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This study investigated the influence of metacognitive guidance on pre-service science teachers' scientific knowledge, science process skills, and views about the nature of science. The sample included 48 pre-service science teachers taking a first-year chemistry laboratory course in a public university in Turkey. During the 11-week course, the students conducted 11 experiments. Four scales were administered to a control group and an experimental group as pre- and post-tests. Differently from control group, experimental group discussed the experimental design and completed a reflection form before and after each experiment. Moreover, experimental group answered questions about daily life implications. Results indicate that the inclusion of metacognitive guidance helped the students in the experimental group to improve their process skills and conceptual understanding.

Keywords: metacognitive awareness, learning outcomes, preservice science teachers

INTRODUCTION

The focus of the study is creating metacognitive awareness in a laboratory course. Specifically, it aims to examine the impact of creating metacognitive awareness during a lab course on pre-service science teachers' scientific knowledge, science process skills, and views about the nature of science (NOS). In order to create metacognitive awareness, the study makes use of metacognitivie prompts including questions, discussions, and reflections during the lab classes. In the study, "scientific knowledge" refers to science content knowledge including procedural, declarative, and conceptual knowledge. "Science process skills" refers to observation, experimentation, data collection, and interpretation. "NOS" refers to epistemological commitments underlying these processes (Abd-El-Khalick, Bell, & Lederman, 1998).

Laboratory work has been considered indispensable to learning in science (Hofstein & Lunetta, 1982). Freedman (2001) found that students who had regular laboratory instruction acquired significantly more scientific knowledge than students who had no laboratory instruction. According to Tobin (1990), "Laboratory activities appeal as a way of allowing students to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science" (p. 405). It has been assumed that laboratory work helps students improve their analytical and critical skills as well as their creativity and enhances their interest in science through inquiry (Ottander & Grelsson, 2006). It seems that practical experience in the laboratory also helps students understand the nature of science (Ottander & Grelsson, 2006). In addition, the literature also suggests that (e.g., Mamlok-Naaman & Barnea, 2012) inquiry-based laboratory activities have a potential for students in fostering meaningful learning,

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State of the literature

- Increasing laboratory course hours and decreasing lectures hours are suggested in the literature for effective science teaching.
- Traditional "cookbook" laboratory practice (only hands-on) has been criticized because students verify the facts and concepts rather than being mentally engaged (also minds-on) in the learning process.
- For a deeper cognitive engagement in the learning process, laboratory instruction should engage students in the process of inquiry, identifying problems, designing investigations, and doing quantitative measurements; and provide them with opportunities for social interaction and reflection.

Contribution of this paper to the literature

- This study empirically examines whether metacognitive guidance during a laboratory work can develop pre-service science teachers' scientific knowledge, science process skills, and contemporary understandings of the nature of science (NOS).
- The results of the study showed that, in the experimental group, the inclusion of metacognitive guidance helped the participants improve their process skills and conceptual understandings.

conceptual understanding, and understanding of the nature of science.

Hone (1971) advocated the necessity of reducing the lecture courses. According to Hone (1971), "… teacher preparation in science must spring from direct involvement in the kind of science activities that can be used in the elementary classroom." (p.321). However, not all educators agree that laboratory work is an effective component of science teaching (Hofstein & Lunetta, 2004). "Cookbook" laboratory exercises have been criticized for focusing on procedures and information verification rather than cognitive engagement in learning (Hart, Mulhall, Berry, & Gunstone, 2000). This common form of laboratory experience may not contribute significantly to major aims of science education, such as improving science process skills. To be more effective, laboratory instruction should engage students in the process of inquiry, identifying problems, designing investigations, and doing quantitative measurements rather than following a "recipe" provided by the teacher (Shimizu, 1997). Additionally, providing students with opportunities for interaction and reflection can lead to more meaningful learning. Developing metacognitive skills could be an essential component of effective lab work (Baird, 1990). According to Sherman, et al. (1987), metacognitive abilities facilitate more sophisticated mental actions and cognitive development. Briefly, the literature suggests that learning is an active and dynamic process through which learners personally define learning tasks and apply their learning abilities for performing these tasks (Sherman, 1985) and in order for effective learning to occur, students should be exposed to metacognitive experiences.

In this study, we empirically examine if metacognitive guidance during a laboratory work facilitate acquisition of scientific knowledge, science process skills, and contemporary understanding of nature of science (NOS). The study uses a experimental design in which the experimental group is exposed to mecognitive prompts including questions, discussions, and reflections during the lab work. The influence of creating metacognitive awareness in the experimental group is discussed with a comparison to the control group.

METHOD

Sample

Forty-eight pre-service science teachers were the subjects of this study. They were in a first-year chemistry laboratory course at a public university in 2007-2008. This sample was divided randomly into two instructional treatment classes, one of which became the control group (n=26) and the other the experimental group (n=22).

Instruments

Five scales, namely the Motivated Strategies for Learning Questionnaire (MSLQ), the Test of Integrated Processes (TIPS), the Conceptual Knowledge Test (CKT), the VNOS-C, and an Achievement Test of knowledge of chemistry (AT) and were administered to the control group and the experimental group before and after the treatment.

Table 1. The research design

Group	Pre-test	Implementation	Post-test
Control group	VNOS, TIPS, AT, CKT	11 experiments, reports	VNOS, TIPS, AT, CKT
Experimental group	VNOS, TIPS, AT, CKT	11 experiments, reports, reflection forms, pre- and post-discussions	VNOS, TIPS, AT, CKT

The *Motivated Strategies for Learning Questionnaire (MSLQ),* developed by Pintrich, Smith, Garcia & Mc Keachie (1991), assesses college students' motivational beliefs and their use of learning strategies in a college course. It is an 81-item self-reporting instrument, consisting of a motivation section and a learning strategies section. The learning strategies section is based on a general cognitive model of learning (Weinstein & Meyer, 1986). This section has three general types of scales: cognitive, metacognitive, and resource management. The items of the MSLQ are scored on a 7-point Likert scale, from 1 (not very much like me) to 7 (very true of me). The metacognitive section was used in the present study. The test was adapted into Turkish by Altun (2005). The Cronbach alpha reliability coefficient of metacognitive learning strategies was 0.85 (Altun, 2005; Altun & Erden, 2006).

The *Test of Integrated Processes (TIPS)* was developed by Burns, Okey, & Wise (1985) and adapted into Turkish by Özkan, Geban, & Aşkar (1990). The Cronbach alpha reliability coefficient of the Turkish version of this instrument was 0.85. The TIPS is a 36 multiple-choice item instrument which measures five science processes: identifying variables; identifying and stating hypotheses; operationally defining and designing investigations; and graphing and interpreting data.

The *Conceptual Knowledge Test (CKT)* consists of 11 questions intended to measure conceptual understanding of topics closely related to the experiments (Saribas, 2009). Specifically, the topics were reaction rate, chemical equilibrium, salts, and chemical phenomena at the particulate level. Each item in the test consists of a multiple-choice tier and a follow-up tier that asks for an explanation of the response given in the first tier. The items were scored as 2 if the responses to both tiers were correct, 1 if only the response to the multiple-choice tier was correct, and 0 if the response to the multiple-choice tier was incorrect. Two experts in chemistry education examined the items in the test and testified to their validity.

The VNOS-C is a qualitative instrument with 10 open-ended items. It is intended to assess views with regard to tentative, empirical, inferential, creative, and theory-laden nature of science (NOS); the functions of and relationships among theories and laws; the social and cultural embeddedness of science; and the existence of a common scientific method. The psychometric properties of the English version of VNOS-C was established by Abd-El Khalick (1998) and found to be reliable and valid. Turgut (2005) adapted the test into Turkish.

The *Achievement Test (AT),* consisting of 30 multiple-choice items, was used to measure the pre-service teachers' procedural and declarative knowledge of the chemistry content of the experiments, including reaction rate, chemical equilibrium, precipitation reactions, acid-base equilibria, and buffer solutions. The test was developed by Saribas (2009) in order to evaluate students' retention of information and understanding of concepts in terms of declarative knowledge as well as problem-solving applications of concepts in a procedural context. The test has a total possible score of 30, one point for each item. The AT had a Cronbach alpha reliability coefficient of .72.

Procedure

The study presented here was conducted on a sample population of 48 freshmen in a chemistry laboratory course given by the Science Education Department of a public university. The sample was divided randomly into two groups. One became the control group (n=26) and the other the experimental group (n=22). Participants in both groups performed the same 11 experiments during the eleven-week course about the topics of reaction rate, chemical equilibrium, solubility and precipitation, and acids and bases. They worked in groups of 3 or 4.

All of the students were administered all the instruments used in this study as pre- and post-tests (Table 1). Both experimental and control groups were exposed to 11 experiments each of which were conducted in a week. The students in each group were asked to write a report of each experiment. However, the students in experimental group filled reflection forms and discussed the design of the experiment during the course while the students in control group conducted the experiments following the procedures written in lab manual without any reflection and discussion.

Lessons provided for the control group employed the traditional, or information verification method. Those for the experimental group included metacognitive questioning throughout the instructional process. The control group followed the instructions in the laboratory manual. The experimental group discussed the experimental design before and after each experiment, thereby promoting metacognitive awareness of the process. Moreover, each student in the experimental group was asked to complete four types of reflection form during the course. Form one, completed by students at the beginning of the course, and form four, completed at the end, elicited their expectations and beliefs about the course. Form two, completed before each experiment, and form three, completed after each experiment, elicited their ideas about the experiments and related scientific topics.

Table 2. Post-test scores

	Group	N	Mean	SD	df	t	p
Metacognitive learning strategies	Control	26	57.19	10.95	48	2.25	0.030*
	Experimental	22	63.95	9.70			
TIPS	Control	26	23.88	4.61	48	2.63	0.011*
	Experimental	22	26.86	2.85			
CKT	Control	26	9.84	4.11	48	2.08	0.043*
	Experimental	22	12.13	3.38			
AT	Control	26	17.08	4.30	48	0.07	0.948
	Experimental	22	17.00	3.79			

Table 3. The frequencies of misconceptions

	Pre (%)			Post (%)		
Misconception	**Control N=26**	**Exp. N=22**	**Total N=48**	**Control N=26**	**Exp. N=22**	**Total N=48**
Science is procedural more than creative	2 (7.7)	0 (0)	2 (4.2)	1 (3.9)	0 (0)	1 (3.9)
No place for social and cultural influence in science	20 (76.9)	15 (68.2)	35 (72.9)	18 (69.2)	16 (72.7)	34 (70.8)
Hypotheses become theories, which in turn become laws	8 (30,8)	7 (31.8)	15 (31.3)	13 (50.0)	11 (50.0)	24 (50.0)
Experiments are the only route to science	25 (96.2)	17 (77.3)	42 (87.5)	25 (96.2)	18 (81.8)	43 (89.6)

Both groups wrote and submitted a report and answers to questions about each experiment. While preparing their reports, students in control group answered the questions in their lab manual. The experimental group, in addition to answering the questions in the lab manual, was required to analyze and explain the daily life implications of the experiments and related topics.

RESULTS

The results of the pre-tests indicated that there was no significant difference between the control group and the experimental group in terms of metacognitive learning strategies ($t=0.25$; $p>0.05$), science process skills ($t=1.59$; $p>0.05$), conceptual knowledge ($t=1.07$; $p>0.05$), and declarative and procedural knowledge ($t=0.34$; $p>0.05$). On the other hand, the experimental group outperformed the control group in the post-tests of metacognitive learning strategies of MSLQ, TIPS and CKT. There was no significant difference between the procedural and declarative knowledge of each group after treatment. The post-test scores of each group are presented in Table 2.

The paired sample t-test results reveal significant differences between pre- and post-test results for the control group ($t=6.29$; $p<0.05$) and the experimental group ($t=5.60$; $p<0.05$) in terms of their declarative and procedural knowledge. Although the students' procedural and declarative knowledge changed positively with the course, there was no significant difference between the control group and the experimental group in the post-test results of AT ($t=0.07$; $p>0.05$).

The analysis of VNOS-C indicates that the pre-service science teachers' NOS views in both groups were not consistent with the contemporary understanding of science ex-ante and ex-post. That is to say, common misconceptions discussed by McComas (1996) were found in the present study, such as "Hypotheses become theories which become laws," "There is no cultural influence in science (science is universal)," "Science is procedural more than creative," and "Experiment is the only route in science." Moreover, treatment in neither group led to an improvement in NOS views. The frequencies of misconceptions held by the pre-service teachers are given in Table 3.

DISCUSSION AND CONCLUSION

The results of the study are consistent with expectations based on the literature about a laboratory courses.

The findings of the study show no significant difference before treatment between the control group and the experimental group in terms of their metacognitive skills, science process skills, conceptual knowledge, and procedural and declarative knowledge. After the treatment, students in the experimental group seemed to be able to use more metacognitive learning strategies as compared to students in the control group. This finding suggests that metacognitive prompts throughout the semester contributed to the development of metacognitive skills.

There was no significant difference between the control group and the experimental group in the post-test results of AT; students in each group improved their declarative and procedural knowledge throughout the course. This result is consistent with the literature that says that that laboratory instruction contributes to the acquisition of scientific knowledge (Hofstein & Lunetta, 1982; Trowbridge & Bybee, 1990; Jegede & Taylor, 1995).

Students in the experimental group after the treatment seemed to have a better conceptual understanding as compared to their peers in the control group after the treatment. So, inclusion of metacognitive prompts in laboratory instruction could lead to better conceptual understanding than understanding gleaned from a traditional laboratory course. This result supports the findings of Mason (1994), who showed a positive correlation between cognitive and metacognitive skills and conceptual change.

After treatment, the science process skills of students in the experimental group seemed to be developed more as compared to those in the control group. This finding supports the view that science process skills can be improved by such experiences as identifying and defining variables and designing investigations (Mattheis & Nakayama, 1988). Science process skills are fundamental components of teaching and learning science. According to Ango (2002) teachers should use effective strategies and practices to enable their students learn these skills. Metacognitive guidance seems to form such a strategy. The findings of this study support earlier findings that show the positive effects of metacognitive guidance on learning outcomes (Zion, Michalsky, & Mevarech, 2005).

Enhancing pre-service science teachers' science process skills may be regarded as s significant gain for their cognitive development. As Ozgelen (2012, p.291) stated, "[D]eveloping science process skills supports students' reasoning, inquiry, evaluation, and problem solving skills, as well as their creativity."

Concerning the influence of the course on NOS views, results from VNOS-C show that the course did not result in improved NOS views. In other words, the pre-service science teachers retained typical misconceptions about NOS after treatment (McComas, 1996). This finding is consistent with the literature that emphasizes the need for an explicit approach to the development of NOS views rather than the implicit approach of targeting NOS views through inquiry (Akerson, Abd-El-Khalick, and Lederman, 2000)

In conclusion, the use of metacognitive prompts resulted in a better understanding of scientific concepts and science process skills. In this respect, the present study supports the earlier findings that show the positive effects of metacognitive guidance on learning outcomes (Tien, 1998; Zion, Michalsky, & Mevarech, 2005). However, the treatment did not create any difference between the control group and the experimental group in terms of their NOS views or their declarative and procedural knowledge. What the study shows most clearly is that metacognitive awareness in laboratory lessons improves students' process skills and their understanding of scientific concepts.

Although the results of this study showed positive effects of metacognitive guidance on pre-service science teachers' science process skills, one of our major concerns should be the issue whether pre-service science teachers have competence to teach them. Science teachers should not only be able to use these skills, but also should have experience and competence to develop students' science process skills, especially integrated process skills. Inquiry-based instruction may be efficient in this respect. Research studies showed the positive effect of inquiry-based laboratory instruction (Mattheis & Nakayama, 1988; Roth & Roychoudhury, 1993; Basaga, Geban, & Tekkaya, 1994) on students' science process skills. Furner & Kumar (2007) advocate that teachers should be able to incorporate more problem solving/inquiry approaches to their teaching.

Hofstein & Lunetta (1982; 2004) focused on the development of cognitive and metacognitive skills in inquiry-type laboratories for an effective science instruction. More recently, Mamlok-Naaman & Barnea (2012) highlighted the complexity of using inquiry approaches in science classrooms by comparing to the traditional approaches, and thus the need for teachers to have different kinds of skills, high level of expertise, familiarity, and comfort in teaching it. Saad & BouJaoude (2012) also suggested further research that investigates the relationship between teachers' beliefs and attitudes about inquiry and their classroom practices is needed. Therefore, further investigation is required to develop pre-service science teachers' capability to design inquiry-based lab lessons, to improve teachers' attitude toward inquiry teaching, and to review the interactions between metacognition and inquiry practices in science education.

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