International Journal of Human Sciences
ISSN:1303-5134

Volume: 6 Issue: 1 Year: 2009

The efficiency of metacognitive development embedded within a motivating lab regarding pre-service science teachers' learning outcome[*]

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Abstract

The aim of this study was to improve pre-service science teachers' science process skills and attitude towards chemistry by developing their metacognitive skills embedded within a motivating chemistry laboratory. The sample of the study was 54 pre-service science teachers who took the first year chemistry lab course at Marmara University. Both the control (n=27) and the experimental group (n=27) carried out 11 experiments, each of which was performed over a lab course. The students comprising the control group performed the experiments following the instructions described in the laboratory manual. However, in the experimental group, pre- and post-discussions about the design of the experiments were held in order to create metacognitive awareness of the experimental design. The students in the experimental group were supported and encouraged during the course and were given four semi-structured reflective interview forms developed by the authors. As opposed to the control group, the students in the experimental group were asked to inquire of the researcher what subjects they should study. While the students in the control group were provided no feedback on their reports, the students in the experimental group were consistently provided positive feedback. The findings showed that the experimental group outperformed the control group in the Science Process Skill Test, particularly in the categories of identifying variables and operationally defining. The first and the last interview forms, which were given at the beginning and the end of the semester, were used for a deeper analysis of the students' metacognitive skills, motivation and attitude towards the course. The second and the third reflective forms were used to create metacognitive awareness in students. Although the students reflected very positive feedback on the last interview form, the results of the t-test analysis showed that no significant gain was achieved either in the control or experimental group in terms of their attitudes towards chemistry. The results of the analyses seem to be in favor of the experimental group in terms of the development of science process skills, motivational beliefs and metacognitive learning strategies.

Keywords: metacognitive development; science process skills; motivation; attitude towards chemistry.

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Saribas, D., Bayram, H. (2010). The efficiency of metacognitive development embedded within a motivating lab regarding pre-service science teachers' learning outcomes. *International Journal of Human Sciences* [Online]. 7:1. Available: http://www.insanbilimleri.com/en

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Motive edici laboratuvar ortamında bilişüstü gelişimin fen öğretmen adaylarının öğrenme sonuçları açısından verimliliği

Özet

Bu çalışmanın amacı, motive edici laboratuar ortamında fen öğretmen adaylarının bilişüstü becerilerini geliştirme yoluyla, bilimsel işlem becerileri ve kimyaya karşı tutumlarını arttırmaktır. Çalışmanın örneklemini Marmara Üniversitesi'nde birinci sınıf kimya laboratuar dersini alan 54 öğretmen adayı oluşturmuştur. Hem kontrol (n=27), hem de deney grubu (n=27), her bir deney bir derste gerçekleştirilecek şekilde 11 deney yapmıştır. Kontrol grubundaki öğrenciler deneyleri, deney föylerindeki yönergeleri izleyerek gerçekleştirmişlerdir. Deney grubunda ise, bilişüstü farkındalık yaratmak amacıyla, deneyin tasarımıyla ilgili deney öncesi ve sonrası tartışmalar gerçekleştirilmiştir. Deney grubundaki öğrenciler her derste desteklenmiş ve cesaretlendirilmiş; ayrıca araştırmacılar tarafından geliştirilmiş olan yarı-yapılandırılmış yansıtıcı formları doldurmuşlardır. Kontrol grubunun aksine, deney grubundaki öğrenciler araştırmacının onlardan çalışmalarını istediği konuları araştırmışlardır. Kontrol grubundaki öğrencilere herhangi bir geri-bildirim verilmezken, deney grubundaki öğrenciler sürekli olarak olumlu geri-bildirim almışlardır. Çalışmanın bulguları, deney grubundaki öğrencilerin Bilimsel İşlem Becerileri Testinde, özellikle değişkenleri belirleme ve işlemsel açıklamalar getirebilme kategorilerinde kontrol grubuna kıyasla anlamlı olarak daha başarılı olduğunu göstermiştir. Dönem başında ve sonunda verilen ilk ve son görüşme formları, öğrencilerin bilişüstü farkındalıkları, motivasyonu ve derse karşı tutumlarını daha ayrıntılı olarak analiz etmek amacıyla analiz edilmiştir. İkinci ve üçüncü yansıtıcı formlar, öğrencilerde bilişüstü farkındalık yaratmak amacıyla kullanılmıştır. Öğrenciler son görüşme formuna çok olumlu geri-bildirim vermiş olmalarına rağmen, t-testi analizleri, gerek kontrol, gerekse deney grubundaki öğrencilerin kimyaya karşı tutumunda herhangi bir gelişme olmadığını göstermiştir. Analiz sonuçları, bilimsel işlem becerileri, motivasyonel inançlar ve bilişüstü öğrenme stratejileri açısından deney grubunun lehine görünmektedir.

Anahtar Kelimeler: bilişüstü gelişim; bilimsel işlem becerileri; motivasyon; kimyaya karşı tutum

1. Introduction

Laboratory instruction has long played a significant role in science education. The benefits that students realize from engaging in scientific laboratory activities are well established in relevant literature (Tobin, 1990; Garnett, Garnett & Hacking, 1995; Hodson, 1996; Hofstein & Lunetta, 1982; 2004; Freedman, 1997). Despite the benefits of laboratory work, students rarely focus on the purpose of the scientific experiments in which they are engaged. In other words, students generally try to determine only the expected results from the experiments they conduct, but do not mentally engage sufficiently to see the connection between laboratory work and other learning experiences (Hart, Mulhall, Berry & Gunstone, 2000). Laboratory instruction should give students a wider range of learning experiences than simply verifying textbook claims (Tsai, 2003).

In recent years, the main focus in science classrooms has been on mastering science skills and conducting science as it is practiced in real laboratory situations by scientists (Shuh, 2002). In contrast to traditional science instruction, which emphasized the use of lectures to efficiently present scientific information and encouraged students, to memorize facts from textbooks, today's scientific instruction emphasizes problem-solving and inquiry-based laboratory activities. It rejects the view of science as the sum of information that must be memorized (Stuart & Henry, 2002). Although the development of lab skills may be a useful component of scientific learning, it is not sufficient, on its own, to develop student science process skills. Students may follow the step-by-step procedure of the laboratory manual without really understanding the scientific process. In order to make laboratory activities more effective, other aspects of science process skills, such as identifying problems, developing experimental designs and applying quantitative measures need to be developed by students (Shimizu, 1997).

A considerable amount of literature has stressed science teachers' poor attitude towards science and their low confidence and self-efficacy beliefs in teaching science (Talsma, 1996; Mulholland & Wallace, 1999; Appleton, 2002; Garcia, 2004; Taylor & Corrigan, 2005). Literature also shows that negative feelings towards science affect teaching self-efficacy negatively (Tarık, 2000). If teachers feel that they can teach science and have the skills to perform experiments effectively, science instruction will benefit from teachers who can develop creative curricula based on ideas and strategies using an inquiry-based process. University-level teacher training programs need to reflect more of what the teachers will need in the classroom and process skills need to be emphasized more in the classroom. Lessons should also involve inquiry learning and promote social interaction (Garcia, 2004).

Motivation and interest are also significant components for effective learning in science (Taylor & Corrigan, 2005). It is the student who decides to engage in learning or not (Pintrich, 2000). Fishbein's expectancy-value theory suggests that an individual's attitude toward any object is a function of his beliefs about the object. In Fishbein's model, beliefs affect attitudes and these attitudes then affect intentions and behaviors (Weinburgh & Englehard, 1994). Weinburgh & Englehard's study examined students' attitudes towards biology laboratory experiences and found that students who had positive beliefs about the usefulness of laboratory experiences tended to report positive attitudes toward working in the laboratory. This result supported Fishbein's expectancy-value model. However, Weinburgh and Englehard (1994) pointed out the necessity of additional research that focused on student attitudes toward science in general and also within specific disciplines.

From the self-regulated learning perspective, metacognition should also be taken into consideration. In recent years, metacognition has been regarded as an important factor in learning in science. Much research focused on science teaching has found that metacognitive processes promote meaningful learning, or learning with understanding (e.g., Baird, 1986; Gourgey, 1998; White & Mitchell, 1994; Rickey & Stacey, 2000; Thomas & McRobbie, 2001; Davidowitz & Rollnick, 2003). Most of this research suggests that one of the main characteristics of meaningful learning is the students' ability to *control* a problem-solving process and their performance on assignments. The research further links this *control* to the students' *awareness* of their physical actions during the performance of a certain task (Kipnis & Hofstein, 2008).

In the 21st century, in a continuously changing world, it is impossible for individuals to acquire all existing knowledge and it is also difficult to predict which knowledge will be essential for the future (Georghiades, 2004). The development of metacognitive abilities that will enable students to study desirable knowledge in the future becomes essential (Kipnis & Hofstein, 2008). Attaining essential information requires the learner to be aware of and have control over his/her knowledge and of the options to expand it. This means that the student must utilize and develop metacognitive skills (Kipnis & Hofstein, 2008).

1.1. Self-Regulated Learning

Self-regulated learning is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate and control their cognition, motivation and behavior, guided and constrained by their goals and the contextual features in the environment. Self-regulated learners are viewed as active, constructive participants in the learning process. It is generally assumed that learners can potentially monitor, control and regulate certain aspects of their own cognition, motivation and behavior as well as some features of their environments (Pintrich, 2000). According to Zimmerman's definition (1986), students are self-regulated to the degree that they are metacognitively, motivationally and behaviorally active participants in their own learning process. Of the three subprocesses of self-regulation, the components of metacognition and motivation are the concern of this study.

1.1.1. Metacognition

Metacognition includes skills that enable learners to understand and monitor their cognitive processes (Schraw, Crippen & Hartley, 2006). According to Schraw's model (1998), there are two main subcomponents in metacognition:

1. *Knowledge of cognition* refers to what individuals know about their own cognition or about cognition in general. It includes three different kinds of metacognitive awareness: declarative, procedural and conditional knowledge.
    - *Declarative knowledge* includes knowledge about oneself as a learner and about factors that influence one's performance (knowing 'about' things).
    - *Procedural knowledge* refers to knowledge about doing things. Much of this knowledge is represented as heuristics and strategies (knowing 'how' to do things).
    - *Conditional knowledge* refers to knowing when and why to use declarative and procedural knowledge (knowing the 'why' and 'when' aspects of cognition).
2. *Regulation of cognition* refers to a set of activities that help students control their learning. Although a number of regulatory skills have been described in the literature, three essential skills are included in all accounts: planning, monitoring and evaluation.

- *Planning* involves the selection of appropriate strategies and the allocation of resources that affect performance. Planning includes goal setting, activating relevant background knowledge and budgeting time.
- *Monitoring* includes the self-testing skills necessary to control learning. It refers one's on-line awareness of comprehension and task performance.
- *Evaluation* refers to appraising the products and efficiency of one's learning. Re-evaluating one's goals, revising predictions and consolidating intellectual gains.

In terms of laboratory activity, knowledge of cognition should be reflected during the discussion of the observations by asking appropriate questions and operating a suitable inquiry stage. Regulation of cognition should be expressed during the planning of the experiment, while performing it and evaluating the results regarding the assumption (Kipnis & Hofstein, 2008).

1.1.2. Motivation

Although there are many motivational theories that include some type of expectancy and value constructs, this study focused on one model that has generated the most theory and research on academic achievement in classroom settings. The model comes from the work of Eccles and Wigfield and their colleagues (e.g., Eccles, 1983; Eccles, at al., 1989; Wigfield, 1994; Wigfield & Eccles, 1992, 2000). This social cognitive model focuses on the role of students' expectations for academic success and their perceived value of academic tasks. This model arose from a general perspective based on personality, social and developmental psychology (Pintrich & Schunk, 2002).

In this social cognitive expectancy-value model, achievement behavior is predicted by two general components: expectancy and value. The value construct refers to a student's response to a question, "Why should I do this task?" (Eccles, 1983). Responses would include interest (I'm interested in this topic), importance or utility beliefs (This topic is important or useful to me for my future career) and costs (If I take this difficult course, I will not be able to play sports) (Pintrich & Schunk, 2002).

In contrast, the expectancy constructs refers to the question "Am I able to do this task?" (Eccles, 1983; Wigfield & Eccles, 1992; Wigfield, 1994). Expectancy refers to actual beliefs that students have about their future expectations of success; that is, whether they believe that they will perform a task well (Pintrich & Schunk, 2002).

In Bandura's (1977) theory, motivation is activated and maintained by expectations concerning the predicted outcomes of actions and self-efficacy for performing those actions. Bandura (1977) defines outcome expectancy as a person's opinion that a given behavior will lead to certain outcomes and efficacy expectation as the judgment that one can successfully execute the behavior required to produce the outcomes. From a motivational perspective, outcome expectations are important because students think about potential outcomes of various actions and act in ways they believe will achieve the outcomes they value. Academically motivated students believe if they study persistently, they will make good grades (Pintrich & Schunk, 2002). Outcome and efficacy expectations are differentiated because individuals may believe that particular actions will produce certain outcomes, but question whether they can perform those actions (Bandura, 1977).

1.1.2.1. Expectancy: Control and Self-Efficacy Beliefs

Expectancy refers to students' perceptions of the probability of their success in an academic task (Keller, 1983). Internal control beliefs refer to students' perceptions that academic outcomes are dependent on their own actions, for example, increased effort or effective study techniques, rather than on external factors beyond their control, for example, task difficulty or a teacher's prejudice (Lefcourt, 1982).

Self-efficacy refers to people's judgments of their capabilities to organize and execute actions required to attain types of performances (Bandura, 1986, p. 391). Self-efficacy affects an individual's choice of activities, effort and persistence. People with low self-efficacy for accomplishing a task may avoid it; those who believe they are capable of accomplishing the task are likely to participate. Especially when they encounter difficulties, efficacious students work harder and longer than those with doubts. People acquire information to estimate the value of self-efficacy from their actual performances, vicarious (observational) experiences, forms of persuasion and psychological symptoms (Pintrich & Schunk, 2002).

Although efficacy beliefs and outcome expectations are usually related, it is possible for a student to have relatively high self-efficacy for a task but a negative outcome expectation. However, an individual's behavior largely determines the actual outcome, and in the same way, beliefs about outcome expectations are dependent on self-efficacy judgments. Teachers who are not confident about their capability to foster student learning may have negative impressions about their classrooms; those with greater confidence are likely to think of their students as motivated to learn (Pintrich & Schunk, 2002).

Self-efficacy has been shown to be an important mediator of all types of achievement behavior as well as many other types of behavior. Self-efficacy is similar to task-specific self-concept and self-perceptions of competence because each represents individuals' judgments of their capabilities. At the same time, self-efficacy is more situation specific than are the other expectancy constructs. This assumption has led researchers to measure self-efficacy under particular circumstances and at a microanalytic level. Related to this situational specificity, self-efficacy beliefs are assumed to be more dynamic, fluctuating and challengeable than the more static and stable self-concept and self-competence beliefs. One's self-efficacy for a specific task on a given day might vary due to the individual's preparation, physical condition (sickness, tiredness) and affective mood, as well as external conditions such as the nature of the task (length, difficulty) and social environment (general classroom conditions). In contrast, other views of self-competence view it more globally (e.g., math competence) and are less concerned with microlevel instability of beliefs (Pintrich & Schunk, 2002).

1.1.2.2. Value: Goal Orientation and Task Value

The value assigned to a task depends on whether a student pursues intrinsic goals and rewards or extrinsic ones. Intrinsically oriented students are motivated by challenge, curiosity, or independence, while extrinsically oriented students are motivated by instructor approval, good grades, or less difficult tasks (Harter, 1981; Pintrich & Garcia, 1991).

There are a number of different models of goal orientation that have been suggested by different achievement motivation, but the main construct that is involved is goal orientation, which concerns the purposes for engaging in achievement behavior. In contrast to Locke and Latham's (1990) goal setting theory, which focuses on specific goals (e.g., trying to get an A on an exam), goal orientation theory is concerned with why individuals want to get an A. The goal-content approach focuses on many different possible goals that can guide behavior, while goal orientation remains focused on the goals and purposes for the achievement of tasks (Pintrich & Schunk, 2002). Although there are several definitions of goal orientation in literature, it is generally defined as the reasons why people engage in certain tasks (Pintrich, 2000; Pintrich & Schunk, 2002).

Most models propose two general goal orientations concerning the reasons why individuals continue to engage in a task. Those two goal orientations are labeled as learning and performance goals (Dweck & Legget, 1988), or task-involved and ego-involved goals (Nicholls, 1984), or mastery and performance goals (Ames, 1992), or task-focused and ability-focused goals (Maehr & Midgley, 1991). We will use the terms mastery and performance goals to refer to the two general goal orientations.

A *mastery goal* orientation refers to focus on the development of knowledge, skill and competence according to self-set standards or self-improvement. In this manner, mastery goal orientation is self-referential. Research shows that individuals who have mastery goals do not avoid learning or mastering a task. In contrast, a *performance goal* orientation reflects a focus on demonstrating competence and ability by trying to outperform peers in carrying out academic tasks. Performance goals concern how one's ability will be judged relative to others, using normative and social comparative standards. It also involves trying to be the best and avoiding judgments of poor ability or appearing stupid (Pintrich, 2000; Pintrich & Schunk, 2002).

The most important aspect of goal theory is the distinction between mastery and performance goals and how these goals are connected to different cognitive, motivational and behavioral mediators and outcomes (Pintrich, 2000; Pintrich & Schunk, 2002). Generally, research suggests that a mastery goal orientation brings about positive affect and interest, higher levels of cognitive engagement, more effort and persistence and adaptive help-seeking and risk-taking. By contrast, an avoid performance goal orientation (avoiding looking stupid) often causes higher levels of anxiety, lower value for tasks, less cognitive engagement, withdrawal of effort, failure to persist and lower levels of performance (Pintrich & Schunk, 2002). Goal oriented students assess specific task values according to the importance, interest, and utility associated with the task (Eccless, 1983).

1.1.2.3. Affect: Test Anxiety

Affective behavior refers to the emotional responses to a particular academic task. A common measure of such emotional responses is test anxiety. Test anxiety can be defined as a set of phenomenological, psychological, and behavioral responses that accompany an unpleasant feeling about an exam or such evaluative situation (Pintrich & Schunk, 2002). Studies of college students have shown that test anxiety is negatively related to performance (Benjamin, McKeachie & Lin, 1987; Pintrich & Garcia, 1991).

On the basis of this theoretical background, various studies propose instructional strategies that teachers can use in their classrooms to develop their students' cognitive and metacognitive skills, to enhance their self-efficacy beliefs and make them more mastery oriented. Although all of these studies suggest guidance for supporting students' different aspects of self-regulated learning skills, the most common suggestions involve encouraging students to engage in inquiry learning activities (Schraw, Crippen & Hartley, 2006; Kipnis & Hofstein, 2008) and supporting self-recording and self-reflection techniques (Smith, 2001; Zion, Michalsky & Mevarech, 2005) such as inventory instruments and diaries in terms of metacognitive development; designing tasks at an appropriate level of challenge, allowing students to express their opinion, giving positive feedbacks on students' assignments (Schunk, 1988; Schunk, 1991; Smith, 2001; Taylor & Corrigan, 2005) and encouraging them to see that errors are part of the learning process rather than evidence of ability (Smith, 2001; Taylor & Corrigan, 2005) in order to enhance self-efficacy; focusing on meaningful aspects of the task, providing opportunities for students to have some choice and control over the activities, de-emphasizing competition and social comparisons, encouraging peer interaction and recognizing student effort in terms of mastery goal orientation in the classroom (Smith, 2001; Pintrich & Schunk, 2002). However, little of this research emphasizes both metacognition and motivation.

2. Methodology

2.1. Purpose

The main goal of this research is to examine the effect of creating metacognitive awareness embedded within a motivating chemistry laboratory on students' motivation and metacognitive skills. This study addresses two issues relating to their motivational and metacognitive development:

1. Does metacognitive development embedded within a motivating laboratory affect students' science process skills?
2. Does metacognitive development embedded within a motivating laboratory affect students' attitudes towards chemistry?

2.2. Sample

Fifty-four pre-service science teachers entering the General Chemistry Laboratory-I course at Marmara University Ataturk Education Faculty, Department of Primary Education, Science Education Program in the second semester of 2007-2008 participated in this study. The population was randomly assigned into two instructional treatment classes. One was the control group (n=27) and the other was the experimental group (n=27). The students in the control group were taught traditionally, while the students in the experimental group were taught with an instructional method intending to develop students' metacognitive skills embedded within a motivating chemistry lab.

2.3. Procedure

In order to assess the impact of the instructional strategy employed with the experimental group, compared to a more standard lab experience, an experiment was designed so that the control and the experimental groups would be as similar as possible. To achieve this goal, great effort was made to ensure that the primary difference between the two groups was the learning environment in the laboratory, accompanying a general chemistry lecture class. First, the students in both control and experimental groups carried out the same 11 experiments, each of which was performed over a lab course. The topics of the experiments were as follows:

- The effect of the type of the substance on reaction rate
- The effect of the concentration on reaction rate
- The effect of temperature on reaction rate
- Chemical equilibrium
- Precipitation and solubility product
- Weak and strong acids/bases, neutral substances and the concept of pH
- Indicators
- Weak acids/bases and ionization constant of acids/bases

- Buffer solutions
- Acid-base titration
- Hardness of water

Second, both of the groups were taught by the first author and these two groups were taught together by an experienced instructor (the second author) in accompanying general chemistry lecture. Third, both of the groups were taught in similar time periods (approximately two hours). Fourth, all the students performed the experiments in small groups (three or four students in each group).

The students in the control group performed the experiments following the instructions described in the laboratory manual. Students were given the topic, aim and procedure of the experiment. The researcher gave the required information before and after performing the experiments and answered questions the students posed, but no additional effort was made by the researcher during the course of control group. However, in the experimental group pre- and post-discussions about the design of the experiments were held in order to create metacognitive awareness of the experimental design. Through these discussions the aim was to make the students aware of scientific knowledge and science process skills in relation to each experiment. The students in the experimental group were encouraged to design the experiments and interact with their peers and teacher. They were always provided with positive feedback (e.g., "You are doing well" or "I can see you are trying hard") during the experiment, while the students in the control group were provided no such feedback. The students in the experimental group were also given four semi-structured reflective interview forms. The second and third form reflected students' ideas about the experiment and the topic related to the experiment before and after the course in order to activate students' metacognitive strategies. The first and last interview forms, which were given at the beginning and the end of the semester, revealed students beliefs and expectations about the lab course and were used to gain a deeper understanding of the students' metacognitive skills, motivation and attitude towards the course besides activating their metacognitive skills.

All the students were asked to write a report about the experiment and to answer the questions described in their laboratory manual. Distinct from the control group, in order to promote the use of metacognitive strategies, the students in the experimental group were encouraged to inquire the subjects the researcher wanted. The students in experimental group were not only informed about the errors they made in their reports but were also consistently provided positive feedbacks, such as "Thank you for this elaborate and neat study" or "Well done!" If a report was not good enough, the feedback given was a sentence something like "I believe that you can do much better if you try." The students in the control group had no feedback regarding their reports except for grades.

The teaching method used in the experimental group was based on Pintrich's (2000) model of four phases of self-regulation: planning, monitoring, controlling and reflecting. The authors adapted Pintrich's learning model to the chemistry lab course and developed a teaching method consisting of five phases: introduction, awareness and planning, performing the experiment, self-control and self-assessment and reflection.

1. *Preparatory:* The courses began with the second reflective form, which the teacher asked the students to fill out and submit before the experiment. The questions on the form aimed to improve students' metacognitive skills by making them set their goals and be aware of their goal orientations and self-efficacy beliefs. After submitting these forms, the teacher posed one or more questions relating to the design of the experiment or a problem encountered in daily life.
2. *Awareness and planning:* The question posed to the class in the first phase was elaborated in this phase. The students discussed this question first in small groups, then with other groups of the class. The teacher intervened in these discussions by asking appropriate questions to the students, but without directing them. The purpose of this phase was to enhance students' motivation, planning skills and understanding of scientific knowledge and scientific processes regarding the experiment and also to make them aware of the reason of doing this experiment.
3. *Performing the experiment:* Following the discussions, the students performed the experiment that they designed together. The researcher (first author) watched them carefully, tried to give them positive feedback and encouraged them to ask as many questions as possible.
4. *Self-control:* The students tested their hypotheses by discussing the results of the experiment. In this phase the researcher provided explanations if necessary.

5. *Self-assessment and reflection:* In this last phase, the researcher sometimes made a demonstration experiment, related to the experiment that had just been performed and asked questions about the demonstration experiment or elicited questions from the students. The aim was to make the students assess their learning and improve their inquiry skills. The students were supposed to answer both the questions written in the lab manual and those posed during the course. The researcher asked the students to answer these questions in their reports which would be delivered the following week. The students were assigned to write reports, and the researcher added her feedback to the reports after reading them and returned them to the students. At the end of the course, the students were asked to fill out and submit the third reflective form. The questions in this form aimed to improve students' metacognitive skills by making them aware of whether there was a change in the goals they set, their goal orientations or their self-efficacy beliefs.

2.4. Instruments

Motivated Strategies for Learning Questionnaire (MSLQ): The MSLQ is the 81-item self-report instrument designed by Pintrich, Smith, Garcia & Mc Keachie (1991 cited in Altun, 2005) to test college students' motivational orientation and their use of different learning strategies for a college course and was adapted into Turkish by Altun. There are two sections that make up the original instrument: a motivation section and learning strategies section. The motivational subscales are based on a general social cognitive model of motivation that proposes three general constructs (Pintrich, 1988): expectancy, value and affect. The motivation section tests six different student perceptions: intrinsic and extrinsic goal orientation, task value, control of learning beliefs, self-efficacy beliefs and test anxiety. Participants responded to all of the items in this scale and all of the results of the motivation section will be presented in this paper.

The learning strategies section is based on a general cognitive model of learning and information processing (Weinstein & Meyer, 1986). This has three general types of scales: cognitive, metacognitive and resource management. The metacognitive section of the scale the participants responded to will be presented in this paper.

The items associated with categories 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 validity and the reliability analysis of the Turkish version of the survey were made by Altun (2005). The Cronbach alpha reliability coefficients of the categories in the motivation section are 0.80 for intrinsic goal orientation; 0.83 for extrinsic goal orientation; 0.91 for task value; 0.80 for control of learning beliefs; 0.89 for self-efficacy beliefs; and 0.82 for test anxiety. The Cronbach alpha reliability coefficient of metacognitive learning strategies is 0.85 (Altun, 2005; Altun & Erden, 2006). This survey was used as both a pre- and post-test.

Science Process Skills Test (SPST): The Turkish version of this test was used both as a pre- and post-test to determine the students' science process skills. This test had been developed by Burns, Okey, & Wise (1985) and was adapted to Turkish by Özkan, Geban & Aşkar (1989 cited in Geban, 1990). Five different science processes were measured on the SPST: (1) identifying variables, (2) identifying and stating hypotheses, (3) operationally defining, (4) designing investigations, and (5) graphing and interpreting data. The SPST is a 36 multiple choice item instrument that includes the five aforementioned dimensions. The Cronbach alpha reliability coefficient of the Turkish version of this instrument is 0.85.

Attitude Towards Chemistry Scale (ATCS): The ATCS, a 12-item survey, is based on a 5-point Likert scale. It was designed by Berberoğlu (1993) to test five different student attitudes: (1) interest in chemistry, (2) attitudes towards the laboratory, (3) attitudes towards chemistry as profession, and (4) anxiety towards chemistry. Students chose a number between 1 and 5 to show whether they agreed with the statement (5) or disagreed with the statement (1). The Cronbach alpha reliability coefficient of this instrument is 0.87. This scale was used both as a pre- and post-test.

3. Results and Discussion

The data obtained from the study were assessed by using the SPSS program. Prior to treatment, an independent t-test was employed to determine whether there was a statistically significant difference between the control and the experimental groups with respect to science process skills, attitude towards chemistry and motivational beliefs and use of metacognitive learning strategies. The hypotheses were tested in the 0.95 confidence interval. The results of independent samples t-test analysis showed that there were no significant differences between the control and the experimental group in terms of their science process skills (SPST) (t=1.334; p>0.05), attitude towards chemistry (ATCS) (t=0.598; p>0.05) and MSLQ scores (t=1.180; p>0.05). There was no significant difference between two groups in terms of their pre-test scores of the subscales of three tests, either. This result indicated that students in the control and the experimental groups were similar regarding these three variables.

After the treatment, SPST, ATCS and MSLQ were utilized as post-tests on both the control and the experimental groups. The results of independent t-test analysis of the post-test scores of MSLQ showed that there was no significant difference between the total scores of motivational beliefs of the students in each group (t=1.358; p>0.05) but the scores of the subscales of control of learning beliefs (t=2.102; p<0.05) and self-efficacy beliefs (t=2.051; p<0.05) of the students in the experimental group were significantly higher than those of the students in the control group; however no significant differences were found between the two groups in terms of the other subscales of motivational beliefs (p>0.05) (Saribas & Bayram, 2009).

Table-1 Motivational Beliefs of the Control Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre motivation-post motivation	13.04	32.77	6.31	0.073	26.001	2.067	26	0.049[*]

[*] p<0.05

Paired samples t-test was used in order to investigate whether there was a significant change in students' motivational beliefs and in the dimensions of their motivational beliefs, both in the control and the experimental group. Table-1 shows that the motivational beliefs of the students in the control group significantly decreased over the instructional period. However, as shown in Table-2, there was no significant difference between the pre- and post-test scores of motivational beliefs of the students in the experimental group.

Table-2 Motivational Beliefs of the Experimental Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre motivation-post motivation	-4.93	23.12	4.46	-14.094	4.242	1.104	26	0.280

Table-3 Subscales of the Motivational Beliefs of the Control Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre intrinsic-post intrinsic	1.11	6.32	1.22	-1.389	3.611	0.913	26	0.369
pre extrinsic-post extrinsic	1.19	5.33	1.03	-0.923	3.293	1.156	26	0.258
pre task value-post task value	1.52	8.54	1.64	-1.858	4.896	0.924	26	0.364
pre control -post control	1.67	6.03	1.16	-0.720	4.053	1.436	26	0.163
pre efficacy-post efficacy	4.63	9.88	1.90	0.721	8.538	2.435	26	0.022*
pre anxiety-post anxiety	2.93	5.62	1.08	0.705	5.147	2.707	26	0.012*

*p<0.05

Paired samples t-test analysis of the subscales of the motivational beliefs section indicates that self-efficacy beliefs of the students in the control group decreased and their test anxiety increased while other dimensions of the motivational beliefs did not change significantly throughout the research (Table-3). Nevertheless, control of learning beliefs and self-efficacy beliefs of the students in the experimental group seem to have increased significantly after the treatment, while there was not any significant difference between their pre- and post-test scores of the other subscales of the motivational beliefs (Table-4).

Table-4 Subscales of the Motivational Beliefs of the Experimental Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre intrinsic-post intrinsic	-1.48	5.54	1.07	-3.671	0.708	1.391	26	0.176
pre extrinsic-post extrinsic	-0.85	6.40	1.23	-3.384	1.680	0.691	26	0.495
pre task value-post task value	0.81	7.79	1.50	-2.267	3.897	0.543	26	0.591
pre control -post control	-2.19	3.41	0.66	-3.534	-0.837	3.331	26	0.003*
pre efficacy-post efficacy	-2.63	6.55	1.26	-5.222	-0.038	2.085	26	0.047*
pre anxiety-post anxiety	1.41	7.34	1.41	-1.496	4.311	0.996	26	0.328

*p<0.05

Providing positive feedback regarding students' abilities may enhance self-efficacy, skill performance and ultimately, motivation. Attributing a learning outcome to something that is controllable is also fundamental to enhancing motivation (Smith, 2001). The designed approach in this study seem to have achieved the goals of providing positive feedback and attributing a learning outcome to something that is controllable with respect to self-efficacy and control of learning beliefs. The instructional design implemented in the experimental group did not decrease students' test anxiety, but it also did not increase it.

Table-5 Metacognitive Learning Strategies of the Control Group

	Paired Differences					t	df	p
	Mean	Std. Deviation	Std. Error Mean	95 % Confidence Interval of the Difference				
				Lower	Upper			
pre metacognition - post metacognition	-2.37	9.71	1.87	-6.212	1.471	1.268	26	0.216

Table-6 Metacognitive Learning Strategies of the Experimental Group

	Paired Differences					t	df	p
	Mean	Std. Deviation	Std. Error Mean	95 % Confidence Interval of the Difference				
				Lower	Upper			
pre metacognition - post metacognition	-10.89	9.45	1.82	-14.628	-7.150	-5.986	26	0.000*

$^{*}p<0.05$

The post-test scores of the metacognitive learning strategies subscale of the MSLQ showed that the students in the experimental group used more metacognitive learning strategies than the students in the control group (t=2.282; p<0.05) (Saribas & Bayram, 2009). In order to find out whether there was a progression in the students' use of metacognitive learning strategies in each group, a paired samples t-test was used. Table-5 indicates that there was not any significant change in students' use of metacognitive learning strategies in the control group after the study. However, as shown in Table-6, students' use of metacognitive learning strategies in the experimental group increased significantly following the instruction.

Self-recording is one of the most common methods of increasing student awareness of learning behaviors and enabling students to evaluate progress toward a goal. Self-recording includes various forms of reflective writing that requires students to put into writing their thoughts, ideas, and questions with respect to a certain topic. Use of inventory instruments can also affect a student's self-awareness positively by forcing him/her to consider specifically what he/she was thinking about before, during, and after the learning process (Smith, 2001). In addition to the reflective forms, which seem to have increased students' self-awareness, according to Kipnis and Hofstein (2008), the inquiry laboratory provides the students with the opportunity for metacognitive activities.

Independent t-test analysis indicated that students in the experimental group outperformed students in the control group in the post-test scores of SPST (t=2.315; p<0.05). When the subscales of the SPST were analyzed, it could be seen that the students in the experimental group were more successful than the students in the control group in the subscales of identifying variables, operationally defining, and designing investigations (p<0.05) (Saribas & Bayram, 2009).

Table-7 Science Process Skills of the Control Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre SPST - post SPST	0.33	3.79	0.73	-1.167	1.834	0.457	26	0.652

$^{*}p<0.05$

Table-8 Science Process Skills of the Experimental Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre SPST - post SPST	-3.52	2.97	0.57	-4.692	-2.345	-6.164	26	0.000^{*}

$^{*}p<0.05$

In order to find out whether there was an improvement in the science process skills of the control and the experimental group, paired samples t-test was utilized. Table-7 shows the comparison of pre- and post-test scores of SPST of the control group. As seen in this table, there was not any progression in the total scores of SPST of the students in the control group. Table-8 shows the comparison of pre- and post-test scores of SPST of the experimental group. It is evident in Table-8 that science process skills of the students in the experimental group improved throughout the course. Because the process skills tested represented the analytical thinking and reasoning ability that have great influence in students' understanding of science (Sungur, Tekkaya & Geban, 2001), this result is important for our research.

Table-9 Subscales of the Science Process Skills of the Control Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre variable-post variable	0.59	1.97	0.38	-0.185	1.370	1.566	26	0.129
pre hypothesis-post hypothesis	0.11	1.74	0.33	-0.577	0.799	0.332	26	0.743
pre operation-post operation	-0.22	1.37	0.26	-0.763	0.319	0.844	26	0.406
pre design-post design	0.22	0.89	0.17	-0.130	0.574	1.295	26	0.207
pre interpret-post interpret	-0.37	1.15	0.22	-0.825	0.084	1.676	26	0.106

Examining the subscales of the SPST, it can be seen that none of the process skills of the students in the control group improved, while the treatment in the experimental group improved all the students' mentioned skills significantly. The comparison of pre- and post-test scores of the subscales of the SPST of the control group is shown in Table-9, and that of the experimental group is shown in Table-10.

Saribas, D., Bayram, H. (2010). The efficiency of metacognitive development embedded within a motivating lab regarding pre-service science teachers' learning outcomes. *International Journal of Human Sciences* [Online]. 7:1. Available: http://www.insanbilimleri.com/en

Table-10 Subscales of the Science Process Skills of the Experimental Group

	Paired Differences							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95 % Confidence Interval of the Difference**		**t**	**df**	**p**
				Lower	Upper			
pre variable-post variable	-1.30	2.45	0.47	-2.264	-0.328	2.753	26	0.011*
pre hypothesis-post hypothesis	-0.74	1.32	0.25	-1.262	-0.219	2.920	26	0.007*
pre operation-post operation	-0.56	1.28	0.25	-1.062	-0.049	2.253	26	0.033*
pre design-post design	-0.33	0.62	0.12	-0.579	-0.088	2.793	26	0.010*
pre interpret-post interpret	-0.59	1.31	0.25	-1.110	-0.075	2.353	26	0.026*

*$p<0.05$

No significant differences were found between the two groups either in the total scores of the ATCS (t=1.189; p>0.05) or those of the four subscales of the ATCS: attitudes towards laboratory (t=0.692; p>0.05), attitudes towards chemistry as professional (t=1.095; p>0.05), interest in chemistry (t=0.968; p>0.05), and anxiety towards chemistry (t=1.353; p>0.05). Furthermore, no significant gain was achieved in the total scores of the ATCS of the students in the control (t=0.639; p>0.05) nor in the experimental group (t=0.328; p>0.05). In addition to this finding, there was no significant improvement in the subscales of attitudes towards laboratory (t=0.896; p>0.05), attitudes towards chemistry as professional (t=0.111; p>0.05), interest in chemistry (t=0.178; p>0.05), and anxiety towards chemistry (t=0.564; p>0.05) of the students in the control group. Similarly, it seems that the treatment could not enhance students' attitudes in neither of the subscales of attitudes towards laboratory (t=0.701; p>0.05), attitudes towards chemistry as professional (t=0.424; p>0.05), interest in chemistry (t=0.789; p>0.05), and anxiety towards chemistry (t=0.568; p>0.05) in the experimental group. However, the students stated that this course contributed to their learning and that they enjoyed performing experiments in the reflective forms. On the other hand, they frequently complained about filling these reflective forms.

4. Conclusions

The main purpose of the present study was to improve science process skills and attitudes towards chemistry through the development of metacognitive skills embedded within a chemistry laboratory. The findings of this research support the findings of previous studies showing the positive effects of metacognitive guidance on learning outcomes (Tien, 1998; Zion, Michalsky, & Mevarech, 2005). The results of this study showed that the treatment implemented in the experimental group contributed to the students' learning outcomes in many aspects. In spite of the equivalence of the motivational beliefs of the students, both in the control and the experimental group, following the instructional period, traditional laboratory seem to have decreased student motivation, while the teaching method executed in the experimental group did not seem to have any significant effect on student motivational beliefs in total. A detailed analysis showed that traditional laboratory instruction tends to increase student test anxiety and decrease self-efficacy beliefs. On the other hand, creating metacognitive awareness and motivating students in a laboratory course seems to have increased their self-efficacy beliefs and control of learning beliefs. This result leads to the conclusion that if the students are motivated while performing experiments and given opportunities to metacognitively engage and design the experiments, they may attribute their success or failure to their efforts for the task. This result also indicates that the teaching method carried in the experimental group enhanced students' expectancy beliefs, rather than their value beliefs and affective states. One possible reason of not achieving any gain in students' value beliefs and affective states could be explained by the short instruction period (11 weeks). Young (2005) stated that clear goals that emphasize learning over grades will increase intrinsic motivation. Another possible reason may be the lack of these clear goals.

Green (2002) has suggested that task value will be promoted whenever the teacher provides a reason for the task, emphasizes the usefulness and importance of the task, emphasizes the enjoyment that can be gained from the task, offers choice within the task, and models enthusiasm for the task. In order to improve students' metacognitive skills and make them use more diverse metacognitive skills, students were asked the usefulness and importance of the course and whether they enjoyed the experiments they performed in the reflective forms given at the end of the course. In these reflective forms, the students expressed various reasons for the usefulness and importance of the course and that they had pleasure with performing the experiments in these reflective forms. They also stated that the feedback the teacher gave to their reports contributed to their learning and motivated them. However, the teacher emphasis on these issues is lacking in this study.

Traditional laboratory instruction seems to have decreased students' self-efficacy beliefs and increased their test anxiety. This general decline in motivation has been well documented in the literature (Pintrich & Schunk, 2002; Zusho & Pintrich, 2003). However, the treatment implemented in the experimental group seems to have enhanced their self-efficacy beliefs and not to have affected the students' test anxiety. This result supports Palmer's view (2005) that seeing fear and anxiety as indicators of inability may weaken self-efficacy belief, while considering anxiety and fear as normal responses may lead to higher self-efficacy beliefs. This result can be interpreted that some of the experiments in chemistry laboratory are so challenging that students may have some troubles about the efficacy of performing these experiments and feel anxious about this course. However, creating metacognitive awareness in a motivating lab appears to have caused the students think that the main purpose of performing experiments was for scientific inquiry rather than for doing it without a mistake. This thought seems to have brought about higher self-efficacy beliefs and lower anxiety in comparison with the traditional laboratory instruction which makes the students focus on the procedures of the experiments without any mental engagement.

In addition to students' motivational outcomes, there was a significant difference between the two groups in terms of students' metacognitive development. The t-test results of both the MSLQ and the analysis of the reflective forms provide evidence to the benefits of the instructional method in the experimental group regarding students' metacognitive development. However, traditional laboratory instruction seems not to have the potential to facilitate students' metacognitive development.

Through a review of related research studies, it is clear that science process skills can be taught and learned if the students have an opportunity to experience the actions related to this ability (Mattheis & Nakayama, 1988). The findings of this study indicate the positive effect of metacognitive development and a motivating laboratory on students' science process skills.

The results of this study also show that creating metacognitive awareness and motivating students can make laboratory instruction more beneficial regarding science process skills. Following the instruction, the students who carried out the experiments by metacognitive questioning in a motivated laboratory outperformed in science process skills the students who were instructed with the traditional laboratory, both in total scores and in the subscales of identifying variables, designing investigations, and operational skills (Saribas & Bayram, 2009). Furthermore, traditional laboratory does not seem to have improved students' science process skills either in total or in any of the dimensions of these skills. It can be concluded that one semester of traditional laboratory course is not sufficient to improve students' science process skills by a traditional laboratory instruction. On the other hand, metacognitive questioning in a motivating laboratory seems to have developed both students' total scores of science process skills and all the dimensions of these skills. This finding supports the literature that states laboratory instruction, in which students follow the procedures of the laboratory manual in a cookbook style without any mental engagement, is not effective (Singer, Hilton & Schweingruber, 2005; McComas, 2005). It also shows that metacognitive questioning in a motivating laboratory seems to have a positive impact on students' science process skills. Because students in the experimental group designed the experiments, discussed every step of the experiments with their peers, inquired about problems related to the topic of the experiment, and got feedback from the researcher, it is not surprising that students developed all the dimensions of science process skills.

Although the students in the experimental group defined the experiments they performed as instructive and enjoyable in the reflective forms, no significant difference was found between the groups in any of the four attitudes towards chemistry. It seems that more time is needed to achieve any gain in a standardized instrument such as an attitude survey. Another possible reason may be the negative effect of the students' unwillingness to fill out the reflective forms regarding their attitude towards the course.

5. Recommendations

Metacognitive questioning and motivating students in a laboratory course seems to have a positive effect on pre-service science teachers' motivation, metacognitive strategies and science process skills. Therefore, it is recommended that laboratory instruction be designed and implemented for developing university students' metacognitive skills and motivation. However, while designed approach improved some of the aspects of the motivational beliefs, it did not affect students' attitude towards chemistry and some dimensions of motivational beliefs in one semester of instructional period. Further investigation, in longer periods, is needed about the topics of student interest, motivation, metacognition and science process skills. Some recommendations for further research are presented below in order to overcome the potential limitations of this study.

First, this study was based on a sample from one university, suggesting that replication in alternative educational settings is needed for greater generalization. Studies in different science laboratories on the other learning strategies, such as cognitive learning strategies and resource management strategies, with students at different grade levels are needed.

Second, longer instructional periods may be needed in order to accomplish the development of motivational beliefs and attitudes. Longitudinal studies may be essential in this respect.

Third, this study focuses on guided inquiry, in which students are required to identify a scientific problem, analyze data, formulate hypotheses, design experiments to test the hypotheses, and explain the chemical phenomenon for the basis of the experiments. However, an open inquiry activity, which requires students to design a follow-up experiment based on both the information cited in the previous experiment and on new information (Zion, Michalsky & Mevarech, 2005) they will search as homework, may be included in such a study. As Zion, et al. (2004) suggested, emphasizing the dynamic characteristics of the open inquiry process may assist in the judgment and justification processes. Since argumentation would predict success at problem-solving processes (Hong et al, 2001; Cho & Jonassen, 2002), we also suggest adding to lab courses an argumentation process that would allow students to defend their solutions.

Fourth, even if the method is designed to develop students' metacognitive skills and enhance their expectancy beliefs in chemistry laboratory, it may not increase their value beliefs and affective outcomes. Students should be aware of the fact that scientists work not only in a room called "laboratory" but also in nature centers, at students' homes, and in every place that investigations can take place (McComas, 2005). Extending the research area of investigation may increase students' attitude towards chemistry as well as improve their inquiry skills. Assigning student homework on a research topic that uses household chemicals may be beneficial in this respect.

Fifth, laboratory assessment may be more effective through the use of hands-on exercises than paper-and-pencil instruments. From this point of view, the authentic assessment, in which students' progress is measured in respect to some real-life tasks, could be more effective as both an instructional and diagnostic tool (McComas, 2005). By this way, students' interest and motivation, and thereby their engagement in tasks and experiments, may be increased.

Sixth, giving positive feedback regarding students' reports and encouraging students during experiments seems to have increased their self-efficacy beliefs. Students need to know that their work is valued, but, at the same time, that the teacher is always in control. The designed approach seems to have also increased students' expectation of success based on their efforts. However, this approach does not impact students' value beliefs. The teacher's emphasis on the value and the pleasure of learning, rather than on scores or external rewards, will be useful in overcoming this limitation.

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