliefs. The second importance of investigating pre-service science teachers' epistemological beliefs is based on their educability. The literature shows that people's educational backgrounds predict their epistemological beliefs (King & Kitchener, 2004; Muis, Trevors, Duffy, Ranellucci, & Foy, 2016). Therefore, one can expect that a pre-service science teacher's epistemological beliefs can be qualified by education. However, before intervening to qualify pre-service science teachers' epistemological beliefs, we should first investigate how and why their epistemological beliefs relate to their conceptions.

2.1.2. Type D: conceptions of teaching and learning

Conceptions of teaching and learning (COTL) are defined as teachers' beliefs about what teaching and learning are and how these processes should be realized (Chan & Elliott, 2004). Research, primarily phenomonographic studies, first examined students' learning conceptions (Bahcivan, 2014b; Marton, Beaty & Dall'Alba, 1993; Tsai, 2004), which include "memorizing", "calculating and practicing", and "making science" as examples of learning. Additionally, pre-/in-service science teachers' conceptions of teaching were investigated in qualitative studies (Koballa, Graber, Coleman, & Kemp, 2000; Tsai, 2002), which included concepts such as "transferring knowledge", "interacting" and "constructivist". Science educator studies suggested that pre-/in-service science teachers' COTL are coherent (Koballa et al., 2000; Tsai, 2002). For this reason, Tsai (2002) referred to these conceptions as nested epistemologies. Considering the results of these studies, Chan and Elliott (2004) placed COTL on a traditional-constructivist continuum. A traditional conception indicates that learning is a passive process in which teachers present true knowledge to learners, whereas a constructivist conception means that learning is an active process in which learners' feelings and previous learning experiences should be considered. Pre-service science teachers' COTL are critically important to science teacher educators for two reasons. First, these conceptions relate to their scientific epistemological beliefs (Bahcivan, 2014a) and self-efficacy beliefs (Bahcivan & Kapucu, 2014); therefore, they should be noted as an important domain of pre-service science teachers' teaching belief system. Researchers also suggest that pre-service teachers who hold constructivist conceptions attempt to integrate technology into learning environments (Mumtaz, 2000; Sang, Valcke, van Braak, & Tondeur, 2010). Second, these conceptions have an effect on pre-service science teachers' teaching practices (Koballa, Glynn, Upson, & Coleman, 2005).

2.2. Digital literacy

It is difficult to provide an exact definition of "digital literacy" because this term has been used for a variety of meanings in the literature. The concepts used interchangeably include digital literacy, IT literacy, computer literacy and media literacy, reflecting rapidly changing technology and the popularity of technology-related literacy. There appears to be a consensus in the literature that the term digital literacy covers the meanings of the above-mentioned concepts (Bawden, 2008; Martin, 2006). Digital literacy includes basic ICT (Information and Communication Technology) skills and more advanced skills regarding the creative and critical use of digital tools (Sefton-Green, Nixon, & Erstad, 2009).

Digital literacy is one of the most important 21st century competencies (Vavik & Salomon, 2015; Voogt, Erstad, Dede, & Mishra, 2013). For this reason, today's teachers should have digital literacy skills in order to provide contemporary and high-quality education for digital natives. From this point of view, teacher education programs should adopt current requirements in education considering the rapid developments in ICT and the integration of ICT into education (Albion, Tondeur, Forkosh-Baruch, & Peeraer, 2015; Fu, 2013). This adoption has many dimensions, one of which is to educate digitally literate teachers. A digitally literate teacher is expected to have numerous competencies, such as using technology to improve teaching, being familiar with technology tools, having a positive attitude towards the use of technology in teaching practice, and having adequate technical, cognitive and socio-emotional skills in digital literacy. Therefore, research in teacher education should focus on teacher competencies in terms of digital literacy and consider other variables that are related to digital literacy. This study focuses on the epistemology and teaching-learning conceptions of pre-service science teachers together with digital literacy skills, because these variables have the potential to interact. Teaching-learning conceptions refer to beliefs about teaching and the learning process, whereas epistemology addresses the structure of knowledge and how people know. For this reason, digital literacy cannot be addressed independently of these variables, if researchers tend to offer practical recommendations for the integration of technology into the teaching-learning processes.

In this research, the digital literacy model (Ng, 2012a) has been taken into consideration. This model proposes the following three dimensions of digital literacy: technical, cognitive and socio-emotional. The technical dimension refers to “possessing the technical and operational skills to use ICT for learning and in everyday activities”. The cognitive dimension refers to the “ability to think critically in the search, evaluate and create cycle of handling digital information”. The socio-emotional dimension refers to “being able to use the internet responsibly for communicating, socializing and learning” (Ng, 2012a).

However, digital literacy assessment is not an easy task. Because there are numerous types of digital literacy assessment instruments (Covello, 2010), feasibility and alignment with context should be considered when determining which instrument to use. For this reason, we adapted the items developed by Ng (2012b) to assess the digital literacy skills of pre-service science teachers.

3. Proposed model

Considering the aforementioned research, we examine the structural relations proposed in Fig. 1. In the model, we accept scientific epistemological beliefs (SEBs) as a Type C belief; Type C beliefs are related to sources of knowledge and, thus, to SEBs. COTL were accepted as Type D beliefs, because these beliefs are derived from SEBs in the literature (e.g., Chan & Elliott, 2004; Hofer & Pintrich, 1997). Therefore, the belief system model of the study involved two types of beliefs.

The literature also presents evidence that pre-service science teachers' COTL relate to their digital literacy skills (Kivunja, 2014, p. 81; Mumtaz, 2000; Nawaz & Kundi, 2010; Pascarella, 2008; Sang et al., 2010). Therefore, considering the previous studies, we expect that pre-service science teachers' SEBs, COTL and digital literacy skills relate to one another. For example, we expect that when pre-service science teachers hold sophisticated SEBs, they will possess constructivist COTL. This conception may direct the teachers to obtain qualified skills regarding digital literacy because they must use technology to adapt their science teaching environment for different students.

However, studies also present converse relations among these variables based on cultural variations. In the second part of the study, we examine why these variables relate to each other to present a more comprehensive model for pre-service science teachers' digital literacy skills.

3.1. Research questions

Considering the purpose of this study, we address the following research questions:

1) What are the structural relations among pre-service science teachers' SEBs, COTL and digital literacy skills?
2) Why do pre-service science teachers' SEBs, COTL and digital literacy skills relate to each other?

4. Method

The first research question requires quantitative research because it examines the structural relations among the variables, whereas the second research question requires qualitative research because it seeks reasons for these relations. This study prioritizes

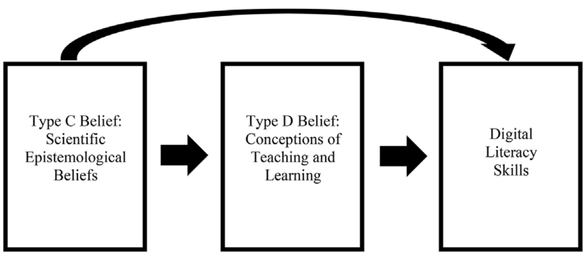

Fig. 1. Proposed model.

quantitative research followed by qualitative research, thereby using a sequential explanatory research design (Creswell, 2003).

4.1. Quantitative part (study I)

4.1.1. Participants

A selection of 979 pre-service science teachers (764 female and 176 male; others did not denote gender) from 13 state universities was made via convenience sampling, which was applied to reach the maximum number of participation. Ages were observed between 18 and 37 years old (M = 21.7). The students were particularly selected from 3^{rd}- (530 participants) and 4^{th}-year (431 participants) students because they had already taken certain courses related to the epistemology of science and science teaching methods as well as technology integration in science teaching. However, 18 participants did not mark their class year.

4.1.2. The instrument

The instrument involved 4 parts. The first part was prepared to collect demographic information regarding participants' schools, years, ages and genders. The following parts involved the 3 scales given below.

4.1.2.1. Digital literacy scale. This scale was developed by Ng (2012b) to investigate the digital literacy skills of undergraduate students. The original scale involved 17 items in a 5-point Likert mode (1 = strongly disagree to 5 = strongly agree). These items were distributed for 4 dimensions: attitudes towards ICT for learning dimension (7 items); technical dimension (6 items); cognitive dimension (2 items); and social-emotional dimension (2 items). For this study, the attitudes dimension was not used; therefore, 10 items of digital literacy dimensions (technical, cognitive and socio-emotional) of the scale were adapted to measure pre-service science teachers' digital literacy skills.

The first step of the adaptation was back translation process of the items. In this process, the first author of the study translated the items into Turkish language. Then the second author translated the items back to English. Both of the authors were graduated from universities providing education in English. After checking the coherence between the original and back translated items, the authors decided to apply for assistance of a Turkish language expert. After back translation procedures, we adapted the instrument using an exploratory factor analysis (n = 979). A maximum likelihood analysis, together with a Varimax rotation, was executed. The KMO measure of sampling adequacy index was calculated as 0.90, and Bartlett's test of sphericity was significant, chi-square (3298, n = 979), $p < 0.0001$. Various verifications (eigenvalue > 1, scree plots and communality value > 0.5) were considered in the process of exploratory factor analysis. The analysis presented a one-factor solution that comprised all of the items having factor loadings of 0.46–0.74. This one-factor solution explained 40% of the total variance and obtained an Alpha reliability of 0.86. At this point, finding a one-factor solution instead of a three-factor can be explained by the strong relationship among these three dimensions.

4.1.2.2. Scientific epistemological beliefs (SEBs) scale. The scale was originally developed by Conley, Pintrich, Vekiri, and Harrison (2004) to measure elementary students' SEBs. The scale includes four dimensions: certainty (e.g., all questions in science have one right answer); source (e.g., everyone must believe what scientists say); justification (e.g., ideas about science experiments come from being curious and thinking about how things work); and development (e.g., certain ideas in science today are different than what scientists previously thought). There are 26 5-point Likert items (1 = strongly disagree to 5 = strongly agree) distributed as 6, 5, 9 and 6 items, respectively, for the certainty, source, justification and development dimensions. After recoding all items in certainty and source dimensions inversely, higher scores corresponded to sophisticated epistemological beliefs. The instrument was adapted by a sampling of Turkish pre-service science teachers by Bahcivan (2014a), who reported acceptable fit indices ($\chi 2/df = 1.44$, CFI = 0.95, TLI = 0.93 and RMSEA = 0.04) and acceptable Alpha reliability scores between 0.66 and 0.82. In this study, we conducted a confirmatory factor analysis (n = 979) for validation purposes. One item from the certainty dimension was eliminated because of factor loadings lower than 0.40 (Shevlin & Miles, 1998). Next, the analysis was executed again, producing acceptable fit indices ($\chi 2/df = 3.14$, CFI = 0.93, TLI = 0.92 and RMSEA = 0.04), factor loadings between 0.48 and 0.72, and acceptable Alpha reliabilities of 0.78, 0.78, 0.83 and 0.69 for the certainty, source, justification and development dimensions, respectively.

4.1.2.3. Conceptions of teaching and learning (COTL) scale. The COTL scale was developed by Chan and Elliott (2004) to measure pre-/in-service teachers' COTL. The scale has 30 5-point (1 = strongly disagree to 5 = strongly agree) Likert-type items distributed within two dimensions: constructivist (e.g., learning means students have ample opportunities to explore, discuss and express their ideas); and traditional (e.g., learning means remembering what the teacher has taught). The first dimension involved 12 items and the second was composed of 18 items. Higher scores in each dimension corresponded to holding that conception. The instrument was adapted into Turkish by Eren (2009). The author reported acceptable fit indices ($\chi 2/df = 2.42$; NNFI = 0.93; CFI = 0.94; RMSEA = 0.061) and high Alpha scores of 0.92 and 0.89 for constructivist and traditional dimensions, respectively. In this study, we validated the scale results by a confirmatory factor analysis (n = 1000). Four items from the traditional dimension were excluded because of factor loadings below 0.40. Then, the analysis were conducted again, producing acceptable fit indices ($\chi 2/df = 3.14$, CFI = 0.93, TLI = 0.92 and RMSEA = 0.04), factor loadings between 0.47 and 0.74, and high Alpha reliabilities as 0.89 and 0.86 for constructivist and traditional dimensions, respectively.

4.1.3. Data collection and analysis

The instrument was first presented to the Ahi Evran University Ethical Committee for approval. We informed the participants

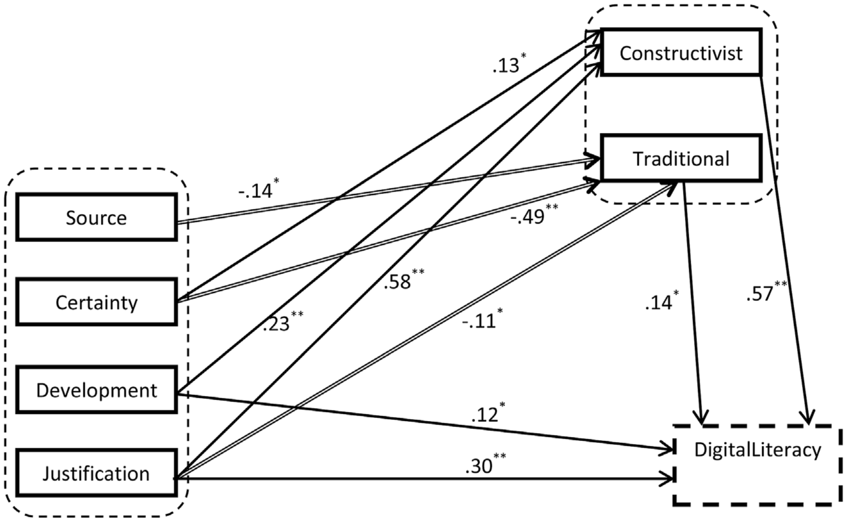

Fig. 2. Statistical model (*p < 0.05, **p < 0.001).

about the aims of the study and then distributed 1087 instrument forms during their regular courses. A total of 982 students responded; however, 3 of their forms were eliminated because of missing data. Although university students were asked to write their names or nicknames in order to conduct interviews for the qualitative portion of the study, they were assured of confidentiality regarding the results.

The data were entered into SPSS 21. After validation procedures, a structural equation modeling analysis was conducted by AMOS 20 to investigate the relation covered by the proposed model.

4.1.4. Results and discussions for study I

To respond to the first research question, a SEM analysis ($n = 979$) investigating relationships among pre-service science teachers' SEBs, COTL and digital literacy skills was conducted. The statistical model had an acceptable fit ($\chi^2/df = 2.44$, $CFI = 0.89$, $TLI = 0.88$ and $RMSEA = 0.03$). Regression weights, which were significant, are presented in Fig. 2.

The statistical model shows that participants' SEBs (except for source dimension) positively predicts their constructivist COTL. In addition, participants' SEB dimensions (except for development) are negatively related to their traditional COTL. In other words, when pre-service science teachers hold sophisticated epistemological beliefs, they have constructivist conceptions, whereas their naïve epistemological beliefs made them inclined to have traditional conceptions. This result is generally coherent with the literature (Chan & Elliott, 2004; Hofer & Pintrich, 1997; Rokeach, 1968). Furthermore, pre-services' SEBs covered by development and justification dimensions positively predict their digital literacy skills. If students believed that scientific knowledge was developing/changing (development) and required verification (justification), they also claimed to have more qualified skills in digital literacy. However, participants' SEBs covered by source and certainty dimensions did not have any significant relationship with their digital literacy skills. This unexpected result will be queried in Study II. Finally, the results showed that pre-service science teachers' constructivist and traditional COTL positively related to their digital literacy skills. Considering the findings of previous researchers (e.g., Kivunja, 2014, p. 81; Mumtaz, 2000; Nawaz & Kundi, 2010; Pascarella, 2008; Sang et al., 2010), we had expected the positive relationship between constructivist COTL and digital literacy skills. However, the positive relationship between traditional COTL and digital literacy skills were contradictory to our expectations. This result will also be queried in Study II.

4.2. Qualitative part (study II)

The second research question examines the reasons for both consistencies and inconsistencies among the variables. Considering the nature of this question, we decided to select different types of cases whose scores were in/coherent with the relationships presented by the structural model of the study. Therefore, a multiple case study was applied for this step (Creswell, 2007).

4.2.1. Participants

Eight pre-service science teachers, (4 consistent and 4 inconsistent scorers) were selected by purposive sampling (Creswell, 2008). Two of the consistent scorers were selected among high scorers corresponding to participants having sophisticated SEBs and qualified skills for digital literacy, whereas the other consistent scorers were selected among low scorers. Additionally, 2 inconsistent scorers among each of the naïve SEB-qualified digital literacy and sophisticated SEB-unqualified digital literacy cases were selected. To determine the cases, descriptive scores were examined for the highest and lowest scores by SPSS.

4.2.2. The interview protocol and data collection

The study included 3 semi-structured interview sessions described as follows: confirmation, investigation and member checking. During the confirmation session, participants were informed about their item scores and interviewed to confirm their beliefs. For example, to confirm their beliefs related to COTL, we asked, “Can you please define what science learning means? Why?” At the end of this session, participants were given details about the purpose of the research and then asked to consider reasons for the in/coherences in their measurement scores. One week later, we conducted the second session and directly asked the participants to explain the reasons for the in/consistencies. At the third session, the authors presented the codes attained in their interview transcripts, explaining the meanings of the codes. The participants were then asked to examine the convenience of the codes in their responses. The interviews were conducted individually at the authors' offices and audio recorded. Each session took approximately 30 min.

4.2.3. Data analysis

Because language was analyzed in the study, content analysis was applied to interview transcripts and lesson plan forms to determine coding units (i.e., SEBs, COTL, digital literacy) and categories (i.e., sophisticated, constructivist, qualified [Krippendorff, 2004]). The first author read the documents and applied the categories. Both holistic (investigates each case independently) and embedded (compares cases among themselves) analyses were implemented to uncover the reasons comprehensively (Creswell, 2007). In other words, content analysis was applied to determine the coding units and categories. Additionally, holistic and embedded analyses were applied to disclose the complete picture of the relation between beliefs and digital literacy.

Multiple data sources and member checking were used for validation purposes (Creswell, 2007). Participants' instrument scores and interview transcripts were used as multiple data sources. In addition, the last interview session was conducted for member checking. Furthermore, to examine the reproducibility (inter-coder reliability), the first author selected random parts of each coding unit and asked the second author to apply the coding categories on the selected parts. Then, Krippendorff's α was calculated by hand as 0.92, which corresponds to high reliability (Krippendorff, 2004).

4.2.4. Results and discussions for study II

Study II examined the reasons for relations among pre-service science teachers' SEBs, COTL and digital literacy skills. As mentioned above, Study II involved three sessions of interviews, which were conducted with PSTs who held consistent and inconsistent belief systems. In the first interview session, we confirmed whether their marks on the scales represented the pre-service teachers. The distribution of coding categories and examples of quotations in the confirmation sessions are presented in Tables 1 and 2.

In selecting the cases, we focused on the situation of in/consistency between the students' SEBs and digital literacy skills. However, we also investigated their COTL during the confirmation session. The results showed that except for two cases (case no. 5 and 7), participants' SEBs were consistent with their COTL. In other words, when pre-service science teachers had sophisticated SEBs, they most likely would hold constructivist conceptions in terms of learning and teaching. This result is consistent with our findings in Study I as well as with the findings and claims of certain researchers (Brownlee et al., 2002; Chan & Elliott, 2004; Hofer & Pintrich, 1997).

In the investigation session, we focused on the reasons for in/consistencies within the participants' belief systems and digital literacy skills. Before constructing a comprehensive belief system model presenting in/consistencies among their beliefs, a coding list was investigated. This coding list, as well as examples of quotations for each coding unit and categories, is presented in Table 3.

Reflecting the embedded analyses conducted on participants' transcripts, Fig. 3 presents the comprehensive model. According to the model, the participants' beliefs interacted through two types of forming filters. First, their epistemological beliefs appear to generate their epistemological perspectives, which in turn form their COTL and digital literacy skills. The second type of forming filter was observed between the COTL and digital literacy skills. This filter involved two types of coding units: enabler and task definition. In Fig. 3, dotted lines were used to indicate that a participant might be defined by the coding categories designated in that line. Six participants believed that they had to present certain experiments; however, these experiments were dangerous or required advanced materials in terms of implementation in a classroom learning environment. Because these participants believed that digital technologies enabled them to present these experiments, this coding unit was labeled enabler. Additionally, five participants' COTL

Table 1
Distribution of coding Categories in Accordance with the coding units and cases for confirmation session.

Case type	Case no	Coding units		
		SEBs	COTL	Digital literacy skills
Consistent	1	Sophisticated	Constructivist	Qualified
	2	Sophisticated	Constructivist	Qualified
	3	Naïve	Traditional	Unqualified
	4	Naïve	Traditional	Unqualified
Inconsistent	5	Sophisticated	Traditional	Unqualified
	6	Sophisticated	Constructivist	Unqualified
	7	Naïve	Constructivist	Qualified
	8	Naïve	Traditional	Qualified

Table 2
Examples of quotations for confirmation session.

Coding units	Coding categories	Example of quotation
SEBs	Sophisticated	… to me, scientific knowledge changes in accordance to the new types of verifications and developments in technology …
	Naïve	Scientific knowledge has a simple structure for me, because we, at the moment, know its borders … if it was complex, we couldn't comprehend it.
COTL	Constructivist	Learning is to be able to apply what you have learnt … Science teachers should consider what their students have already learnt and provide them to participate actively in learning contexts …
	Traditional	Learning science is obtaining the knowledge presented in physics, chemistry and biology … The teacher should know everything to present his subject meaningfully …
Digital Literacy Skills	Qualified	I utilize digital technologies for several reasons … in order to not only make effective communications with others but also to compare scientific results to justify scientific knowledge …
	Unqualified	I don't like using digital technologies in my daily life but have to use due to obligation. People think that it is impossible to live without these technologies … to me, they are harmful in terms of sustainability of social interactions …

Table 3
Examples of quotations for investigation session.

Coding units	Coding categories	Sample quotation
Forming filter	Epistemological perspective	To me, scientific knowledge changes according to different perspectives … so by utilizing digital technologies, I can develop myself in these different perspectives … I believe that knowledge is constructed and justified by human beings, so I should create a science learning environment that creates opportunities for my students in terms of constructing and justifying their own knowledge …
	Enabler	If I do not utilize digital technologies, how can I show certain experiments whose results and materials are dangerous for students …
	Task definition	I believe that I should continuously find different ways for knowledge presentation … technological support is inevitable for me …
Delimiters	Daily needs	I utilize digital technologies for several reasons … in order to not only make effective communications with others but also to compare scientific results for justifying my scientific knowledge …
	Self	I believe we should have warm relationship with others, but digital technologies prevent us from holding such relationships …
	Interest	I enjoy designing web pages …. .I try to develop my software programming skills …
Experiential pool	–	In my school experience courses I detected that all the students cannot learn with the same ways … I want to teach like some of my ex-teachers … Now I can see that those teachers had actually hold constructivist approaches … In my high school years I participated in digital exams by my personal computer. Those exams affected positively my university entrance exam score …
Verification	–	Digital technologies provide opportunities to verify my beliefs about scientific knowledge …

generated a perception regarding how they had to teach or how students could learn in a science classroom. When these perceptions corresponded to different task definitions such as "visual support" or "different ways for knowledge presentation", these task definitions appeared to form their digital literacy skills. Therefore, the results of this study confirm certain researchers' conclusions that teachers' beliefs filter their attitudes and behaviors (Ajzen, 1991; Fives & Buehl, 2012; Pajares, 1992).

Moreover, the results showed that three types of delimiters also affected the formation of the future teachers' digital literacy skills. These delimiters were labeled daily needs, interest and self. Daily needs involve certain daily activities such as online surfing, communication and homework-report preparations. Interest was utilized to label future teachers' interest in digital technologies. Two participants noted that they had been interested in advanced digital technologies such as web design and programming since childhood. This interest seemed to contribute to their digital literacy skills positively. Inversely, three participants noted their disinterest in digital technologies, causing them to hold a negative perspective and unqualified skills regarding digital technologies. In addition, five participants indicated "self" as the reason for their digital literacy skill status. For example, if a participant described his/her relations with others as prominent, s/he accepted digital technology as a preventer of intimate relationships. Such a self-construal was defined as related-self by Kağıtçıbaşı (2007). Rokeach's (1968) Type A and B beliefs (which were the most central beliefs) corresponded to beliefs about self. Therefore, the effect of self-related beliefs on the future teachers' digital literacy skills seems consistent with the literature. Furthermore, all the participants stated that their digital literacy skills contributed positively to examining their epistemological beliefs. For example, independent of their qualifications related to digital literacy skills, if a future teacher holds sophisticated epistemological beliefs, s/he uses digital technology to find scientific knowledge that verifies his/her SEBs. Therefore, it was observed that the relationship between participants' SEBs and digital literacy skills was not one-dimensional from SEBs to digital literacy skills, but rather, that the latter also contributed the former.

Finally, the participants' COTL and digital literacy skills were also formed by their previous experiences, labeled experiential pool in Fig. 3. The effects of previous experiences were also observed as the reason for inconsistencies among their teaching beliefs and digital literacy skills. For example, one of the naïve (in terms of her SEBs) participants, appeared to hold constructivist COTL, which

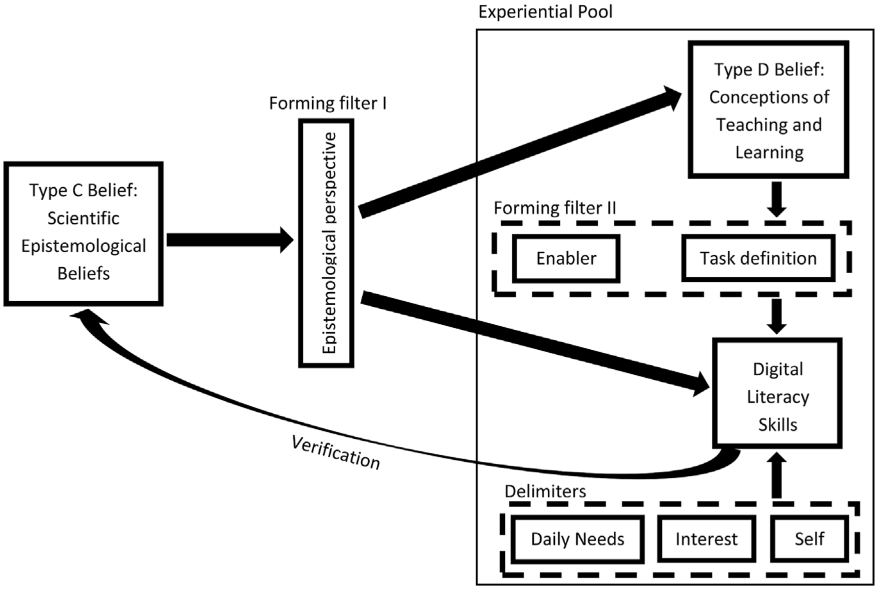

Fig. 3. The comprehensive model presenting calibration.

was converse to the researchers' expectations. Notably, the participant had high school teachers who held constructivist conceptions, which the participant believed had contributed to her understanding of science more positively in comparison to other teachers (see Table 3).

As concluded in the literature, there is a hierarchy among pre-service science teachers' beliefs (Fishbein & Ajzen, 1975; Rokeach, 1968), although there might be certain inverse relations among these beliefs (Pajares, 1992). The results of this study showed that a teachers' belief system cannot be comprehensive if her previous experiences are not considered. There is a calibration between future teachers' beliefs and experiences that interferes with the relationships among their beliefs and skills. The results showed that this calibration was permanently biased to their experiences. In other words, the pre-service teachers' more central beliefs predicted their more peripheral beliefs if there was a consistency between their peripheral beliefs and previous experiences. The inconsistencies between their previous experiences and peripheral beliefs seemed to prevent consistency in their beliefs. This prevention was also observed in the relationships between beliefs and digital literacy skills.

5. Conclusions and implications

Considering the results of this study, it can be concluded that Turkish pre-service science teachers' SEBs had an effect on their COTL. Therefore, in guiding pre-service teachers to hold more constructivist COTL, educators should find ways to support their epistemological sophistication. Argumentation may be a qualified candidate for this purpose. Second, pre-service teachers' COTL contribute more positively to their digital literacy skills if they hold constructivist COTL. For this reason, we suggest that future teachers holding constructivist COTL will make use of digital tools in their classes in a more effective manner and will be able to adapt to future developments in ICT. Science teaching method courses and other courses can particularly be used to support their constructivist conceptions. Third, it can be concluded that pre-service science teachers' previous experiences impact their beliefs and digital literacy skills. For this reason, science teacher education curricula should be reviewed to provide students with more positive experiences regarding constructivist COTL and digital literacy qualifications. Furthermore, students should gain positive experiences concerning digital technologies even in primary or secondary schools. Digital literacy, which is one of the most important 21st century skills, can be more effectively supported if teacher education programs consider pre-service science teachers' belief systems. This study produced critical findings regarding this relationship.

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