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A Meta-Synthesis of Turkish Studies in Science Process Skills

Murat YILDIRIM[a], Muammer ÇALIK[b] and Haluk ÖZMEN[b]

[a] Erzincan University, Erzincan, TURKEY [b] Karadeniz Technical University, Trabzon, TURKEY

ABSTRACT

This study thematically evaluates Turkish studies in science process skills (SPS) from 2000 to 2015. In looking for SPS studies, the authors entered the keywords 'process skills, science process skills, science education and Turkey/Turkish' in well-known databases (i.e., Academic Search Complete, Education Research Complete, ERIC, and Springer LINK Contemporary). Further, in case the online search may have missed a substantial part of important SPS literature, the authors also conducted a manual search of the related journals. To present insights of SPS studies, a thematic matrix (needs, aims, methodologies, data collection tools, general knowledge claims, implications for teaching and learning) was used. Their general knowledge claims referred to (a) development of students' and teachers' SPS (b) effect(s) of variable(s) on SPS achievement level(s) (c) integration of SPS into science curriculum and (d) SPS measurement. Also, they showed that inquiry-based learning approach acted as a driving factor in developing SPS. Since science curriculum plays an important role in improving students' SPS, the studies under investigation suggest curriculum developers to increase the number of science activities in science curriculum.

Introduction

Because science process skills (SPS) act as a driving factor for scientific inquiry, scientists generally deploy them for scaffolding knowledge and thinking about possible solving strategies (Ministry of National Education–MoNE, 2005). Given importance of SPS in the scientific inquiry, science educators have critically been inquired how to equip students with

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CORRESPONDENCE Muammer ÇALIK muammer38@hotmail.com

SPS. They mostly recommend a gradual approach called as basic process skills (e.g. observing, classifying, communicating, measuring, predicting, and inferring) and integrated process skills (i.e. controlling variables, formulating hypotheses, interpreting data, defining operationally, experimenting and formulating models). The gradual approach of SPS means that types of SPS may depend on grade (Akgün, Özden, Çinici, Aslan, and Berber 2014). For instance, primary school students are generally expected to achieve basic process skills; whereas middle and/or upper secondary school students are intended to attain integrated process skills (Akgün et al., 2014).

A closely interrelation between SPS and science applications plays a cornerstone role in teaching and learning scientific content knowledge (Harlen, 1999; Keil, Haney and Zoffel, 2009). Therefore, the principal aim of science education is to give an opportunity for the students to grasp SPS (Germann, Aram, and Burke, 1996; Harlen, 1999). Given the significance of equipping the students with these skills (Tan and Temiz 2003), science curricula in developed and developing countries have proposed an integration of SPS into learning environments (Akgün et al. 2014; Harlen, 1999). Hence, curriculum outcomes via SPS are expected to (1) facilitate science learning, (2) engage students in actively participating in their learning continuum, (3) underpin analytical thinking, (4) construct knowledge through problem solving, (5) encourage students to take responsibility for their own learning, (6) enable students to retain newly gained knowledge/skills into their long-term memory, and (7) get them to acquire inquiry strategies for lifelong learning (Hazır and Türkmen, 2008; Howe and Jones, 1993).

Turkey, as a developing country, deploys a top-down model in developing all school curricula. For this reason, all schools across the country have to follow the same curricula suggested by MoNE (Çalık and Ayas, 2008). Turkish MoNE revised and/or re-built science curriculum four times from 1992 to 2013. As a matter of fact, SPS was firstly integrated into Turkish science curriculum in 1992. In the view of Dindar and Taneri (2011), this curriculum mainly referred to SPS within the experimental processes of science activities. Another Turkish science curriculum released in 2000 did not literally itemize SPS into its objectives (Taşar, Temiz and Tan, 2002). Başdağ (2006), who compared Turkish science curricula launched in 2000 and 2004 with each other, denoted that science curriculum in 2004 was more efficient in improving students' SPS than that in 2000. Further, some studies (e.g., Parim 2009; Şimşek and Karapınar 2010) suggest that science curriculum with an inquiry-based learning approach, released in 2013 as a revised version of previous science curriculum, may be highly effective in developing students' SPS (MoNE, 2013). Therefore, the developmental period of Turkish science curriculum has principally viewed SPS as an important outcome (Çalık and Ayas, 2008). Hence, science educators have paid more attention to such questions as: How is SPS developed? What strategy is more effective in improving SPS? What is the role of a teacher in improving SPS? What are the students' perceptions of SPS?

Classifying, evaluating, and synthesizing the studies not only reveal their trends, but also provide a rich source for decision makers, researchers, practitioners, and curriculum developers (Çalık and Sözbilir, 2014). Hence, a meta-synthesis of educational studies prevents time wasting for these stakeholders. An examination of the needs and aims of each study will guide future researchers on unexplored issues. Further, a synthesis of the studies' methodologies will emerge how to measure and evaluate related issues. Also, an outline of general knowledge claims will keep the teachers, researchers and curriculum developers informed on the different methods and techniques developing students' SPS in practicum. Given researchers' and teachers' workloads, a content analysis (thematic review) of the implications for teaching and learning of these studies sheds more lights on grasping message(s) of each study for future studies and on integrating SPS into practicum. However, a lack of a meta-synthesis regarding the Turkish studies in SPS points to a crucial gap in related literature and calls a thematic review of Turkish studies in SPS for identifying their common and distinguishable trends. Overall, evaluating and synthesizing the results of Turkish SPS studies will make a valuable contribution to educational literature. This study also enables researchers to avoid repeating similar SPS studies and to overcome their ambiguities. Moreover, novice researchers and teachers, who want to follow science curriculum-based SPS studies, may easily access to related SPS studies and/or results.

This study thematically evaluates the Turkish studies in SPS from 2000 to 2015. We discuss the following research questions in this meta-synthesis.

1. What needs do the Turkish studies in SPS address?
2. What are the aims of these studies?
3. What are the methodologies of these studies?
4. What are the data collection tools of these studies?
5. What are the general knowledge claims of these studies?
6. What are the implications for teaching and learning of these studies?

Methodology

Because this study purposes to present a meta-synthesis of Turkish studies in SPS, a matrix (needs, aims, methodologies, data collection tools, general knowledge claims, implications for teaching and learning) developed by Çalık, Ayas, and Ebenezer (2005) was employed to summarize the findings and insights of SPS studies. The general knowledge claims referred to: (a) development of students' and teachers' SPS (b) effect(s) of variable(s) on SPS achievement level(s) (c) integration of SPS into science curriculum and (d) SPS measurement. Also, implications in SPS studies were investigated for teaching and learning. Using these categories, each of SPS studies was described within a cell of the matrix. Thus, the general trends and unique features of each study were clearly apparent.

Within an interpretive account of SPS studies, the authors entered the keywords 'process skills, science process skills, science education and Turkey/Turkish' in the following databases: Academic Search Complete, Education Research Complete, Education Resources Information Center: ERIC, Springer LINK Contemporary, Taylor and Francis Journals, Wiley online Journals, Science Direct Journals, Pro-Quest Dissertations and Theses Full Text, Royal Society of Chemistry, Sage Premier, Web of Science, Google Scholar, Higher Education Council (Yüksek Öğretim Kurumu) Dissertations and Theses, and Turkish National Database (ULAKBIM). In case the online search may have missed a substantial part of the important SPS literature, the authors also conducted a manual search of the related journals. Care was taken to avoid duplication, as some entries were present in more than one database. The authors preferred including well-known and open-access databases in their universities. The authors excluded studies published in 2016 from this meta-synthesis because of incomplete publication issues. These factors (date coverage and databases under investigation) may be seen as the limitations of this study.

This study includes a total of 200 Turkish studies in SPS (see Supplementary Material at the link https://www.academia.edu/28277623/IJESE). Each study to ensure reliability was categorized and discussed by a group of experts (post-graduate students--four PhD and four master students enrolled to 'Meta-analysis in science education' course—and the lecturer). Therefore, any unclear areas and/or disagreements were solved through negotiation.

Results

SPS studies are presented in regard to research questions/themes under investigation (needs, aims, methodologies, data collection tools, general knowledge claims, and implications for teaching and learning).

Needs addressed by the studies under investigation

SPS studies (e.g. Aydoğdu 2006; Hazır and Türkmen 2008; Özden and Açıkgül Fırat 2013; Özgelen, 2012) indicated that students possessed low levels of SPS. Such a deficiency seems to have motivated 108 studies focusing on the development of SPS. Some of these studies (n=29) covered the effects of some variables (i.e. gender and socioeconomic issue) (e.g. Aydoğdu and Buldur, 2013; Hazır and Türkmen, 2008) on the achievement levels of SPS. The role of science curriculum in developing SPS stimulated 12 studies to concentrate on this issue. Also, 13 studies focused on determining (e.g. Karslı, Şahin, and Ayas 2009) teachers' ideas of SPS. Frequencies of the studies on developing SPS questionnaires and evaluating SPS in science textbooks were the same (n=8).

Table1. The needs identified by SPS studies

Needs	Frequency*
To develop students' SPS	108
To investigate effects of some variables (i.e., gender and socioeconomic issue) on SPS achievement levels	29
To determine teachers' ideas of SPS	13
To develop SPS in science curriculum	12
To develop an SPS questionnaire	8
To evaluate SPS in science textbooks	8
To investigate the relation(s) between SPS and other factors (e.g., science achievement, critical thinking, scientific creativity, ICT)	6
To facilitate science teaching via SPS	6
To facilitate SPS teaching	4
To investigate SPS levels in textbooks	3
To identify the effect of SPS-oriented science teaching on the students' attitudes towards science	2
To emphasize the importance of SPS	1
To independently measure SPS from content knowledge	1
To evaluate SPS in student selection exams	1
To investigate the relationship between SPS and problem solving skills	1

*Since some studies contain a few needs, a total of frequencies may exceed the total number of studies under investigation.

Aims of the studies under investigation

As seen in Table 2, 115 of SPS studies focused on developing students' or student teachers' SPS. Taking two principal components (teachers and students) in instructional/classroom environment into consideration, all SPS studies normally aimed to enhance students' and teachers' SPS. While twenty nine of SPS studies strived to determine variables affecting SPS, fourteen studies concentrated on determining students' or teachers' views of SPS. Also, eleven studies focused on developing science curriculum via SPS. Ten of the SPS studies intended to developed reliable and valid tests to measure SPS. Nine studies aimed to improve science textbooks/guide books with SPS whereas seven studies investigated the relationship between SPS and other cognitive skills (i.e., creative thinking, scientific creativity). Further, the remaining four studies determined the effect(s) of SPS-based science teaching on attitudes towards science and learning outcome.

Table 2. The aims identified by SPS studies

Aims	Frequency*
Developing students' or teachers' SPS	115
Determining variables affecting SPS	29
Determining teachers' or students' views of SPS	15
Developing science curriculum via SPS	11
Measuring SPS	10
Improving science textbooks/guide books with SPS	9
Investigating the relation between SPS and another skills (i.e., academic achievement or scientific creativity)	7
Determining the effect(s) of SPS-based science teaching on attitudes towards science and learning output	5

*Since some studies contain a few aims, a total of frequencies may exceed the total number of studies under investigation.

Methodologies of the studies under investigation

SPS studies deployed eight different research designs: Experimental research (n=93), survey (n=45), case study (n=8), mixed method (n=6), document analysis study (n=4), action research (n=2), phenomenological study (n=2) and comparative study (n=1). Also, forty-two studies did not explicitly clarify their methodologies.

Table 3. The methodologies of SPS studies

Methodology	Frequency*
Experimental research	93
Survey study	45
Case study	8
Mixed method	6
Document analysis study	4
Action research	2
Phenomenological study	2
Comparative study	1
Undefined	42

*Since some studies contain a few research methods, a total of frequencies may exceed the total number of studies under investigation.

Data collection tools of the studies under investigation

This section initially displays data collection tools (see Table 4) and then addresses each tool in detail.

Table 4. Data collection tools of SPS studies

Data collection tools		Frequency*
Questionnaire	Multiple-choice question	156
	Open-ended question	38
	Likert type	6
Interview		18
Document Analysis		15
Observation		14
Rubric		12
Worksheet		7

*Since some studies contain a few data collection tools, a total of frequencies may exceed the total number of studies under investigation.

Questionnaire

Majority of SPS studies utilized questionnaires in three subgroups: Likert-type (n= 6), open-ended (n= 38) and multiple-choice questions (n= 156). Because questionnaires are comparatively economical and give an opportunity for researchers to collect data from a large sample, SPS studies tended to mostly prefer them. Further, multiple-choice questions and Likert scale, which require participants to select and/or mark a choice, have some advantages for conducting quantitatively statistical analysis. On the other hand, open-ended questions give a freely responding chance to participants and somewhat yield qualitative results.

Interview

Eighteen studies used interview sessions involving an interactive empathetic environment between interviewer and interviewee. Indeed, most of these studies preferred using semi-structured interview protocols that give an opportunity for the interviewer to flexibly elaborate the interviewees' answers (Ültay and Çalık, 2012). For example; Anagün and Yaşar (2009) deployed semi-structured interview protocols to determine the extent to which constructivist approach in the science curriculum affects grade 5 students' SPS. Similarly, Sinan and Uşak (2011) employed semi-structured interview protocols to deepen three preservice biology teachers' views of SPS.

Document Analysis

Taking a dual function of document analysis (as data collection tool and research design) into account, fifteen studies deployed document analysis as a data collection tool to evaluate SPS in documents (i.e. textbooks and science curriculum). For example, Bağcı Kılıç, Haymana and Bozyılmaz (2008) used document analysis to analyze SPS in science curriculum. Likewise, Feyzioğlu and Tatar (2012) employed document analysis to evaluate SPS activities in science and technology textbooks.

Observation

Fourteen studies recruited observation to unveil the issue(s) under investigation (McMillan and Schumacher, 2010). For example, Aydoğdu (2006) observed teaching and learning processes in science lessons to determine teachers' SPS. In a similar vein, Zeren-Özer et al. (2011) used observation to analyze the degree to which a science laboratory covers SPS.

Rubric

Twelve studies used rubrics to emerge and score performance level of SPS. For instance, Özbek, Çelik and Kartal (2012) evaluated science student teachers' SPS performance levels through rubrics. Similarly, Zeren-Özer and Özkan (2012) used rubrics to evaluate science teachers' project outcomes.

Worksheet

Seven studies employed worksheets in conjunction with other data collection tools. Hence, they tended to ensure reliability through varied data collection tools. For example; Sinan and Uşak (2011) recruited worksheets to determine biology student teachers' SPS. Likewise, Durmaz and Mutlu (2012) deployed worksheets to measure students' SPS.

Sample groups

As seen in Table 5, the samples of SPS studies ranged from kindergarten students to teachers. However, most of them focused on middle school students and student teachers. Moreover, only one study sampled kindergarten students.

Table 5. The samples of SPS studies

Samples	Frequency*
Middle school students	67
Student teachers	63
Primary school students	26
Teachers	15
High school students	15
Kindergarten students	1

*Since some studies analyzed SPS levels in textbooks and/or science curricula, this issue was 'not applicable' for them. Hence, a total of frequencies may lower the total number of studies under investigation.

General knowledge claims of the studies under investigation

Taking the general knowledge claims of SPS studies into account, six sub-headings were apparent: Developing SPS, effects of some variables (i.e., gender and socioeconomic situation) on SPS, SPS level in science curriculum, determining (student) teachers' ideas about SPS, developing measurement tools of SPS and others.

Developing students' SPS

Some of SPS studies revealed that various methods/techniques affected development of these skills. However, inconsistent results are available for SPS development. For instance, some researchers (e.g., Anagün and Yaşar, 2009; Kanlı and Yağbasan, 2008) reported that constructivist approaches (i.e., 5Es, 7Es learning models) improved students' SPS; while Toprak (2011) oppositely depicted that constructivist approach did not develop students' SPS. Similarly, a few studies (e.g. Gürses et al., 2007; Tatar and Oktay, 2011) revealed that problem-based learning and cooperative learning methods were more effective in developing students' SPS than did traditional ones. Nevertheless, some studies (e.g. Serin, 2009; Taşaoğlu and Bakaç, 2010) found that problem-based learning and traditional methods had the same effect on developing students' SPS. In a similar vein, some studies deduced that project-based learning was more successful in developing students' SPS than did traditional one (e.g., Yurdatapan, Güven and Şahin, 2013; Zeren-Özer and Özkan, 2012). However, a few studies (e.g. Gültekin, 2009) implied that project-based learning did not affect students' SPS. The same inconsistency exists for the effect(s) of inquiry-based learning on developing students' SPS (e.g., Ateş, 2005; Parim, 2009).

These researchers addressed inconsistent results within several reasons as crowded-class, sample size, convenient timeline, number of limited variables, and error rate of data collection tool(s). Thereby, such deficiencies may hinder to produce efficient results by restricting students' active engagements (Yurdatapan et al., 2013). Also, SPS studies confess that acquiring SPS properly takes a longer period of time.

The other experimental studies employed varied teaching interventions: demonstration (Erdoğan, 2010), hands-on learning activities (e.g. Başdaş, 2007), the nature of science activities (Can and Pekmez, 2010), science laboratory lessons/activities (e.g. Koray, Köksal, Özdemir, and Presley, 2007), discussion accompanied by guided-inquiry (Bağcı-Kılıç, Yardımcı and Metin, 2011), Predict-Observe-Explain strategy (Bilen and Aydoğdu, 2012), creative drama (e.g. Taşkın-Can, 2013), reflective thinking based instruction (Keskinkılıç, 2010), formative assessment (Metin and Birişçi, 2009), self-regulated learning (Gülay, 2012), computer-assisted learning (e.g., Kışoğlu, Erkol, Dilber and Gürbüz, 201), Vee diagrams (Özkan, 2011; Tatar, Korkmaz and Şaşmaz-Ören, 2007) and model-based teaching (Ünal-Çoban, 2009). All of them denoted that their teaching interventions were efficient in developing students' SPS.

Effects of some variables (i.e., gender and socioeconomic situation) on SPS

SPS studies implied positive effects of the following variables on students' SPS: socio-economic situation (e.g. Böyük et al., 2011; Öztürk et al., 2010; Saraçoğlu et al., 2012), use of information communication technologies (e.g. Özden and Açıkgül Fırat, 2013), student attitudes toward science (e.g. Aydoğdu, 2006; Dönmez and Azizoğlu, 2010; Korucuoğlu, 2008; Öztürk et al., 2010; Topkara, 2010), creativity (e.g. Şahin-Pekmez et al.,

2010) and laboratory facility (Feyzioğlu, 2009). However, SPS studies also reported some mismatched results. For example, *gender* had a positive effect (i.e. Akbaş, 2010; Çakır and Sarıkaya, 2010; Dönmez and Azizoğlu, 2010) and no effect (i.e. Aydoğdu and Buldur, 2013; Böyük, Tanık and Saraçoğlu, 2011; Demir, 2007; Saraçoğlu et al., 2012) on students' SPS . Similarly, Aydoğdu (2006), Böyük et al. (2011), Hazır and Türkmen (2008) and Öztürk et al. (2010) found a positive correlational impact between parent's education level and student's SPS; however, Demir (2007) and Saraçoğlu et al.(2012) depicted that parent's education level had no direct effect on students' SPS. Likewise, Böyük et al. (2011), Dönmez and Azizoğlu (2010), Korucuoğlu (2008), Özgelen (2012) found a significant difference between elementary school students' SPS and their grades; however, Hançer and Yılmaz (2007) and Saraçoğlu et al.(2012) reported contrast results for this issue. In a similar vein, some researchers elicited statistically meaningful relationships between student academic achievement and their SPS (Aydoğdu and Buldur, 2013; Öztürk et al., 2010); but Topkara (2010) drew out no relationship between them.

Temiz (2010) indicated that content knowledge affected students' SPS. Moreover, Akar (2007) found a low correlation between SPS and critical thinking skills. Also, Demir (2007) elicited that university entrance exam scores, average science scores, scores from basic quantitative courses, and science self-efficacy did not explicitly influence SPS.

SPS in science curriculum

SPS studies stated that newly released science curriculum was more promising to enhance students' SPS than previous one (e.g., Başdağ, 2006; Şenyüz, 2008). Taşar et al. (2002) implied that SPS was inadequately embedded within the goals of science curriculum in 2000 although its aims emphasized significance of SPS. Bağcı-Kılıç et al. (2008) pointed out that science curriculum launched in 2004 stressed basic process skills rather than integrated ones. Yalçın (2011) pointed out satisfactory SPS at 'structure and properties of matter' unit in the teacher guide books, supplied within science curriculum in 2004. However, Dökme (2005) and Feyzioğlu and Tatar (2012) found out that SPS was not systematically embedded within textbooks. Similarly, Şahin (2009) identified that science curriculum released in 2004 implicitly involved some SPS in its own activities.

Determining (student) teachers' ideas about SPS

SPS studies in this sub-heading indicated a lack of theoretical knowledge/pedagogical knowledge of SPS (e.g. Işık and Nakiboğlu, 2011; Yıldırım, Atila, Özmen and Sözbilir, 2013; Zeren-Özer, Güngör and Şimşekli, 2011), inability to transfer SPS in practicum (e.g. Farsakoğlu, Şahin, Karslı, Akpınar and Ültay, 2008), insufficient familiarity with SPS (i.e. Işık and Nakiboğlu, 2011;Zeren-Özer et al., 2011), confusing SPS types with each other (Karslı, Yaman and Ayas, 2010) and with Bloom's taxonomy and the stages of problem-solving (Laçin Şimşek, 2010) and a limited awareness of

SPS (Yıldırım et al., 2013). For instance, Laçin Şimşek's (2010) sample (elementary school student teachers) was good at determining basic process skills but failed to identify experimental process skills. Furthermore, there were somewhat promising results of (student) teachers' SPS ideas. For example, Celep and Bacanak (2013) indicated that science teachers enrolled to post-graduate education were better equipped with SPS. Similarly, Sinan and Uşak (2011) expressed that biology student teachers' SPS were very high.

Developing measurement tools of SPS

SPS studies concentrated various grades (from primary school to in-service science teachers) on providing reliable and valid tools that measure SPS (e.g. Çalışkan and Kaptan, 2009; Feyzioğlu, Akyıldız, Demirdağ and Altun, 2012; Şardağ, 2013; Temiz, 2007). For example, Aydoğdu, Tatar, Yıldız and Buldur (2012) prepared a questionnaire to measure elementary school students' SPS. Likewise, Şardağ (2013) deployed daily life problems to develop a SPS test with multiple-choice and open-ended questions for grade 8 students.

SPS-based science teaching

Studies of SPS-based science teaching depicted that their interventions were effective in: (a) improving problem-solving skills (Bahadır, 2007; Batı and Kaptan, 2013), (b) logical and creative thinking skills (Karahan, 2006), and (c) acquiring properly SPS (Kurnaz, 2013). However, Karahan (2006), Bahadır (2007) and Duran and Özdemir (2010) reported that their teaching interventions did not lead to positive attitudinal change towards science. Moreover, some researchers presented SPS-based science activities as hypothetical sample teaching designs (e.g. Bağcı Kılıç, 2003); however, they did not test their effectiveness.

Implications suggested by SPS studies under investigation

SPS studies recommended several implications for curriculum developers: (a) an increase in open-ended activities in science curriculum instead of crowded-content knowledge (e.g. Yalçın, 2011; Bağcı Kılıç, et al., 2008; Feyzioğlu, 2009), (b) a support need for professional development and guide materials (e.g. Bağcı Kılıç, 2003); an increase in integrating constructivist-based SPS activities into early childhood science curriculum (i.e. Nuhoğlu and Ceylan, 2012), (d) including more systematically SPS activities into textbooks (Karslı et al., 2010; Sinan and Uşak, 2011), (e) considering gender difference in developing science curriculum (Akbaş, 2010), and (f) systematically embedding SPS into any science activity/task (Taşar et al., 2002).

SPS studies also suggested a few implications for developing students' and (student) teachers' SPS: (a) looking for alternative teaching method(s)—constructivist-based activities (i.e. Ayvacı, 2010; Böyük et al., 2011; Yıldırım et al., 2011), hands-on activities (Başdaş, 2007), open-ended and/or guided inquiry (e.g. Bağcı Kılıç et al.,2008; Feyzioğlu, 2009; Saraçoğlu et al.,2012; Şenyüz, 2008), and outdoor activities (Ayvacı, 2010)--, (b) equipping schools with laboratory facilities (Işık and Nakipoğlu, 2011; Karslı et al., 2009; Sinan and Uşak, 2011), (c) designing professional development seminars/courses--in-service education (i.e. Ayvacı, 2010; Dönmez and Azizoğlu, 2010; Karslı et al., 2010) and pre-service education (e.g. Laçin Şimşek, 2010; Işık and Nakipoğlu, 2011)--, (d) embedding more SPS within science classroom/science teaching (Durmaz and Mutlu, 2012), (e) giving more opportunies for students to engage with scientific experiments/tasks (Öztürk et al., 2010; Saraçoğlu et al.,2012), (f) use of proper terminology in teaching SPS (Ateş, 2005), (g) a reasonable student number/classroom capacity in science classes (rather than over-crowded) (Anagün and Yaşar, 2009; Sinan and Uşak, 2011), and (h) a need for a longer period of time in developing SPS (Bağcı Kılıç et al., 2011).

They made a few recommendations for SPS measurement: (a) a need for a progressive approach over a longer period of time (e.g. Aktamış and Yenice, 2010; Aydoğdu et al., 2012;), (b) using multiple-tools (i.e., multiple-choice test, interview, and observation) (i.e. Aydoğdu et al., 2012; Aktamış and Yenice, 2010;), (c) developing a valid and reliable instrument with different and/or large samples (Çalışkan and Kaptan, 2009), (d) taking content knowledge into consideration (Temiz, 2007, 2010).

Discussion

Given research questions of the current study, results of each theme under investigation (needs, aims, methodologies, data collection tools, general knowledge claims, and implications for teaching and learning) are discussed as follows.

Needs addressed by the studies under investigation

Because SPS studies noted pitfalls in developing SPS, most of them addressed a need for improving students' SPS by embedding various practices, methods and strategies within (science) content knowledge. Hence, the interaction between SPS and (science) content knowledge emerges and constructs scientific literacy for all future citizens. Further, this interactive framework promotes science education and science learning. That is, the more one succeeds in developing SPS, the more he/she accomplishes science learning. In a similar vein, identifying the teachers' awareness or knowledge of SPS may be a starting point for professional development and/or in-service education that inquiries how to improve students' SPS. In brief, most of the studies emphasized to the pivotal role of SPS for further developmental need(s).

These studies investigating the effects of some variables (i.e., gender and socioeconomic issues) on the students' SPS denoted the need for the influential role of personnel differences/backgrounds in developing SPS factors. For example, if one achieves to define variables that increase the students' SPS, he may evolve his science learning/teaching via SPS. Because science curriculum, as an outcome of formal education, has principally an influential role in the development of SPS, twelve studies investigated SPS in the science curriculum. This means that any improvement/revision in the science curriculum affords the students to develop SPS at a satisfactory level.

Aims of the studies under investigation

The principal aim of the SPS studies was students' and teachers' development of SPS. Thus, teacher educators may at least have an opportunity to think of further vital changes on developing SPS. Also, teachers may self-directly improve their capacities of SPS given their existing views. Further, they may critically consider how to transform their pedagogical content knowledge in action (science learning). Some of the SPS studies, which focused on the factors affecting SPS, may have taken personnel differences in account. Fifteen studies on the students' and teachers' views of SPS (see Table 2) may be invaluable in shaping and revising curricular documents and school practices. In addition, these studies may appear their awareness and learning inquisitiveness of SPS to trigger their development. By doing this, any stakeholder may also facilitate science learning.

Eleven studies on developing science curriculum via SPS (see Table 2) may enable teachers to make science appeal and interesting for students through inquiry-based learning. In a similar vein, ten studies measuring SPS revealed a need for a valid and reliable instrument of SPS. This means that measurement is a pre-request for posing the next steps of SPS (i.e. teaching intervention). Overall, all SPS studies at least referred how to develop scientific literacy via SPS. Indeed, this is not surprising in that scientific literacy is seen as an outcome of any science curriculum and/or science teaching,

Methodologies of the studies under investigation

As seen in Table 3, the highest frequency in the methodologies of the studies was belonging to the experimental research design. This may come from the framework of any intervention that mainly concentrates on the effect of any independent variable on dependent one. Survey study, which was the second highest frequency in the methodologies of the studies, seems to be the best way to seek how the characteristics of the participants are distributed over one or more variables (e.g., gender, age, and religion preference) (Wallen and Fraenkel, 2001) without any intervention. Only eight studies implemented a case study research design to explore students' and teachers' SPS perception(s) and/or knowledge in-depth. Further, six studies conducted a mixed method research design (named a combination of qualitative and quantitative methods) to yield more triangulated results of SPS (Johnson and Onwuegbuzie, 2004). Also, four studies deployed a document analysis research design to analyze textbooks/guide books with regard to SPS. Only two studies employed an action research design in which a teacher acts as a researcher to elicit and improve a certain situation/practice in his classroom (Büyüköztürk, Çakmak, Akgün, Karadeniz and Demirel, 2012). Sharing teacher's actual experiences/results with their colleagues/experts is quite worthy in solving and deciding educational problems. However, existence of only two studies in action research design was disappointed. Phrased differently, researchers seem to have engaged in literature-based-educational problems instead of the real ones. Similar explanations were valid for phenomenological and comparative study designs. Moreover, a significant proportion of 'undefined' theme illuminates that these studies may have preferred explaining the data collection instruments to the research methodologies. Indeed, this may come from a lack of knowledge of research methodologies. That is, any researcher, which has difficulty describing the research methodology, may tend to avoid such a methodological description.

Data collection tools and sample groups of the studies under investigation

The fact that majority of SPS studies employed at least two varied data collection tools (as multiple methods) sheds more light on data triangulation. Thus, they seem to have achieved reliability and validity of the data. For example, Aydoğdu (2006) used observation and multiple-choice questions (as data collection tools) to ensure the reliability and validity of the study. Because SPS involve in cognitive and psychomotor skills, measuring these skills with only a questionnaire may be a problematic issue. This calls complementary data collection tools for reliability and validity of the results to effectively measure and evaluate SPS.

The fact that most of SPS studies employed multiple-choice questions may result from some advantages (e.g. easily administering, objectively scoring, and studying with a large sample). However, they have a shortcoming in looking for reason(s) for the selected choice(s). At that point, others (i.e., observation, interview, and rubric etc) may be alternatives to probe the participants' SPS views in depth. However, several disadvantages (e.g., studying with a small sample, time-consuming in transcribing and coding data from observation and interview, and in devising a feasible rubric) should be considered very well. Table 4 shows that SPS studies tended to follow conventional data collection trend rather than complementary one.

The fact that SPS studies generally focused on middle school students and student teachers may stem from 'convenient sampling' preference. That is, science educators seem to have easily accessed to middle school students and student teachers. Only one study (Ayvacı, 2010) with kindergarten students reveals the need to develop basic SPS in early childhood. In fact, a functional role of early childhood education in properly building SPS can be explained by a Turkish idiom 'You cannot teach new tricks to old dogs'. Because teachers play a crucial role in shaping and improving students' SPS, a significant proportion of SPS studies concentrated on teachers' and student teachers' SPS. However, how to integrate SPS into all grades (or school years) should be critically thought. For this reason, further studies are needed for some samples to make viable comparisons.

General knowledge claims from the studies under investigation

Any teaching intervention in SPS studies reported its efficiency in increasing students' or teachers' SPS as compared to the existing/traditional instruction. However, few studies have attempted to compare varied learning models (e.g., problem-based learning and cooperative learning) with one another. SPS studies showed that inquiry-based learning approach acted as a driving factor for developing SPS (i.e. Parim, 2009). In fact, this is not astonishing because SPS and inquiry-based learning approach are intertwined in conducting science activities and/or scientific research with each other (Wilke and Straits, 2005).

Taking variables (i.e., gender, socio-economic situation, grade, academic achievement) impacting SPS into account, it can be inferred that the development of SPS is a complex procedure. For this reason, SPS-based science teaching should cover several variables to result in better achievements. Given interaction between SPS and science literacy, SPS plays a significant role in accomplishing requirements and targets of science curriculum. However, SPS studies highlighted a need for further efforts to positively advance students' SPS throughout science curriculum. Unfortunately, SPS studies showed several shortcomings in the teachers' professional development and content knowledge of SPS. This effort, in turn, asks for improving and empowering teacher's content and pedagogical knowledge. Taking measurement tools of SPS into account, paper and pencil tests were very dominant in SPS studies (see Table 4). This issue arises a critique question: 'At which level do paper and pencil tests measure SPS? In fact, such tests indirectly measure participants' knowledge of SPS in mind. For this reason, their standard error margins are very high even though they are such advantages as objective scoring, studying with a large sample, time-efficient. Needless to say, SPS also requires psychomotor skills to do something in action that cannot be measured by paper and pencil tests. Therefore, a combination of various measurement tools may provide more reliable and valid results of content and psychomotor domains of SPS. Also, since SPS and subject matter knowledge are interrelated with one another, measurement tools underpinning this interrelation need to be improved.

Implications suggested by the studies under investigation

Since science curriculum plays an important role in improving students' SPS, SPS studies suggested curriculum developers to increase the number of science activities in science curriculum. Of course, SPS-enriched science curriculum may enhance the students' learning opportunities if the teachers comprehend its messages adequately. For this reason, SPS studies called professional development (in-service and pre-service education) for effectively understanding and implementing science curriculum.

Given deficiencies of the teaching interventions in SPS studies, they recommended further studies (which conduct various teaching designs and compare them with one another) to find the most effective instructional method in developing satisfactorily SPS. A need for a longer period of time to develop SPS properly came out a recommendation about longitudinal studies.

Taking recommendations for measurement of SPS into account, measurement tools embedded within real-life problems and/or case studies should be improved and tested. Especially, data collection diversity ought to be enhanced to measure and evaluate SPS in science learning/teaching. Questions 'How to score psychomotor skills?' and 'How to integrate psychomotor skills into cognitive ones' are supposed to be handled to produce well-qualified SPS results.

Future Studies

Given a gradually progressive nature of SPS, future studies should pay more attention to early childhood education that dominantly shapes students' learning habits and attitudes towards science. In fact, because SPS are already available in children's indigenous scaffolds (e.g., observing, testing, classifying), further studies should critically think about how to evolve them. For example, a longitudinal study of indigenous scaffolds over educational continuum or grade could be carried out. To measure psychomotor skills, science educators and/or researchers are supposed to design and administer new complementary measurement tools. Also, question 'Are SPS improved independently or conjointly from content knowledge?' posed by Temiz (2010) should be explored in future studies. Hence, the interaction degree between content knowledge and SPS can be well-investigated (Rillero, 1998).

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Notes on contributors

Murat Yıldırım is research assistant of science education at Erzincan University, Turkey. His research interest covers science process skills, lesson study, designing and implementing in-service education for science teachers.

Muammer ÇALIK is Professor of Chemistry Education at Karadeniz Technical University, Turkey. He has a wide range of research interests including nature of science, socio-scientific issues, scientific habits of mind, identification, design and implementation of intervention strategies to challenge students' conceptions and students' use of analogies, models and

animations as an aid to their conceptual understanding of science concepts, evaluation of science textbooks, and systematic content analysis (e.g. meta-synthesis and meta-analysis).

Haluk ÖZMEN is Professor of Chemistry Education at Karadeniz Technical University, Turkey. His research interests principally embrace identification, design and implementation of intervention strategies to challenge students' conceptions and students' use of analogies, models and animations as an aid to their conceptual understanding of science concepts.

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