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Effects of the Science Writing Heuristic Approach on the Quality of Prospective Science Teachers' Argumentative Writing and Their Understanding of Scientific Argumentation

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Abstract This study investigates the effect of the science writing heuristic (SWH) approach on the quality of prospective science teachers' (PSTs) argumentative writing and their understanding of the components of argumentation in the SWH approach and their own learning. Ten SWH approach activities were implemented during the semester. The study was carried out with 31 PSTs. A case study design was used. Data included the SWH approach's grading rubric and semistructured interviews. While the ANOVA and Bonferroni tests were used to analyze the SWH approach's grading rubric, content analysis was used to analyze the semistructured interviews conducted with 12 PSTs. The ANOVA results showed a statistical difference among the writing performance of the PSTs ($F = 14.493$, $p < 0.01$). The findings gathered from the interviews revealed that the quality of the argumentative writing and research skills of the PSTs increased over time. The PSTs made explicit associations among their beginning questions, data and observations, and claims and evidence, and they made distinctions between their data, observations, and evidence. Multiple representations played an important role in providing evidence to support claims. Moreover, the process of negotiation helped PSTs learn more effectively, and they believed that the argument-based inquiry lab was beneficial to their learning and their future vocational careers as teachers.

Keywords The SWH approach · Argumentative writing · Scientific argumentation · Chemistry education

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Introduction

Most science laboratory courses aim to help learners experience and understand scientific phenomena and procedures (Burke, Greenbowe & Hand, 2006). Over the past three decades, research studies have shown that laboratory courses are authentic learning environments. Students may learn several laboratory techniques and skills and they are given visual aids for concepts when a traditional cookbook laboratory course is implemented (Burke et al., 2006; Hart, Mulhall, Berry, Loughran & Gunstone, 2000). However, traditional laboratory courses are not effective in terms of leading students' new conceptual learning or promoting students' laboratory and science process skills (Acar Sesen & Tarhan, 2013; Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994). To address this problem, inquiry-based strategies have been used to improve students' learning in chemistry laboratories in universities, as well as in primary and secondary schools (Acar Sesen & Tarhan, 2013; Bruck & Towns, 2009; Keys, Hand, Prain & Collins, 1999). During these activities, students are required to identify and form scientifically oriented questions, pose hypotheses, make predictions, determine variables, design and conduct experiments, analyze results, identify underlying assumptions, formulate and revise scientific explanations, communicate results, and support scientific arguments (Bybee, 2000; French & Russell, 2002). In addition, students are more involved, assigned more responsibility, gain more scientific process skills, and learn more effectively (Leonard, 1994).

Educational research has explored the many challenges that practising and prospective science teachers face in successfully designing and implementing effective inquiry-based learning experiences (Talanquer, Tomanek & Novodvorsky, 2013). Moreover, research indicates that science teachers have difficulties in implementing experiments in their classes because of a lack of knowledge about and skills in performing experiments. As a result, teachers who encounter these difficulties prefer not to conduct experiments, perform a limited number of experiments, or use demonstrations (Coştu, Ayas, Çalık, Ünal & Karataş, 2005; Tatlı, 2011). Teachers develop knowledge and skills in theoretical and laboratory courses as preservice teachers (Coştu et al., 2005). Lazarowitz and Tamir (1994) have pointed out that teachers can create an investigative laboratory environment only if they have carried out their own research. In this context, it is important to provide prospective science teachers (PSTs) with experience in this learning environment.

The curriculum for science courses that PSTs will teach in grades 4 to 8 in middle schools in Turkey when they become in-service teachers indicates its vision as to raise all students as individuals who have scientific literacy (Ministry of National Education [MONE], 2013). Within this curriculum, an inquiry-based learning approach is taken into consideration and teachers are expected to provide environments in which their students can express their ideas easily, support their ideas with different reasons, and provide opposing arguments that can refute their classmates' claims with either oral or written arguments (MONE, 2013). In this context, there is a need for PSTs to gain experience in practising argument-based inquiry activities, in designing their own experiments, in revealing their understanding of the approach, and in engaging in scientific argumentation and writing activities to help promote and support metacognitive awareness and a deeper understanding of the content and essential aspects of scientific research (Sampson & Walker, 2012). To address this problem, we used the science writing heuristic approach (SWH), which is an argument-based inquiry approach (Chen, Hand & Park, 2016a) and consists of both writing-to-learn activities and metacognitive support to promote reasoning about laboratory data and concepts (Wallace & Hand, 2007). The SWH approach is closely aligned with the science curriculum. Within this approach, students develop questions, design experiments, gather data, and generate evidence to support claims that address their initial questions and the approach uses student-student dialogue and argumentation, which are rare in traditional science classrooms (Choi, Notebaert, Diaz & Hand, 2010; Schoerning, Hand, Shelley & Therrien, 2015). This approach is also an alternative format to the laboratory report and includes pre-, during, and postlab writing activities, which makes it different from other laboratory approaches (Choi et al., 2010; Gupta, Burke, Mahta & Greenbowe, 2015; Wallace & Hand, 2007). Even though this approach has been used in different contexts, such as in different educational levels and countries (Burke, Greenbowe & Hand, 2005; Burke et al., 2006; Choi et al., 2010; Gupta et al., 2015; Keys et al., 1999; Kıngır, Geban & Günel, 2013; Poock, Burke, Greenbowe & Hand, 2007; Rudd II, Greenbowe & Hand, 2007; Rudd II, Greenbowe, Hand & Legg, 2001), there have been a limited number of studies that use this approach when teaching a national chemistry laboratory course at the university level with PSTs. Therefore, this study aimed to investigate the quality of the argumentative writing completed by the PSTs and their understanding of the components of argumentation found in the SWH approach. The research questions that guided this study are as follows:

1. Does the SWH approach contribute to the quality of the argumentative writing produced by the PSTs?
2. What understanding do the PSTs have of the SWH approach and its components of argumentation?
3. How do PSTs assess their own learning?

Theoretical Framework

Writing-to-Learn in Science Classrooms

Writing has been put forward as a tool for promoting scientific literacy in school classrooms (Yore & Treagust, 2006), and it is beginning to be viewed as an epistemological tool (that is, a tool for developing conceptual understanding), as well as a communication tool (Galbraith, 1999; McDermott & Hand, 2010). There have been essentially two views of writing-to-learn in science classrooms: the school genre approach or traditional writing tasks and the diversified writing approach or nontraditional writing tasks (McDermott & Hand, 2010; Prain, 2006). While the school genre approach includes traditional laboratory write-ups, the diversified writing approach includes a variety of writing types ranging from narratives, stories, brochures, and PowerPoint slides (McDermott & Hand, 2010; Prain, 2006).

The school genre approach focuses on reproducing the traditional written discourse of the science community and on replicating what scientists do. Advocates of this genre argue that students should be aware of the structural and vocabulary components similar to those used by scientists in scientific texts. However, students read these scientific texts without reflecting on the nature of science and scientific knowledge and without the critical stance needed to evaluate knowledge claims (Hand & Prain, 2006). Thus, this traditional approach may align better with Bereiter and Scardamalia's (1987) knowledge-telling model where writing is viewed as a recall process and does not shift the existing knowledge (Hand, 2007).

On the other hand, in the diversified writing approach (or nontraditional writing approach), students are expected to use writing to address related scientific issues and practices beyond the classroom. This offers the opportunity to strengthen connections in students' understanding and to go beyond simple rote learning when students are given an opportunity to unpack meaning and reconstruct understanding (McDermott & Hand, 2010; Prain, 2006). In this context, writing in science classes may be useful if it reflects some of the characteristics of scientists' writing but also fosters students' ability to unpack scientific meaning and build new knowledge (Wallace & Hand, 2007). Thus, the nontraditional approach may align more with Galbraith's (1999) knowledge constitution model where writing is viewed as a process that produces new knowledge because of an interaction between the writer's content knowledge and their rhetorical knowledge (Hand, 2007).

Taken as a whole, the SWH approach adopts the knowledge construction model and can be conceptualized as a bridge between informal and more formal writing, which scaffolds learners in both understanding their own lab activities and connects them to other scientific ideas by using expressive writing modes that foster personally constructed scientific understanding and public modes that focus on canonical forms of reasoning in science (Wallace & Hand, 2007). This approach can be understood as an alternative format for lab reports and a vehicle for science learning and therefore exemplifies writing-to-learn principles. The SWH approach provides a student template, including sections such as beginning questions, tests, claims, evidence, and reading/reflection, in order to build scientific knowledge instead of responding to the five traditional sections: title and aim, procedure, data, discussion and balanced equations, and calculations and graphs. Table 1 shows the traditional lab report format versus the SWH approach's student template (Burke et al., 2005). The SWH approach's student template encourages students to talk about, deliberate and negotiate their understanding of chemistry, participate in inquiry-based lab activities and build their argumentation (Burke et al., 2005, 2006; Choi et al., 2010; Choi, Hand & Greenbowe, 2013).

Research has shown that the SWH approach's student template helps students write lab reports effectively. In this context, when university students were asked to compare the SWH approach's format to the traditional lab report, the majority of the students preferred to use the SWH approach's format because they learned more and were more engaged in the thinking process. Moreover, students indicated that using the SWH approach's format required a more appropriate amount of time and was a more efficient use of their time. Therefore, they spent equal or less time on completing their lab reports (Rudd II et al., 2001). Research has shown that the claim and evidence relationship in the student template has been determined as the critical component of argumentation (Choi et al., 2010, 2013) and that students develop their own claims based on their own data analysis (Choi et al., 2010). In argument-driven approach studies, it has also been reported that claims are not distinct from data but are somehow embodied in them (Sandoval & Millwood, 2005).

Table 1 Writing activities of pre-, during, and postlaboratory work with the components of the SWH approach's student template versus the traditional laboratory report

Time period of the laboratory activities	Traditional lab template	Student requirements for lab template	Components of the SWH approach's student template	Student requirements for each component
Prelab	Prelab questions	No equivalence	1. Beginning questions: What are my questions? (individual). 2. Test and safety: What do I do?	(a) Prepare their individual beginning question(s) (BQs); (b) outline their procedural strategy to find an answer to their BQs; (c) list their safety concerns for the outlined procedural strategy.
During lab	1. Title and aim 2. Procedure	The instructor gives step-by-step directions; the procedure is outlined in the lab manual.	1. Beginning questions (group BQs) 2. Test and safety (group)	(a) Write BQs on the board; (b) discuss their BQs with partner or group members and then with the whole class; (c) decide which BQs they will study; (d) discuss and decide what strategies are appropriate to answer the BQs.
	3. Data and observations	(a) Students perform their experiment individually or with a partner. (b) Students mainly talk with their partners. Dialogue interchange tends to be infrequent and purely teacher-directed.	3. Data, observation, calculation and graphs: What can I see?	(a) Are divided into groups so that they can perform experiment and collect data; (b) draft appropriate data collection tables, including dependent and independent variables to be investigated; (c) look for patterns and anomalies so that they can analyze the collected data; (d) decide who will repeat the experiment and which part(s) need(s) to be repeated if there are anomalies; (e) graph results and interpret their graph(s); (f) enter their data in the class database in order to create an overall course-wide data pool.
	4. Discussion	May ask questions of lab partners or instructor.	4. Claim(s): What can I claim?	Students propose their claim(s).
	5. Balanced equations, calculations, and graph	Lab partners check with one another so that they have all the data.	5. Evidence: How do I know? Why am I making these claims?	(a) Cite supporting evidence for their claim; (b) discuss their results as a class to create an understanding of the concept(s).
Postlab		No equivalence	6. Reading and reflection: How do my ideas compare with others' ideas? How have my ideas changed?	Students use at least three appropriate resources (such as the Internet, instructor, class notes, reference text, etc.) to explain, confirm, or dispute what they have learned in the laboratory.

Using the SWH Approach to Promote Students' Learning from Laboratory

The SWH approach was created as a tool for enhancing students' learning from laboratory activities through writing-to-learn. The approach helps students to negotiate meaning and construct knowledge, reflect on their own understanding via writing, and compare their own understanding with peers in a social context (Keys et al., 1999). There have been several studies that have implemented the SWH approach in chemistry laboratories at the university level (Choi et al., 2013; Gupta et al., 2015; Poock et al., 2007; Rudd II et al., 2001, 2007). Studies have generally used a quasi-experimental design and compared the SWH approach with traditional laboratory work. The studies found that the students who had low chemistry content knowledge or instruction at the beginning of the semester improved their academic performance compared to students who were not educated with the SWH approach. The students who attended sections that followed the SWH approach showed better understanding of the concept being studied (Poock et al., 2007; Rudd II et al., 2001, 2007), and students' argument scores were positively correlated with their achievement level (Choi et al., 2013). Some studies investigated university students' critical thinking abilities using the SWH approach in chemistry laboratories. The results showed that the students who were given guided inquiry-based instruction following the SWH approach showed more improvement in their critical thinking skills than those who followed the traditional approach (Gupta et al., 2015).

Studies involving the SWH approach have been implemented in other science fields and grade levels (Erkol, Kisoglu & Büyükkasap, 2010; Günel, Kabataş-Memiş & Büyükkasap, 2010; Hand, Wallace & Yang, 2004; Kıngır et al., 2013). These studies also used a quasi-experimental design. The results found that the SWH approach better promoted students' conceptual understanding compared to the traditional approach (Erkol et al., 2010; Kıngır et al., 2013). Moreover, the studies reported that using the SWH approach reduced students' misconceptions and it was effective in closing the gap between low-, medium-, and high-level achievement (Grimberg & Hand, 2009; Kıngır et al., 2013). Research has also shown that the SWH approach had a positive effect on students' attitudes toward laboratory and science courses (Erkol et al., 2010; Günel et al., 2010).

Methods

A case study was chosen for this study in order to conduct a detailed investigation of the participants using a combination of qualitative and quantitative techniques (Merriam, 2009). We chose this method since it enabled an in-depth study with a small number of participants. In this context, the case of this study was the quality of writing of one cohort of PSTs and their understanding of scientific argumentation. We selected this case because these PSTs were enrolled in our institution and the information that will emerge from this study will provide insights and offer feedback related to our teaching of these PSTs. Besides, this case looks at a typical example, which will provide us with insights into this issue that can be tested out in other similar cases (Taber, 2007).

Participants

The participants in this study consisted of 31 PSTs enrolled in a university in a central area of Turkey. Ten male and 21 female PSTs participated in the study. Their ages ranged from 18 to 20 years. The PSTs were freshmen in their second semester at the university. A traditional approach to teaching science was implemented with the PSTs in their first semester chemistry laboratory course. However, in their second semester chemistry laboratory course, the SWH approach was used. In the General Chemistry Laboratory I course, the PSTs learned about laboratory study techniques, safety rules, accidents and precautions, safety signs and their meanings, and laboratory equipment and its uses, and they conducted 10 experiments parallel to the General Chemistry I course. These 10 experiments used a closed-ended experimental approach. In contrast, in the Chemistry Laboratory Course II, 10 SWH approach activities were implemented to complement the material in the main course, the General Chemistry II course (Higher Education Council [HEC], 2014).

The Context

Ten SWH approach activities were implemented covering the topics of reaction rate, acid-base titration, chemical equilibrium, mixtures, chemical reactions, concentration effect on reaction rate, gases, solubility, and electrochemistry as part of the regular General Chemistry II laboratory curriculum (HEC, 2014). The typical beginning questions and the basic materials for the activities are shown in Table 2. Each group member developed different beginning questions, but when they came to the laboratory, all group members discussed possible research question(s) and designed their experiments based on the materials and chemical substances they had been given.

Data Collection

Data were collected using the SWH approach's grading rubric and semistructured interviews, which are described in detail below.

SWH Approach's Grading Rubric. The student reports were graded using a 10-category (Burke et al., 2005), 100-point grading rubric. Table 3 shows the SWH approach's grading rubric used in this study. The PSTs were provided with verbal and written explanations related to how to evaluate their laboratory report and score the template. For this purpose, a copy of the SWH approach's grading grid showing how to score each part was given to the PSTs. Each category was given zero to 10 points. Each PST's SWH report was scored each week and feedback was given on the report. The rubric categories included beginning questions, quality of data and observations, claims, evidence, relationship between claims and evidence, questions, ability to analyze data and observations, results of experiments, reflection and reading, and relationships among reflection and reading and beginning questions and claims-evidence.

In this regard, we assumed that the rubric used for each PST's lab reports reflected their argumentative writing since the rubric evaluates the components of argumentation

Table 2 The topics, typical beginning questions, and basic materials used in the laboratory activities

Lab activity	The topic	Typical beginning questions	The basic materials PSTs were given for the activities
1	Reaction rate	How can a reaction rate be calculated?	Separatory funnel, Erlenmeyer (250 mL), beaker (500 mL), gas measuring tube (50 mL), graduated cylinder, H_2O_2, MnO_2, distilled water
2	Acid-base titration	How can I calculate the concentration of an unknown acid solution?	Burette, Erlenmeyer, Pasteur pipette, NaOH stock solution, HCl unknown concentration, phenolphthalein
3	Chemical equilibrium	How is chemical equilibrium affected when a substance is added?	Test tubes, graduated cylinder, dropper, potassium chromate, potassium dichromate, NaOH, HCl
4	Liquid-liquid homogenous mixture	How can I separate liquid-liquid homogenous mixture from each other?	Beaker, flask, graduated cylinder, watch glass, dropper, distilled water, ethyl alcohol, distillation flask, wood splinter
5	Chemical reactions	Can I classify the chemical reactions?	Test tubes, potassium chlorate, manganese (IV) oxide, wood splinter, HCl, Zn granule, silver nitrate, NaCl, Cu pieces
6	Reaction rate	Does concentration have any effect on the reaction rate?	Test tubes, graduated cylinder, chronometer, HCl, $Na_2S_2O_3$, distilled water, white paper
7	Partial pressure of gases	How can I calculate the molecular mass of a bivalent metal?	Metal band, gas measuring tube, HCl, beaker
8	Solubility	Does every liquid dissolve in water?	Test tubes, graduated cylinder, rubber stopper, ethyl alcohol, iodine, NaCl, olive oil
9	Electrochemistry	How do acids react with metals?	Test tubes, dropper, Fe pieces, Zn pieces, Cu pieces, HCl, HNO_3

included in the SWH approach, such as beginning questions, claim, evidence, reflection, and relationships among them, including claims-evidence (Choi et al., 2013; Hand & Choi, 2010).

Semistructured Interviews. Twelve PSTs were interviewed upon completion of the General Chemistry II lab course. They were categorized as high-, medium-, and low-achieving PSTs based on their chemistry laboratory mean scores from the previous semester. Volunteers from each group were selected and interviewed individually. The interviews lasted around 15 – 20 min. The semistructured interviews were used to address the second and third research questions. The interviews were implemented in order to gain in-depth information about the SWH approach's grading rubric and how well the PSTs understood the learning process. Therefore, the interview data helped to elaborate specific features of the SWH approach. The interview questions are provided in the Appendix.

Table 3 The SWH approach's grading rubric for instruction

Rubric items	0	1	2	3	4
1. Can the beginning questions potentially be answered by the results of the lab work?					
2. What is the quality of the data and observations?					
3. Are the claims a direct result of the data and observations?					
4. How well are the data and observations used in the evidence?					
5. Are the claims backed up in the evidence?					
6. How well does the student answer all of the questions that were asked in the laboratory write-up for this particular experiment?					
7. How well does the student analyze the data and observations to make the experimental measurements or observations meaningful?					
8. Do the results of the experiment come close to the accepted values or identify an unknown compound correctly or show an accepted comparison, trend, etc.?					
9. In the reflection and readings, how many sources are used and how are they connected?					
10. Does the reading and reflection discuss the initial questions? Does the reading and reflection aid the claims and evidence?					

Procedure

The study was carried out during regular chemistry laboratory sessions over a 16-week period. The lab sessions were conducted once a week over 2 h. The implementation period began after the PSTs were informed of the SWH approach and the student template. Students' lab reports were graded using the SWH approach's grading following each lab session. At the end of the study, 12 PSTs were interviewed.

A sample laboratory report written in the SWH approach format for "determining the identity of a chemical reactant" was provided for the PSTs at the beginning of the semester (Burke et al., 2005). During the implementation, the PSTs followed similar steps included in the SWH approach components to those outlined in Table 1. In addition, the PSTs constructed pre- and postconcept maps for each experiment. The PSTs were asked to form their own groups at the beginning of the semester. There were eight groups in the lab; seven groups consisted of four PSTs and one group consisted of three PSTs. Students completed 10 experiments. However, the first SWH approach lab activity was completed as an example, so this was not scored. Therefore, nine SWH approach lab activities were graded, taking into consideration the SWH approach's grading rubric.

Data Analysis

Data Analysis for the SWH Approach's Grading Rubric. Every student's lab report was scored each week. Table 4 gives an example of how students' lab reports were analyzed, taking into account rubric categories. At the end of the semester, ANOVA and Bonferroni tests were used to statistically analyze the results gathered from the SWH approach's grading rubric. An assumption test was conducted prior to the

Table 4 Example of rubric category analysis

Rubric item	C	Explanation of category (C)	Example	Point
1. Can the beginning questions potentially be answered by the results of the lab?	0	Questions cannot be answered by doing experimental work or the questions are not related to the lab.	What kind of benefits results from classifying the chemical reactions?	0
	1	One or two inappropriate, trivial or factoid questions	Why are there chemical reactions? What color is my chemical reaction?	1
	2	One directed question that can be answered by doing experimental work	Can we classify chemical reactions?	3
	3	More than one or two questions that demonstrate an understanding of what the lab could be	Can we classify chemical reactions? If so, how can we classify them? How can we understand whether or not a reaction is a chemical reaction?	6
	4	One or two questions that demonstrate an understanding of independent and dependent variables, a generalization or an appropriate application of the lab results	When substances such as AB and CD react with each other, what kind of reaction can occur? How can we classify this reaction? When a substance such as A reacts with B, what kind of reaction can occur? How can we classify this reaction? When a substance such as B reacts with XY, what kind of reaction can occur? How can we classify this reaction?	10

C category

statistical analysis. For this purpose, normality and homogeneity assumptions were taken into account. To examine the normality assumption, the Kolmogorov-Smirnov test and skewness were used. The results showed that the normality assumption was met. To examine the homogeneity assumption, Levene's test of homogeneity of variances was run. The results indicated that the study did not violate the homogeneity assumption (F (8, 270) = 1.059, p = .392).

Data Analysis for Interviews. The interviews were audiotaped and transcribed in full. In the initial stage of analysis, the individual interview transcripts were analyzed line by line and codes were created from the text. For this purpose, in vivo coding, using words or phrases taken directly from the interview data, was used to prevent researcher bias (Saldana, 2013). In the second stage of the analysis, a frequency analysis (Miles, Huberman & Saldana, 2014) was utilized to identify the most popular codes. The codes were categorized in response to the research questions. For this purpose, axial coding, which enables initial categories to be related to subcategories, was used. In the final stage of the analysis, selective coding was used to group categories into core concepts or overall ideas (Strauss & Corbin, 1998). Interrater reliability was tested by asking another researcher to analyze four transcripts and this was found to be 0.86.

Results

Quantitative Results

Results of the First Research Question. The first research question was: "Does the SWH approach contribute to the quality of the argumentative writing produced by the PSTs?" In order to answer this question, the argumentative writing performance of the PSTs for each experiment they conducted was assessed using the SWH approach's assessment form. The mean scores were 39.13, 47.29, 63.55, 66.39, 72.19, 79.19, 74.00, 75.13, and 81.58 for each laboratory experiment, respectively. It was noted that there were differences between the mean scores of the lab activities. In order to determine whether these differences were statistically significant, the ANOVA analysis was conducted. The ANOVA results showed a statistically significant difference among the argumentative writing performances of the PSTs (F = 14.493, p < .01). Since homogeneity of variances was possible, post hoc analyses were conducted. In this context, the Bonferroni test was conducted to confirm whether there were differences between lab activities. As shown in Table 5, the Bonferroni test results showed that there were significant differences between the first activity and the third, fourth, fifth, sixth, seventh, eighth, and ninth activities; between the second activity and the fourth,

Table 5 ANOVA results for grading in the SWH approach

Number of laboratory activities	Number	Mean	SD	F	p	Effect size η^2	Significant difference between lab activities[a]
1	31	39.13	17.7	14.493	<.001		1 − *3*, 1 − *4*, 1 − *5*, 1 − *6*, 1 − *7*, 1 − *8*, 1 − *9*, 2 − *4*, 2 − *5*, 2 − *6*, 2 − *7*, 2 − *8*, 2 − *9*, 3 − *9*
2	31	47.29	21.63				
3	31	63.55	24.62				
4	31	66.39	26.80				
5	31	72.19	20.12			.300	
6	31	79.19	17.91				
7	31	74.00	19.37				
8	31	75.13	19.70				
9	31	81.58	21.96				

[a] Italics indicates programs in which differences mostly appeared in favor

fifth, sixth, seventh, eighth, and ninth activities; and between the third activity and the first and ninth activities. Moreover, the effect size showed that 30.0416% of the variance in the writing scores was due to the implementation of the SWH approach.

As seen in Fig. 1, the mean scores for the PSTs for each item of the SWH approach's grading rubric increased for each experiment. While the mean score related to the first item of the rubric was 4.71 in the first experiment, the mean score significantly increased to 9.55 after the final laboratory experiment. The mean scores in the second, third, fourth, fifth, sixth, seventh, eighth, ninth, and tenth items increased from 4.71, 3.96, 4.09, 4.00, 2.71, 3.39, 4.45, 1.96, and 1.48 to 9.29, 9.09, 8.74, 8.58, 8.65, 9.13, 9.06, 6.19, and 5.35, respectively.

Qualitative Results

Results of the Second Research Question. The second research question was: "What understanding do the PSTs have of the SWH approach and its components of argumentation?" Coding the interview data of 12 PSTs led to the following assertions that corresponded to the research question.

Assertion 1a: Over time, the SWH approach increased the quality of the writing and research skills displayed by the PSTs.

All PSTs in the sample (100%) indicated that the SWH approach had increased the quality of their writing. Seven of the 12 PSTs (58%) stated that the SWH approach had improved their research skills. First, all PSTs were aware that the quality of their writing had developed over time. When they were asked to compare their first and ninth experiments in terms of their writing, they indicated that they had started to write more rationally and more purposefully, while at the beginning of the semester, they were writing randomly without making any connections or offering interpretations from the resources. Some PSTs believed that the quality of their writing had increased due to

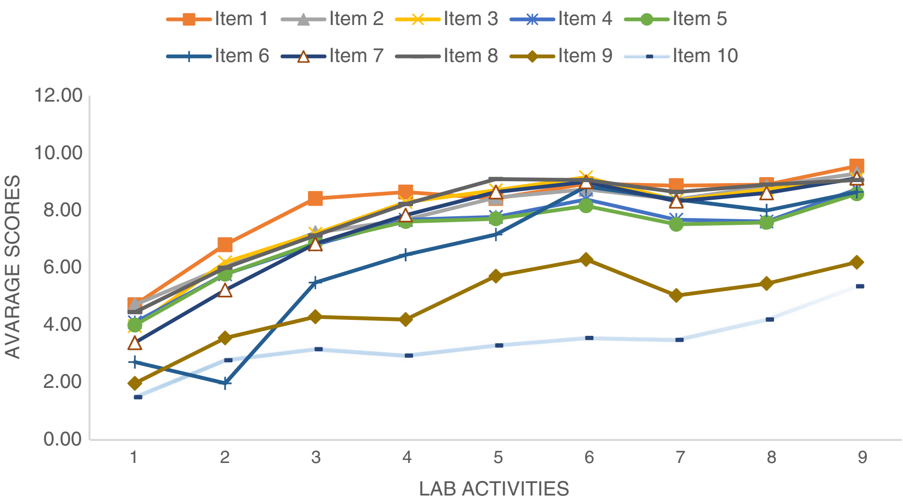

Fig. 1 Mean scores for PSTs for each item of the SWH approach's grading rubric

their adding figures, pictures, and drawings to the text and writing more pages, as well as their ability to offer better reasoning:

> In my opinion, more rational writing skills were developed. For example, in the concept map or while I was searching for three sources of theoretical knowledge, I was not offering any reasoning; I was just searching the sources. Or I was not writing anything on the concept map, I was only able to write a few concepts on the concept map, and I was not able to connect them with each other. But now, I am more able to connect them with each other, I can get more information about them and I can offer better reasoning based on theoretical knowledge. (PST2)

> I do believe that my writing skills have developed a lot. I wrote so many pages and inserted some graphs, drawings and pictures to the text. I think I developed more rational writing skills. (PST1)

Second, students believed that determining their individual beginning questions and procedures before coming to the laboratory and investigating at least three sources to compare with their results developed their research skills. They stated that they watched several videos or investigated written resources on the Internet in order to be able to determine a possible procedure for their lab experiments before they arrived at the lab. Once they completed their investigation in the lab, they indicated that they searched several sources but that they had been selective in terms of the context and reliability of those sources. Some PSTs stated that they felt like scientists when they were determining their beginning questions, making a claim and supporting their claim with evidence, and then searching different sources to combine their experiment results with the written documents:

> As preliminary activities, we watched videos for some experiments and read how they were run before coming to the lab. Therefore, we were able to come up with several ideas while we were determining our own experiment procedure … We had difficulties in finding sources because we were not sure that the information on the websites was accurate. Therefore, we found manuals from other universities or chemistry textbooks, as we believed them to be reliable. We tried to find the same or similar context so that we could associate our experiment with them. (PST4)

> We were determining beginning questions, then making claims and then proving our claims; in other words, we were like scientists. The first semester was not like that … While I was associating the sources with my experiment results, there is a momentary time, that you say, 'Yes, you are doing this in the experiment'. That is, there is a flash in your mind. (PST1)

Assertion 1b: The reading and reflection section appeared to be the most challenging but also the most beneficial component of the SWH approach. For some PSTs, the first two activities were critical in terms of dealing with the SWH approach.

First, when the PSTs were asked whether or not they had any difficulties with the beginning questions, claims, evidence, and reading and reflection components, 6 of the

12 PSTs (50%) noted they had difficulties in reading and reflection. This was reflected in the students' writing lab scores. The PSTs achieved the lowest scores for the reading and reflection component, as seen in Fig. 1 (items 9 and 10). On the other hand, when the PSTs were asked which component of the SWH approach was most beneficial, 7 of the 12 PSTs (58%) stated that the reading and reflection component was the most beneficial part of the SWH approach. These results showed that the reading and reflection component was the most challenging but also the most beneficial component of the SWH approach for most of the PSTs. Moreover, the PSTs indicated that the reading and reflection component was difficult for them because it was difficult to find reliable sources and information from different sources and integrate them with their experiment results. They also believed that this component was more beneficial because it helped them to develop their ideas and understand the topic being investigated:

> I had difficulties in reading and reflection because we were supposed to search at least three sources. It was difficult to integrate the different information that was found in different sources. Therefore, I had difficulties … I believe that reading and reflection enhanced my skills. My ideas changed. If I have one idea at the beginning of lab, after lab I can now put forward more than one idea and I can pose different ideas. (PST5)

Second, three of the PSTs (25%) indicated that they had difficulties in writing their beginning questions, claims, evidence, and reflection components in the first two experiments. This result was consistent with the ANOVA result because it showed that there was a significant difference between students' first, second, and ninth experiments. They also stated that they struggled with the writing and the argument-based inquiry, yet when they became accustomed to the argument-based inquiry, it became more entertaining and enjoyable. Moreover, several students believed that they were going to fail the course at the beginning of the semester. This may show that they had a positive attitude toward lab by the end of the semester:

> I had difficulties while I was writing my claims in the first and second experiments because we were getting used to the approach. We also had difficulties in writing our beginning questions and the reflection component. For example, when I first entered the second term lab, I thought that I was going to fail the course. But as the semester continued, I understood that I had learned a lot. Our claims etc. became more enjoyable. (PST8)

Assertion 1c. PSTs made explicit associations among their beginning questions, observations, data, claims, and evidence.

When the PSTs were asked how they had created their claims and what they had considered while they were writing them, the majority of the PSTs stated (some of the PSTs stated more than one option, such as using beginning questions and data together) that they had considered their beginning questions (8 of the 12 PSTs, 66.6%), data and observations (seven PSTs, 58.3%), and the conclusiveness of their claims (three PSTs, 25%). On the other hand, when the same questions were asked about how PSTs wrote about their evidence, the majority of the PSTs stated that they had considered their claims (seven PSTs, 58.3%), data and observations (six PSTs, 50%), and graph and chemical equations (seven PSTs, 58.3%):

> I was considering my beginning question(s) and my data to see if I could articulate a relationship between variables or make a generalization or find patterns so that I could make my claim. (PST7)

> We were writing our evidence after we completed our lab work. Our evidence included interpretations or explanations of our observations, graphs that we had drawn or chemical equations that we wrote. (PST4)

Assertion 1d. Explanation and interpretation of multiple representations such as graphs and chemical equations played an important role for PSTs in providing evidence to support their claims.

When PSTs were asked about how they wrote their evidence and what they had considered while they were writing their evidence, 7 of the 12 PSTs (58%) stated that they had used explanations and interpretations of graphs, equations, and chemical formulae of the substances that they generated in their data section to support their claims. This result may show that PSTs made a distinction between their evidence and data and observations:

> We were looking at our experiments, graphs, chemical equations or molecular drawings and claims. For instance, in one of the experiments we investigated the solubility of the substances. Our claim was that substances that have similar structures dissolve in solvents that have similar structures. Therefore, we drew the molecular structures of the solutes and solvents and showed their polar or non-polar structures to support my claim … While I was writing my evidence, I considered how I was going to interpret or explain this claim. I was wondering if I was explaining or interpreting the results or if I was just writing like I was recording my observations. (PST6)

Results of the Third Research Question. The third research question was: "How do PSTs assess their own learning?" Coding the interview data of 12 PSTs led to the following assertions that corresponded to the research question.

Assertion 2a: Negotiation helped PSTs learn more effectively.

Eight of the 12 PSTs (67%) stated that group discussions and the negotiation of ideas had helped them learn and better understand the topic being investigated. The PSTs believed that negotiation with their group members helped them learn and realize their mistakes and gave them a chance to remedy those mistakes. Moreover, this helped them to develop their thinking abilities:

> Negotiation helped me to learn. For instance, negotiation remedied the thing that I observed mistakenly or the thing that I wrote mistakenly. In one of the experiments, I came up with opposite ideas; it was an experiment related to reaction rate. I interpreted it differently. And I completed my claims and evidence based on that information. If I had not discussed it with other group members and they

> had not made any corrections, I would have interpreted it incorrectly. Therefore, I changed my reflection component and then I corrected my mistakes in the claim and evidence components. (PST4)

> I think that the discussions we had with group members helped me to learn because everyone comes up with different ideas. We do not know if each idea is correct or not but at least we can discuss those ideas. I think it helps develop our thinking. We can correct each other's mistakes. Therefore, it helped me a lot. (PST5)

Assertion 2b. An argument-based inquiry lab is helpful or beneficial for students' learning and also for their future vocational careers as teachers.

When the 12 PSTs were asked about their preference in terms of studying in the lab, nine (75%) stated that they preferred the second term in which the SWH approach was implemented. Three of the 12 PSTs (25%) indicated that they would choose the first semester because of its ease and convenience and the second semester because of how it helped them to develop their learning. The reason why the PSTs preferred to study in an argument-based inquiry lab is that they believed that studying their own beginning questions, making claims, providing evidence for their claims, and researching written sources (as seen in Assertion 1a, the same reason that increased their research skills) helped them learn more effectively and therefore they believed that the second term was devoted to learning. In the first semester, they followed the step-by-step procedures written in the lab manual; therefore, they believed this was rote learning. However, in the second semester, they were in charge of their learning, as the lecturer was not providing direct information or step-by-step explanations and the students were investigating and combining the information. Moreover, some of the PSTs indicated that argument-based inquiry was not just helpful for their own learning but also helpful for their future vocational careers as teachers:

> When we graduate, we are going to be teachers. When my students ask questions, I would like to answer their questions by conducting experiments. Therefore, I preferred the second term. The lab in the first semester was based on rote learning. We were following the steps shown in the lab manual. When we saw the result, we were done. However, in the second semester, we discussed the beginning questions and our claims and evidence and then we negotiated with our group members. Then we researched three different sources to see if our experiment was compatible with the written information. The second term was more devoted to learning. Therefore, even though I had negative opinions about this approach at the beginning of the semester, I preferred the second term. (PST8)

> There are two things I should consider. One of them is easiness; if we consider easiness I preferred the first term. But if we consider learning, I preferred the second term because I can say that I learned a lot. What we learned is helpful both to chemistry lessons and laboratory lessons. That is why the second term was more rational. If I want to learn something to teach my students, I preferred the second term. (PST5)

Discussion and Implications

This study investigated the effect of the SWH approach on the quality of the students' argumentative writing and understanding of the SWH approach and its components of argumentation. The quantitative results showed that the SWH approach increased the quality of the students' argumentative writing over time (F = 14.493, p < .01). The interview data also supported these results. Moreover, the qualitative results revealed that the PSTs made explicit connections among argument components and made distinctions between evidence and data. Multiple representations played an important role when the PSTs provided evidence to support their claims. The reading and reflection section appeared to be the most challenging but also the most beneficial component of the SWH approach, and the negotiation process helped the PSTs learn more effectively.

The results of the first and second research questions showed that the SWH approach increased the quality of the students' argumentative writing over time. The statistical and interview results showed that while the PSTs had difficulties in distinguishing between their claims and evidence when they started to use this approach, they developed a better understanding over time (Hand et al., 2004; Keys et al., 1999). Moreover, the interview results revealed that the SWH approach enabled the PSTs to make explicit connections among their beginning questions, observations, data, claims, and evidence. When the PSTs stated a claim, they described a pattern, made a generalization, or stated a relationship. They also used multimodel representations such as graphs, chemical equations, pictures, or molecular drawings of substances as evidence to support their claims. When they provided evidence, they used interpretations or explanations of the collected data and multimodel representations. Research has determined that the claim and evidence relationship is the critical component of argumentation (Choi et al., 2010, 2013) and students have difficulties in explaining why the evidence supports the explanation (Sampson & Walker, 2012). Educational research has also reported that students develop their own claims based on their own data analysis (Choi et al., 2010) and claims are not distinct from data but are somehow embodied in them (Sandoval & Millwood, 2005). In this regard, we may argue that the PSTs constructed reasonable written arguments since they were aware that it was critical to provide evidence to support their claims and make interpretations of or offer explanations for the evidence (Choi et al., 2013). We can also argue that the SWH approach's template provided the PSTs with opportunities to develop representational competence, which can be described as a set of skills allowing an individual to reflectively use a variety of representations to think about or communicate information about chemical phenomena, since they interpreted many representations and used them as evidence to support their claims (Kozma & Russell, 1997).

The results of the second and third research questions showed that the PSTs gained a greater outcome of learning when they compared their first and last lab reports. Moreover, studying their own BQs, making claims, providing evidence for their claims, and researching written sources increased their research skills and helped them learn more effectively. Research has shown that the act of writing embedded in the SWH approach supports better understanding of the concepts being investigated (Choi et al., 2013; Kıngır et al., 2013; McDermott & Hand, 2010; Poock et al., 2007; Rudd II et al., 2001, 2007). In this context, the results of these studies are compatible with our study. Writing has the potential to increase conceptual understanding (Wallace, 2007). However, previous studies have indicated that not all writing will lead to learning, such as knowledge-telling writing, since it is a recall process and does not involve the transformation of existing knowledge (Hand, 2007; Bereaiter & Scardamalia, 1987). The reason for writing not leading to learning could be because, in this particular writing process, writers retrieve the information or concept on the basis of their memory organization. In this context, writing does not change the existing knowledge. As a result, learning may not occur (Hand, 2007).

The writing embedded in the SWH approach leads students to construct knowledge. In the interviews, the PSTs indicated that negotiation with group members, reading different sources, and integrating this knowledge through writing helped them to develop their ideas and better understand the topic. These results showed that the PSTs combined their writing and discussion and that this led to a better understanding of the concepts under investigation. Research has shown that students should be provided with opportunities to integrate writing, talking, and reasoning with other forms of action, such as making observations and measurements (Lemke, 1990). The SWH approach is an argument-based inquiry approach that enables negotiation and negotiation is considered a particular form of argumentation that enables students to develop understanding (Chen, Hand & McDowell, 2013; Schoerning et al., 2015). With the SWH approach, the PSTs were more engaged in scientific discussions with their peers, which is rare in traditional science classrooms (Schoerning et al., 2015). In this context, when the PSTs combined talking and writing, this had a positive effect on their learning. Research that has investigated elementary school students' conceptual development using the SWH approach for writing-to-learn activities has shown that when students use talking and writing in sequence or simultaneously, they become more involved in higher cognitive functions, such as reflecting, defending, integrating, and multiple-model representing, than when they use talking or writing alone (Chen, Park & Hand 2016b). These results also support our interview results, in which the PSTs noted that they believed that they carried out more interpretation and integration of the knowledge and inserted more multimodel representations, such as figures, pictures, and drawings, in their writing (Hand, McDermott & Prain 2016). This result may also show that the PSTs used higher and more complex cognitive functions when using this approach.

The interview results also revealed that the PSTs found the reading and reflection section to be the most beneficial in terms of learning the topic yet the most challenging in terms of finding reliable sources and integrating their experiment results with the written sources. This may be because this component of the SWH approach gave the PSTs the opportunity to reconstruct their knowledge and metacognitive awareness (Hand et al., 2004; Burke et al., 2006; Gupta et al., 2015). Moreover, the PSTs indicated that, after negotiation or trying to integrate their claims and evidence with the other scientists, they changed their ideas and group members helped them to realize their mistakes. This may be due to the fact that, as the PSTs developed scientific knowledge, they were engaged in constructing and critiquing their claims and evidence. While they constructed their new knowledge claims, they critiqued their previous knowledge. In this context, when one PST wants to construct scientific knowledge and presents his or her arguments, another group member can critique and evaluate the weaknesses in those arguments. At this point, the PST who wants to construct scientific knowledge returns to their original arguments and tries to improve or strengthen them (Chen, Park & Hand, 2016b; Ford, 2008). In this procedure, the PSTs may learn how to critique their own knowledge claims, as scientists do, and this may lead them to develop their claims and evidence. This may also provide evidence that the generation of knowledge through argumentative reasoning based on public debates and critiques of claims and evidence is an important way in which PSTs can express power in the SWH approach classroom (Schoerning et al., 2015).

The results of this study have highlighted the importance of the use of argument-based inquiry for PSTs in the general chemistry lab course. The PSTs indicated that this approach became more enjoyable and they noted that they believed it was beneficial for their future careers, as well as their learning. As the PSTs indicated, it was also important that this learning environment developed their research skills so that they can understand how scientists work and use advanced knowledge. Since teachers tend to teach the way they were taught, it is important to provide PSTs a learning environment in which they can understand how students learn by taking ownership and constructing and critiquing their written and oral arguments. In traditional classrooms, a student voice generally has a limited role and dialogue interchange is teacher-directed (Shoerning et al., 2015). Research has shown that students whose teachers utilize argument-based inquiry have greater access and power in the classroom (Shoerning et al., 2015). In this context, it is expected that the PSTs who have this experience can provide their students with similar learning environments. Therefore, this study conducted with PSTs may contribute to teacher education programs and the epistemic orientations of PSTs, which can be referred to as a set of beliefs that are developed and used by teachers (Suh, 2016). As a result of this study, we suggest that PSTs should be engaged in argument-based inquiry practices as learners, that they should be encouraged to make connections among their claims evidence and data, that they should be encouraged to use multimodel representations, and that they should interpret and explain their representations so that they can develop representational competence and scientific argumentation.

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Appendix

Interview Questions

1. Are there any differences between first and second semester chemistry laboratory? If so, what is it?
2. What do you think about the SWH approach?
3. Did you have any difficulties while completing any section of the SWH approach?
4. Did determining your own beginning question (s) help you? Why?
5. How did you create your claim? What were you considering when you wrote it?
6. How did you create your evidence? What were you considering when you wrote it?

7. How did you complete reading and reflection sections? Did these sections help you learn?
8. Compare your chemistry lab-I and II courses, which semester would you prefer? Why?
9. Do you think that your writing skills improved between the first and ninth report? Why?
10. Do you think that SWH approach is beneficial? If so, which part is most beneficial for you?

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