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Blending Problem Based Learning and History of Science Approaches to Enhance Views about Scientific Inquiry: New Wine in an Old Bottle

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Abstract

In 2016, the Program for International Student Assessment (PISA) showed that approximately 44.4% of students in Turkey obtained very low grades when their scientific knowledge was evaluated. In addition, the vast majority of students were shown to have no knowledge of basic scientific terms or concepts. Science teachers play a significant role in facilitating students' understanding of science, conceptions of scientific inquiry (SI) and the nature of science (NOS), and the transfer of those conceptions into classroom practice. Therefore, in this paper, I present my experiences of blending problem-based learning (PBL) and the history of science (HOS) with technological approaches. The study aimed to determine the effectiveness of this innovative approach in improving pre-service science teachers' SI views. The Views about Scientific Inquiry (VASI) questionnaire was used as a data collection tool (Lederman et al., 2014). The findings showed that most of the views of pre-service science teachers improved for all SI items except "Consistent with data collected." The results also indicated that the teachers that used these approaches were able to overcome initial barriers in preparing lesson plans for teaching science and SI.

Keywords: scientific inquiry, problem-based learning, history-based approach, blended learning, scientific literacy, pre-service science teachers

1. Introduction

The 21st century has witnessed rapid scientific innovations and technological advancements, increased globalization and an explosion of digital and information technology that will impact the economy, education, culture and politics worldwide. Therefore, students need to be adequately prepared with 21st-century skills to overcome challenges, to participate in and contribute to society, and to ensure their competitiveness in a global era that requires that they have new skills to secure the most promising jobs (Levy and Murnane, 2005; Stewart 2010; Wilmarth, 2010). Incorporating 21st-century skills—*digital literacy* (i.e., information, media, technology), *learning and innovation* (i.e., critical thinking, communication, collaboration, creativity), and *life and career skills* (i.e., entrepreneurship, problem solving, productivity—is crucial (Figure 1).

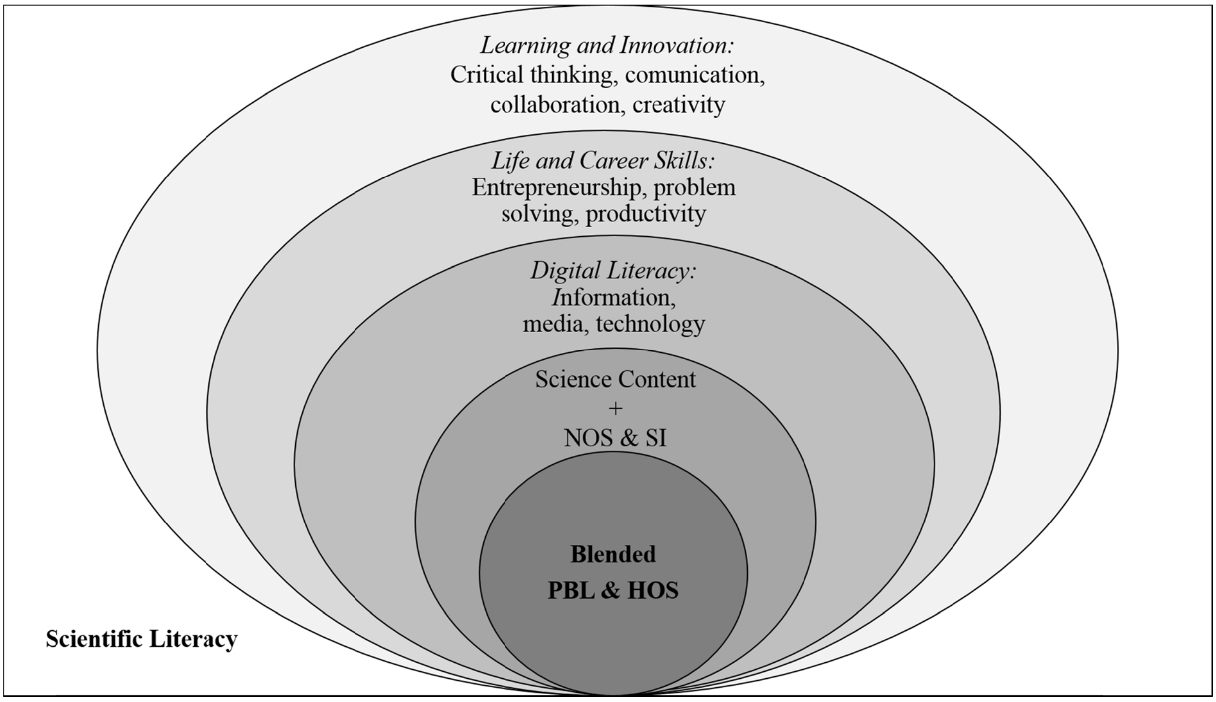

Figure 1. Science, NOS, SI, PBL, HOS, and scientific literacy

Scientific literacy is an important 21st-century skill within the context of science education because various problems are solved through creative thinking and the use of science and technology.

The promotion of scientific literacy is one of the ultimate goals of science education, and it has been the cornerstone of worldwide reform movements over the past three decades (BouJaoude, 2002; National Research Council [NRC], 2000). This current of thinking has led to a common definition of scientific literacy as "*the development of a deep understanding of major scientific concepts, processes of scientific inquiry and the nature of science, as well as the development of the ability to make informed decisions regarding science and technology as they relate to personal and societal issues*" (AAAS, 1990; NRC, 1996; Bell, Blair, Crawford & Lederman, 2003).

Over the past 50 years, many studies have examined students' understanding and misunderstandings of the nature of science (NOS), scientific inquiry (SI) and science in general, as NOS and SI are important parts of scientific literacy. Many of these studies have found that students conceptualizations of NOS and SI concepts differ from those accepted in the scientific community (Abd-El Khalick 2001; Aikenhead 1987; Dogan & Abd-El-Khalick, 2008; Fleming, 1987; Irez, 2006; Mackay, 1971; Rubba, Horner, & Smith, 1981, Solomon, Scott, & Duveen, 1996; Tamir & Zohar, 1991; Tasar, 2006). Moreover, the vast majority of students have no knowledge of many basic scientific terms or concepts, such as mass vs. weight, density, heat, temperature, DNA, genes, evolution, the relative velocities of sound and light, and the roles of hypothesis, theory and experiment (Carlton, 2000; Çepni, 1997; Çepni & Akdeniz, 1996; Kesidou & Duit, 1993; Keleş, Ertaş Uzuna, & Cansız, 2010; Koray, Özdemir & Tatar, 2005; Ongun, 2006). In addition, data obtained through the 2016 Program for International Student Assessment showed that approximately 44.4% of students in Turkey obtained very low grades when their scientific knowledge was evaluated (MONE, PISA REPORT, 2016; Kartal, Dogan & Yıldırım, 2017).

Many factors contribute to the inadequacy or failure of students' scientific knowledge, but the most common cause relates to the shortcomings of teachers, who play a significant role as motivators in increasing students' understanding of science concepts and developing their abilities with regard to applicable methods. Science teachers must have a combination of science knowledge and teaching knowledge, and they need to apply innovative strategies with modern technologies, called pedagogical content knowledge (PCK), to teach their specific subjects clearly and effectively. Teachers can help their students understand NOS concepts and SI; in science education settings, the transfer of science concepts to classroom practice is an essential instructional aim. This aim is especially key in teacher education. Although many techniques enhance the teaching and learning of content and skills related to science concepts, SI and NOS, studies indicate that pre-service science teachers' conceptions of NOS and SI are inadequate and that they do not know how to use a variety of pedagogical techniques to teach NOS in their classroom practices (Boz & Boz, 2008; Abell, 2008). Most science educators have stated that enhancing teachers' conceptions of NOS and SI can effectively translate into their use of different learning styles that emphasize NOS and SI in their explicit instruction (Akerson and Volrich, 2006; Lederman et al., 2014). Hence, this study aims to enhance pre-service science teachers' conceptions of SI and to develop pre-service teachers' PCK for teaching SI and science concepts. In addition, how pre-service science teachers experience blended problem-based learning (PBL) and history of science (HOS) approaches should be examined. These questions are addressed in the context of a pre-service science teacher's NOS and HOS course in the College of Education.

1.1 What Is Problem-Based Learning (PBL)?

Barrows and Tamblyn (1980) originally developed PBL in medical school programs in 1980. Although generally represented as an innovative curricular approach for use in elementary and high schools, PBL was based on different researchers' ideas: Vygotsky's zone of proximal development (Vygotsky, 1978) and support and guidance for students as they make sense of these topics (Driver et al., 1994), including the ideas of Ausubel, Bruner, Dewey, Piaget, and Rogers (reviewed by Dochy et al., 2003). In collaborative group contexts, PBL is consistent with the theory of social constructivism, where students collect data, make decisions, use directions in particular ways, organize principles, solve ill-structured problems, analyze, and evaluate, and with the idea of distributed cognition (Vygotsky, 1986; O'Loughlin, 1992; Hennessy, 1993; Hodson & Hodson, 1998). Furthermore, studies show that there is a significant correlation between PBL and improved critical thinking skills among students (Joyce et al., 2009; Drew, 2013).

Traditionally, well-structured science problems are drawn from textbooks or from fellow teachers; however, students encounter ill-structured problems in real life. These real-life problems entail uncertainty, involve rules and principles, have multiple solutions and stem from authentic everyday practice (Baxter & Shavelson, 1994; Birenbaum, 1996; Shavelson, Gao & Baxter, 1996). In that vein, the use of ill-structured problems provides a perfect landscape for an authentic learning environment, where students can understand what they are learning and why (Gallagher et al., 1995).

Chin and Chia (2004a, 2004b) and Crawford (2000) have suggested various roles for the teacher when using PBL in the classroom. The key question is "What is the role of the teacher in practicing PBL?" Fourteen different roles have been gleaned from the literature, and they have been grouped into the following four areas:

- *Guide* (facilitator, planner, metacognitive mentor, learner, motivator, provocateur, and collaborator)
- *Diagnostician*
- *Innovator* (creator, researcher, and experimenter)
- *Modeler*

Although each of these teacher roles has been identified separately, they are often linked and closely related to one another in reality. Pre-service teachers should be taught these roles in college so that they can collectively implement them and instinctively transfer them into their classroom practices. Consequently, the characteristics of PBL include the use of ill-structured problems and the teacher acting as a metacognitive guide.

What history of science (HOS) should teachers know and teach?

NOS and SI can be explicitly taught using many important scientific concepts through HOS, which is affected by cultural, philosophical, technological, and religious factors (Matthews 2000). Accordingly, these aspects should be emphasized in a culturally embedded science education program that provides students with an understanding of science, deeper epistemological issues and ideas and their origins within a social context through the HOS (Driver et al., 1996). HOS is especially useful in helping students understand how scientific ideas change over time, how scientific knowledge is generated by making observations and offering theoretical explanations, and how to develop an understanding of NOS theories and laws in a broader *interdisciplinary context.* Furthermore, teaching SI and NOS through HOS can help students identify the factors that influence innovation (Burke, 1978) and become able decision makers in personal and civic arenas when they face real-life problems (Bragaw & Hartoonian, 1988).

Although HOS plays a significant role in enhancing science teachers' conceptions of SI and NOS (Klopfer & Watson, 1957; Matthews, 1994; Monk & Osborne, 1997; Abd El Khalick, 2000), very little empirical research on science education has attempted to assess the influence of college-level HOS courses on pre-service science teachers' views of SI and NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000). In addition, many science teachers embrace traditional, general beliefs about teaching and learning because they lack the professional skills needed to teach NOS through HOS and because the HOS content in textbooks and curricula is inadequate. To help students develop more informed SI and NOS views or a more sophisticated understanding of SI and NOS, science teachers must create scenarios from HOS and conceptually and effectively translate them into their classrooms.

1.2 Why Use a Blend of the Two Approaches?

In many cases, *blended learning* represents an essential change in the learning environment that teachers and students inhabit. The terms “hybrid,” “mixed” and “integrative” are used interchangeably, primarily because no consensus has been reached regarding a universal definition for blended learning methodology. Blended learning generally combines formal classroom methods (e.g., PBL, argumentation, project-based approaches) with e-learning. This approach has three components: *the mentor or teacher, online learning materials,* and *the skills developed during the classroom experience*. Although some researchers report that a blended learning approach is more effective (Dowling, Godfrey & Gyles, 2003), others state that it does not change students’ understanding of science concepts (Anderson & May, 2010; Larson &, Chung-Hsien. 2009).

The present research constitutes a conscious effort to focus on blending two effective learning approaches, PBL and HOS, with technology. I was interested in encouraging pre-service teachers to think about HOS and philosophy of science issues and drawing them into an authentic PBL learning environment to develop PCK for SI instruction.

2. Methodology

Over the past 50 years, action research has grown increasingly popular in most countries, where it has been based on a pedagogy-driven conception of specific subjects by pre-service and in-service teachers in higher education (Zeichner & Noffke, 2001). Action research involves the researcher preparing each step, which is generally attractive to an implementer-researcher. Bell (1999) stated that action research provides an opportunity to introduce an innovative strategy or to reflect on the effectiveness of an existing strategy in an effort to improve classroom practice. In addition, conducting action research in a classroom focuses on incorporating students’ own knowledge while improving their conceptions of SI and NOS. For these reasons, I was influenced and motivated by this approach to use my own NOS and HOS course to examine how pre-service teachers’ understanding of SI developed when some of their learning materials were blended, problem-based and historical in an e-learning environment.

2.1 The Purpose of the Study

In designing this study, I was influenced by the work of Abd-El-Khalick and Lederman (2000), who explored the effectiveness of a HOS course on college students’ conceptions of the NOS, as its main goal was very similar to mine. The present study aims to assess the influence of PBL and HOS approaches blended with e-learning on pre-service science teachers’ views of SI. Specifically, this paper addresses the question of whether and, if so, how the shift toward blended PBL and HOS approaches impacts pre-service science teachers’ understanding of SI conceptions. In addition, this research focuses on enhancing pre-service science teachers’ PCK to enable them to develop and use new SI instructional materials—blended PBL, HOS and e-learning—for classroom practice. The rationale for this research is that pre-service teachers need an understanding of SI to help and encourage them to use diverse learning materials in their classroom practice. Those who are involved in action research will also need to gain insights into the processes involved so that they can engage in this process with greater confidence and understanding.

2.2 Pre-Service Science Teacher Population

This study was conducted at a college of education in a small city in Turkey located between two metropolises, İstanbul and Ankara. This university has a diverse population of approximately 30,000 undergraduate students. The student population included in this study was enrolled in the sixth semester of the elementary science education program in 2017. A total of 72 students completed the course during this period; 67 students consented to have their data included in the study. Despite being from different cities, all the students in the sample had the same background knowledge of the pedagogical content, the science curriculum, SI, NOS and HOS, with some previous knowledge of science content. Of the students included in the study, 9 (13%) were male, and 58 (87%) were female. All the participants were 3rd-year science teacher students, and they also had one year of experience as science teachers in elementary schools. The same student population was pooled from two classes to normalize the participant groups, and both classes were taught by the same instructor (the author) to assess action research teaching methods.

2.3 Instrument

Data were collected over a 14-week period. Data sources included pre-service science teachers’ views on SI. A combination of content analysis (Silverman, 1999) and the constant-comparative method (Glaser & Straus, 1967) was used to analyze the responses to determine patterns or themes in the data. The instructor administered the questionnaires to the pre-service science teachers, and these questionnaires took approximately 30 to 40 minutes to complete.

Views about Scientific Inquiry (VASI) questionnaire. The Turkish version of the VASI questionnaire, an open-ended questionnaire developed by Lederman and et al. (2014), was the instrument used in this study. The VASI questionnaire was translated by Han-Tosunoglu, Dogan, Yalaki, and İrez (2017). The items on the VASI questionnaire had been used in a previous study (Gaigher, Lederman & Lederman, 2014; Han-Tosunoglu, Dogan, Yalaki, and İrez, 2017) that investigated changes in SI views among 7th graders. Expert input and pilot testing established content and face validity. The VASI questionnaire includes 8 open-ended questions that specifically address the following components of SI:

"*Begins with a question*," "*Procedures influence results*," "*Procedures are guided by the question asked*," "*Same procedures may not yield the same results*," "*Explanations are developed from data and already known conclusions*," "*Multiple methods*," "*Data are not the same as evidence*," and "*Consistent with data collected*."

3. Data Analysis

In a qualitative study such as this one, increasing validity is important. To make the data more meaningful, two additional researchers helped analyze the data and categorize them as indicating a naïve, partially informed and informed level of understanding. Using a blind round of analysis, the researcher and two science education researchers analyzed the data independently. There was a *high* degree of consensus *among* the researchers in the analyses. A few differences appeared in approximately 10% of the answers, and these differences were resolved through further examination of the data. The results were compared to increase the internal validity of the study. The data analysis included two phases. The first phase involved generating data by categorizing each participant's views of the seven emphasized aspects of SI as *naïve, partially informed,* or *informed*.

This phase involved several repetitions of the category and verification stages. In the second phase, the percentages of participants in the different categories (naïve, partially informed and informed) for each SI aspect were used to compare the pre- and post-treatment status of all preservice science teacher' views about SI. Through this scoring procedure, an answer expressing an appropriate view was categorized as "informed." For instance, the following explanation of one pre-service teacher for why "*there is no single scientific method*" for SI was categorized as "*informed*":

> *Yes. Scientists could observe stars and planets with a huge telescope or observe unseen things with microscope to produce scientific knowledge & models,, for example, "atom models,", "black hole", "gene" etc. or to figure out obesity by developing new drugs through controlled experiments in the lab…*

Pre-service science teachers should understand that a scientist can produce scientific knowledge using several different kinds of investigations or methods.

Responses were categorized as "naïve" if they expressed a view that was inappropriate or inaccurate. For instance, one "naïve" participant explained her "*Consistent with data collected*" view of SI:

> *While getting sunlight less, some plants grow taller. Others grow less with more sunlight. That is, these results show that there is no relationship between the daylight and the growth of the plant…*

During the processes of SI, scientists will make claims based on observable evidence and will justify their claims with relevant evidence. Other scientists often make rebuttal claims, pointing to other evidence that counters the evidence provided to justify the previous claim.

3.1 Components of the Nature of Science (NOS) and History of Science (HOS) Course

The NOS and HOS course is a single compulsory course on science content; pre-service science teachers enroll in this course during their third year at the university. The course teaches basic NOS and SI concepts and integrates these aspects into the content of elementary science units and the student-centered learning environment, with classroom activities including group work that emphasizes collaborative learning. The author taught the course.

Classes were held in three-hour sections each week over a 14-week teaching period. Each teaching session generally consisted of theory sections that addressed basic science concepts and an inquiry-based section that allowed participants to apply and develop their evolving conceptual knowledge. The classroom described in this action research aimed to create an explicit learning environment to provide effective classroom inquiry (Abd-El-Khalick and Lederman, 2000; Lederman et al., 2001). In addition to these sections, the study implemented components to aid in the development of participants' SI and NOS views.

These course components were explicit NOS and SI instruction, explicit HOS instruction, PBL instruction, lesson plan, and creative writing for a scientist's biography. Explicit NOS, HOS and PBL instruction was embedded during contextually relevant intervals, and participants were also engaged in various PBL scenarios at contextually relevant intervals. The assessment of the course consisted of three items: a blended PBL and HOS lesson plan, creative writing for a scientist's biography, and a portfolio. Scientist's biography and portfolio were not used as sources of data in this study.

3.2 Lesson Plans

Turkey has been attempting to reform the national middle and high school science curricula since 2003, which inspired us to use Singapore's primary science curriculum design for this project. Singapore's primary science curriculum is designed around five themes from students' real lives and from the observation of natural phenomena. At the primary level, the five themes are *diversity, cycles, energy, interactions, and systems,* which are recognized as central themes in our national middle school science curriculum.

The author and Ferah Ozer, a PhD student in science education and a researcher for this project, created the six-stage lesson plan. First, the *inception section* begins with the topic or activity that links past and present learning experiences or the subject matter knowledge from previous units to that in the present unit. Second, the *warm-up activity section*, which links a variety of examples from different subjects, may be one of the driving forces that encourages students' learning and curiosity.

Students can show effective ways of discovering science concepts or their teachers guide them to find their own paths to discovery; if students are curious about scientific knowledge, they can and will explore or produce it. Third, in the *PBL section*, students are given a hands-on experience of an ill-structured problem scenario from daily/real life. This scenario intends to explore problem solving to excite students while introducing very real concepts: what the problem is, what they know—or need to know, what they should do or how they should act, and how they can generate possible solutions, identify best solution and share the best solution with their group and class. This section is also suitable for learning SI. Fourth, the *formative assessment of PBL section* includes higher-order thinking questions or different activities to promote critical, reflective and creative thinking and problem solving. Fifth, the *HOS section* is intended to inspire an awareness and appreciation of the appeal and understanding of science, scientists and culture through HOS literacy. In this section, teachers can use guided inquiries of history of philosophy and HOS, the reflection corner, creative writing to understand science and scientists, drama, role play, games, etc. Sixth, a formative assessment of whole activities includes PBL and HOS with open-ended questions, stories, scenarios, games, puzzles, etc. to develop students' higher-order thinking skills.

Pre-service science teachers are responsible for preparing a lesson plan for middle school science units in the middle of the NOS and HOS course. After seven weeks, I use peer, productive classroom and Google classroom online discussions to finalize each lesson plan and to guide pre-service science teachers in enhancing them.

In summary, I have investigated pre-service science teachers' conceptions of SI after receiving instruction in a variety of contexts, including SI, NOS, PBL and HOS. In addition, I have included a discussion of these contexts within the *NOS and HOS course*. These contexts, representations and teaching strategies to enhance conceptions of SI in different settings can be seen in Table 1.

Table 1. The Context of the Study

Pretest	• VASI (Lederman et all 2014) • Views on Practical Utilization Questionnaire
Explicit instruction of SI and NOS (7 -weeks)	• Fossil activity, tricky tracks, black box, drama, role play, • newspapers, PBL, HOS, history of movies, • guided inquiry history of science and philosophy, reflective corner, • creative writing for Scientist's biography, inquiry-based learning
Thematic middle-school science lesson plan	• Blended problem-based learning & • Historical-based of science approaches, • Thematic, Formative assessment
Discussion platform (7-Weeks)	• Peer, small groups and productive class & Google classroom (online) discussions
Posttest	• VASI (Lederman et all 2014) • Views on Practical Utilization Questionnaire

4. Results

The overall enhancement of pre-service science teachers' views about SI was evaluated based on their responses to each aspect, which corresponded with an item on the VASI questionnaire. All the participants were able to explain and justify their answers in the classroom, and by the end of this blended PBL and HOS instruction, all of them understood the importance of these types of approaches when teaching science; they had also reached a consensus on several aspects of SI, such as "*Begins with a question*," "*Procedures influence results*," "*Procedures are guided by the question* *asked*," "*Same procedures may not yield the same results*" and "*Data are not the same as evidence*." Adequate answers to questions regarding aspects of SI were observed to increase from 34% to 73% (Table 2).

Table 2 shows the percentage of the different response types from pre-service science teachers in the pre- and posttests.

Table 2. Percentage of pre-service science teachers with naïve, partially informed and informed views of the eight aspects of SI

N = 67 % of Students		Naïve	Partially Informed	Informed
Begins with a question	*Pretest*	97	3	0
	Posttest	27	33	40
Multiple methods	*Pretest*	84	16	0
	Posttest	19	42	39
Same procedures may not yield the same results	*Pretest*	87	13	0
	Posttest	13	22	64
Procedures influence results	*Pretest*	76	24	0
	Posttest	15	12	73
Procedures are guided by the question asked	*Pretest*	85	15	0
	Posttest	28	24	48
Data are not the same as evidence	*Pretest*	85	15	0
	Posttest	28	24	48
Explanations are developed from data and already known conclusions	*Pretest*	93	7	0
	Posttest	37	19	43
Consistent with data collected	*Pretest*	94	6	0
	Posttest	55	10	34

Notably, pre-service science teachers showed improvements in all the SI aspects except "Consistent with data collected." Some participants continued having misconceptions about this item of SI (Table 2). Nonetheless, most pre-service science teachers (10% naïve and 34% informed) recognized that scientists used supporting evidence to produce scientific knowledge and make claims (Lederman et al., 2014). All the participants needed to understand that the table shows "What the scientist claims," "What the scientific results really say," and "What they really mean," similar to the sixth question of the VASI questionnaire (the "*Consistent with the data collected*" aspect of SI*)*.

Approximately forty percent of the pre-service science teachers answered that scientists can use different methods for scientific investigations and that the data collection method chosen to answer a particular question depends on the scientific question or problem. They answered and explained this item with two examples. First, if scientists aim to determine how one variable affects another, they generally change only one variable and keep all the other variables constant. In addition, scientists can conduct a controlled experiment in which they can investigate something in a lab where everything can be controlled. Second, in biology, scientists might study animal behavior by observing animals in their natural habitats, which is similar to the idea reflected the first question on the VASI questionnaire. Nearly 20% of the respondents belong to the naïve category with regard to the idea that scientific investigations begin by testing a hypothesis and following the orderly steps of the "*scientific method*."

These results showed that pre-service science teachers have misconceptions about scientific investigations. A scientific investigation usually begins with a question or problem statement, and data are then gathered through observations, experiments and inferences to answer questions or solve problems and ultimately generate an explanation based on the collected evidence (Bell, Maeng, Peters, 2013). Abd-El-Khalick and Lederman (2000) stated that teachers should have more experience and guidance in conducting explicit reflective approaches for SI to improve their scientific investigations.

With regard to the SI question about scientists reaching different conclusions when they follow the same procedure, sixty-five percent of the respondents answered that they may not reach the same conclusion because of differences in their views, experiences, imaginations, creativity, sociocultural backgrounds, education, fields, etc. That is, most of the pre-service science teachers (73%) hold informed views regarding the *"Same procedures may not yield the same results"* and *"Procedures influence results"* aspects of SI, and only 15% fell into the naïve category for these two items.

In summary, after a fourteen-week intervention, the results showed a statistically significant change in pre-service science teachers' knowledge of SI (Figure 2).

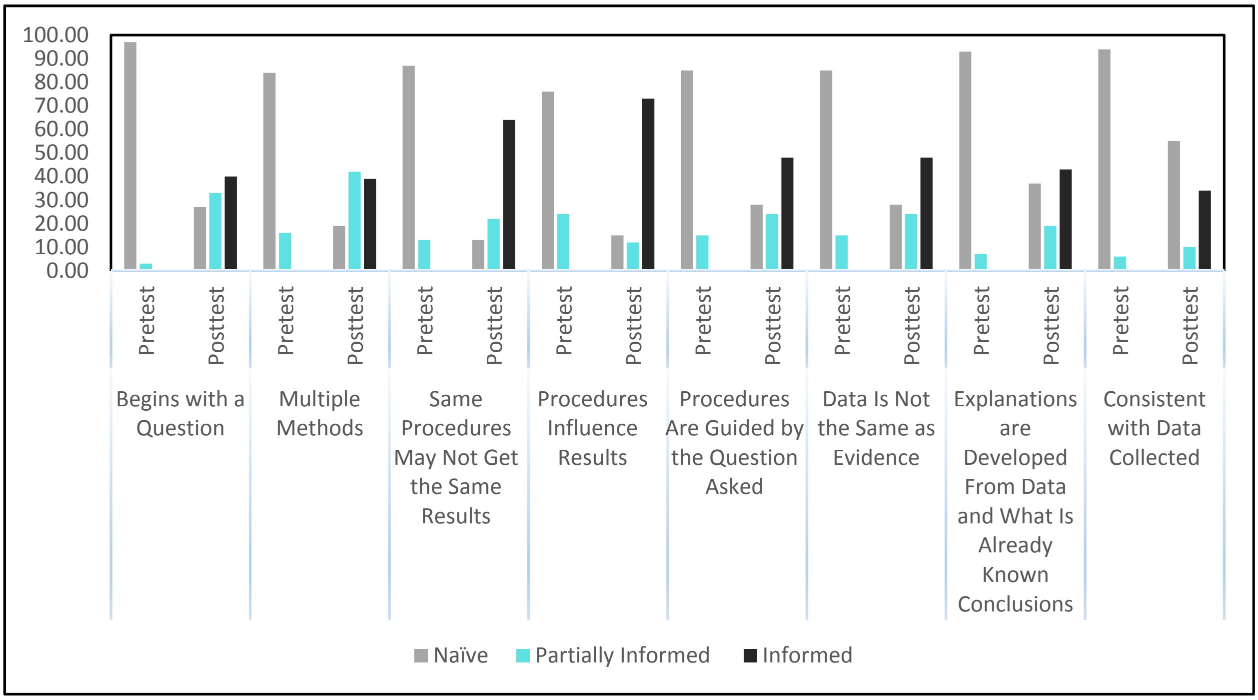

Figure 2. Percentage of pre-service science teachers with naïve, partially informed and informed views of the eight aspects of SI

5. Discussion

Science educators and teachers often complain that students are unable to understand emerging queries, think critically, ask good questions, or analyze scientific knowledge. Despite these challenges among students, teaching science by blending PBL and HOS can help effectively develop 21st-century skills, such as critical thinking, communication, collaboration, creativity, entrepreneurship, problem solving, and productivity, and improve students' views of SI and NOS.

Based on the findings above, blended PBL and HOS instruction can improve not only pre-service science teachers' knowledge of SI more than traditional science instruction but also their PCK for teaching science. These findings confirm those of previous studies (Gibson & Chase, 2002; Marincovich, 2000; Shimoda et al., 2002; Welch et al., 1981) that showed that blended PBL and HOS approaches can enhance teachers' affective domains of learning and help them ably transfer these domains to their classroom practices to make their students scientifically literate in terms of 21st-century skills (Bransford, Brown, & Cocking, 2000; Sandoval & Reiser, 2004).

The NOS and HOS course is designed for pre-service science teachers who want to learn successful science teaching styles through PBL and HOS and the ways in which these techniques can be transferred into their classroom practices. Furthermore, the course serves as a developmentally appropriate, step-by-step approach to using all levels of PBL and HOS for teaching science concepts with SI. By the end of this course, pre-service science teachers will be able to effectively implement classroom practices that provide students with opportunities to explore a question/problem, investigate possible solutions, and improve scientific explanations in light of their collected evidence. At the same time, this setup can serve as a blended approach to improve motivations to learn science, in that most pre-service science teachers are likely to have positive predispositions toward PBL and HOS instruction and to have a mental image of the lesson plan. Nevertheless, this study shows that using this blended PBL and HOS approach may face some pedagogical challenges in classroom practice. *First*, the planning and implementation of this instruction requires overtime from teachers. *Second*, almost all pre-service science teachers have experienced difficulties in finding ill-structured problems, as they have only encountered well-structured science problems in the past, which are always provided in textbooks or by teachers. Many countries still face significant problems with regard to the quality of science textbooks (Abd El Khalick & Waters, 2008; İrez, 2008). Science textbooks should provide students with an awareness of HOS, the history of philosophy and ill-structured problems that entail uncertainty, multiple solutions and authenticity. In addition, teachers should provide students with extra time to explore independent opportunities, projects and discussions to determine the design problem and to ponder more creative ideas in this scenario. *Third*, these study results indicate that pre-service science teachers encountered some challenges with Google classroom or technology (online platforms), even though these tools were attractive for their flexibility (in terms of both time and place). One problem concerned the teachers' abilities to adapt in switching from a traditional face-to-face classroom to the online Google classroom. While some teachers can adapt easily, others have a very hard time adapting to the online learning environment, and their inability to overcome this barrier hinders the success of their courses. In addition, some pre-service science teachers are unable to learn an online course because they live in campus dormitories without internet access, and some of them do not even own computers. Hence, these pre-service teachers have to go their classmates' apartments or the library to access the internet or even computers. The solution to this problem lies in writing online at flexible intervals during the semester. The last problem with technology is that many pre-service teachers lack technological proficiency, for example, in basic computer programs (Publisher, Power Point, etc.). Furthermore, some are unable to upload their files or to handle and/or share their lesson plan materials with their classmates in the Google classroom.

Fourth, for PBL, HOS and e-learning platform instruction to be successfully implemented, pre-service science teachers must be adequately prepared for extensive training and support.

Hume and Coll (2008) reported that a pre-service science teacher's understanding is not easily enhanced through PBL and HOS approaches; instead, they must learn from their course experiences under the guidance of an expert lecturer (Hume & Coll, 2008). In the same vein, some studies have stated that pre-service science teachers need to be provided with more experiences through blended PBL and HOS investigations with e-learning to learn specific science concepts for teaching science to improve their PCK (NRC, 2000). The results of the present study support the existing evidence on teachers being metacognitive guides and providing more experiences as effective treatment for pre-service teachers through blended PBL and HOS approaches.

This research also shows that blended PBL and HOS approaches provide students with the opportunity to acquire theory and content knowledge and supports the improvement of students' written and oral communication skills. While PBL helps develop students' metacognitive abilities, such as critical thinking, problem solving, and communication skills, as well as SI, HOS provides them with a link to scientists and scientific knowledge that can develop gradually within a particular social and cultural context. Enabling students to achieve scientific literacy through the 21st-century skills that they have learned about can be a historical approach that can stimulate learning about cultural perspectives (Barr & Tagg, 1995).

Clearly, rather than an implicit approach, explicit, reflective instruction must be used to effectively understand conceptions of SI. In addition, the blended PBL and HOS approach in science education may sufficiently enhance scientific literacy and an understanding and appreciation of scientific knowledge and scientists. Therefore, it is important for teachers and students to make informed decisions in the 21st century; they must raise questions, find methods for testing ideas, collect and analyze data, support arguments with evidence, and solve ill-structured problems encountered in real life.

New approaches for teaching and assessing SI and practices are essential for guiding students to make informed decisions in an increasingly complex and global society. We encourage teachers to engage in and motivate the implementation of innovative strategies or material and properly equip their students with the tools that they will need to face real-life career challenges in the 21st century.

Obviously, there are limitations here. This instruction had not been given middle school students a chance to intervene directly because the course was designed to help pre-service science teachers create their own lesson plans within a PBL and HOS contextualized setting. By all results, and with proven the other PBL and HOS studies, it is no wonder that blending PBL and HOS was innovative and also beneficial approach for empowerment in teachers' classroom practice because "*new blending approach wine* is poured *in an old PBL and HOS bottle"* through preservice science teachers' learning and my findings. However, my findings are limited because they reflect the dissemination process of only pre-service science teachers from one public university. Further research is required to provide evidence of the effectiveness of blended PBL and HOS approaches in advancing the understanding of middle school students and the practicability of such approaches in the classroom. I suggest that further research is also needed to determine whether the strategy can yield consistent results across different cultures and different grades.

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