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The effects of prospective chemistry teachers' laboratory teaching experiences on their metacognitive thinking skills and perceptions of problem-solving skills

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Abstract
The current study aims to examine the effects of prospective chemistry teachers' chemistry laboratory teaching experiences using different laboratory approaches on their metacognitive thinking skills and perceptions of problem-solving skills. The study is designed as "'the quasi-experimental non-equivalent pre-test/post-test control group research design." Twenty-seven prospective teachers from the Department of Chemistry Education at a public university participated in this study. The prospective chemistry teachers in the experimental group carried out laboratory teaching practices relying on the inquiry-based activities conjugated with a science writing heuristic approach; however, the prospective chemistry teachers in the control group carried out laboratory teaching practices relying on the traditional laboratory approach. The implementation process took 14 weeks. The results showed that there was an overall improvement in the perceptions of problem-solving skills and metacognitive thinking skills in each factor for the prospective chemistry teachers in the experimental group compared to the prospective chemistry teachers in the control group.

Keywords Inquiry-based learning · Metacognitive thinking skills · Perception of problem-solving skills · Science writing heuristic · Teaching experience

Introduction

Current educational environments are expected to incorporate teaching strategies, methods, and techniques through which learners actively engage in the learning process. In this respect, learners are encouraged to be more aware of the environment in which they live and are guided to develop their thoughts based on the new knowledge they acquire (Smith et al., 1993). Science curricula around the world have been restructured to teach the emergent effects of science in real time, to teach how to use scientific knowledge to solve problems, and

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to raise scientifically literate individuals (Lederman et al., 2013; Millar et al., 1998). Science education aims to enable students to learn the basic concepts and ideas in different scientific disciplines and to use them to carry out research, to perceive natural phenomena, analyze and discuss them critically, and to use these skills to make conscious decisions in their daily and professional lives (Talanquer, 2018). Chemistry, which plays a vital role in science, is crucial in explaining a variety of events that occur in everyday life. However, previous research shows that students have difficulty understanding various chemistry topics because of the abstract concepts inherent in chemistry courses. Chemistry is therefore seen as a challenging course for students (Beerenwinkel et al., 2011; Nakhleh, 1992; Orgill & Bodner, 2004). Laboratory classes, which involve hands-on work, offer better opportunities for effective learning and teaching of science subjects (Bretz, 2019). The traditional laboratory approach, in which students are given "cook-book" descriptions of procedures rather than activities such as formulating research questions, formulating hypotheses, planning and designing experiments, and drawing conclusions from their hypotheses, rarely allows students to use higher-order cognitive skills or to discuss scientific knowledge relevant to the investigation (Bicak et al., 2021; Roth, 1994). When laboratory activities are properly organized, they contribute positively to students' attitudes and cognitive development, as well as to the development of twenty-first century skills (Hofstein & Mamlok-Naaman, 2007; Tho et al., 2017). The inquiry-based learning (IBL) approach to laboratory applications in science and chemistry education provides interactive learning environments that allow for teacher-student, student-student, and student-material interaction. Previous studies have also shown that inquiry-based experiments in laboratory investigations improve higher-order thinking skills, including problem-solving, metacognitive skills, critical thinking, experimental design reasoning, and scientific thinking (Hofstein et al., 2005; Mistry & Gorman, 2020; Seery et al., 2019).

Theoretical considerations

IBL, IBLabs, and SWH approach

By its very nature, IBL provides a student-centered approach to science education. As a pedagogical tool, IBL relies on questioning, critical thinking, and problem-solving skills. IBL as an instructional practice occurs when students engage in hands-on and minds-on science activities through which they develop a research-based perspective on learning (Szalay & Toth, 2016; Wang & Jou, 2016). Student-centered IBL environments that engage students in hands-on activities (Colburn, 2000) provide a meaningful, deep understanding of science concepts and develop students' critical thinking skills (Aldahmash & Omar, 2021; Pratt & Hackett, 1998). The IBL environment supports activities such as making observations in the laboratory, designing experiments, formulating hypotheses, and analyzing experimental results. IBL thus enhances students' higher order thinking skills (Hofstein et al., 2005); however, previous studies show that chemistry students lack awareness of metacognitive skills as well as knowledge of how to use these skills in educational contexts (Haidar & Al Naqabi, 2008; Rickey & Stacy, 2000).

Inquiry-based laboratories (IBLabs) are widely used in teaching methods courses and science education literature and are designed to help students independently explore scientific concepts, construct knowledge, and apply what they learn in an inductive process (Deters, 2005; Sönmez et al., 2021). While traditional laboratory settings emphasize a more rigid way of learning, where students are tracked for the steps they take as part of their experimental skills, IBLabs aims to increase student engagement by supporting skills such as asking research questions, testing hypotheses, and thus contributing to the development of higher-order skills, including thinking and problem-solving skills (Gupta, 2012; Irwanto Saputro et al., 2018; Katchevich et al., 2013).

Several scholars (see Lim, 2001; Llewellyn, 2007; Sadeh & Zion, 2012) have identified different levels of inquiry based on the roles teachers and students assume or the nature of the problem in a specific context. Examining the studies conducted in educational settings, we can conclude that the four levels of inquiry are predominantly present in the design of instructional activities. These levels are "Confirmation Inquiry, Structured Inquiry, Guided Inquiry, and Open Inquiry." Confirmation Inquiry refers to the processes by which students engage in research through an activity whose outcomes they already know, while the teacher helps students to pose questions, guide them through the process, and arrive at solutions. At the Structured Inquiry level, students focus on a step-by-step approach that leads to the solution of the problem. In this process, the teacher does not provide the solution to the problem (Banchi & Bell, 2008). By implementing Guided Inquiry, students have the opportunity to be flexible in solving the problem, even though the problem is given by the teacher at the beginning.

As a result, students have more engaging and relevant learning experiences because they are able to explore, research, and construct knowledge on their own (Llewellyn, 2007; Spaulding, 2001), while the teacher provides a more effective learning environment where students are encouraged to find a solution to the problem at hand (Furtak, 2006; Lim, 2001). In Open Inquiry, the highest level of engagement in IBL, students assume the role of a scientist and determine the steps they take to derive questions and solve research problems. As such, they draw their own conclusions, interpret results, and present their findings to expand their knowledge base through classroom discussion (Banchi & Bell, 2008; Llewellyn, 2007). The role of the teacher in guided inquiry, which is the subject of this study, is important in identifying problems, formulating answers, preparing materials, and organizing the learning environment (Açıkgöz, 2008). The teacher organizes a learning environment that encourages students to explore, does not answer their questions itself, but guides them to find the answers to their questions (Furtak, 2006). At this level, which is similar to the structured inquiry level in that the problem situation or the problem to be investigated is presented by the teacher, but is more complex than the structured inquiry level, students have opportunities to learn, plan different experiments, make applications, and collect evidence (Banchi & Bell, 2008).

The science writing heuristic (SWH) approach, based on constructivist philosophy, also encourages students to engage in guided inquiry-based laboratory (IBLab) practices and provides structuring of knowledge through collaborative group work. The SWH is defined as an instructional technique that combines inquiry, collaboration, and writing while providing a structure for both students and instructors to carry out effective activities in the chemistry laboratory (Burke et al., 2006). In the present study, prospective chemistry teachers (PCTs) in the experimental group employed the SWH in the guided inquiry-based chemistry laboratory. The SWH, developed by Keys et al., (1999), is an approach that helps learners to better understand scientific concepts within the framework of an argumentation. The SWH approach is a type of writing activity that consists of both a student and a teacher framework that guides students through the activities and acts as a metacognitive support to encourage students to reason about data (Akkus et al., 2007). This approach involves two dimensions, the teacher and the student. The SWH teacher and student templates are provided in Appendix Table 7 (Keys et al., 1999). The teacher template prepared as a guide for teachers, provides suggestions for teachers (Keys et al., 1999) to engage students in thinking, discussing, writing, and reading abilities about the research they will conduct in the laboratory (Williams, 2007). In this way, teachers can use the SWH to design activities before, during, and after laboratory practices (Hohenshell & Hand, 2006). The student template contains the steps that will guide the students through the laboratory activities. This template, which helps students to construct scientific knowledge during inquiry activities (Choi et al., 2010; Hand et al., 2018) , also has the feature of a laboratory report where students can reflect on their inquiry-based activities and results with the steps and questions given for each step (Poock, 2005). This approach guides teachers in designing creative activities, classroom activities, designing inquiry-based activities to be used in laboratory practices of science courses and making practices (Keys et al., 1999). In the SWH approach, which is closely related to the science curriculum and based on the components of inquiry, students carry out the steps of asking questions, designing experiments, making observations, collecting data, and making claims based on evidence. In addition, this approach involves student-student dialogue and scientific discussion, which are rare in traditional science classrooms (Choi et al., 2010; Hand et al., 2018; Katchevich et al., 2013; Yaman, 2018). The teacher aims to create a learning environment in which students can acquire and improve the skills necessary to answer their own questions using the SWH (Schoerning et al., 2015). Learners learn how to find information, how to access the source, and how to use it to solve problems through learner-centered approaches (Llewellyn, 2007). Aguirre-Mendez et al., (2020) found that students who learn chemistry through the SWH approach develop more positive attitudes towards learning chemistry and have better conceptual understanding and argumentative skills than students who do not engage in implementations of this approach. Hand et al., (2021) conducted a systematic review of a total of 81 master's and doctoral theses based on "a knowledge generation approach to the learning of science called the SWH approach." These theses focus on students and/or teachers. The research highlighted the importance of questioning for success, the need for interactive dialogue/discussion environments, and the use and development of writing. It was also emphasized that the time to participate in the approach is important to achieve the desired outcomes for students and to develop teachers' expertise.

Perception of problem-solving skills, metacognition, IBLabs, and the SWH

Problem-solving is defined as finding the best ways to overcome the obstacles encountered (Morgan, 2000). Problem-solving is a process that begins with the perception of a problem and continues until the individual finds a solution, and it involves a series of efforts to overcome the challenges that arise in achieving the goal (Bingham, 1998; Güçlü, 2003). Problem-solving skills include the attitude and performance of the individual in the process of solving the problem. This skill is learned from childhood and is developed throughout the school years (Miller & Nunn, 2001). Problem-solving perception is an aspect of how individuals deal with problems they encounter. More specifically, it refers to one's belief in one's ability to solve problems, as well as one's awareness of the way one goes about solving problems. The perception of problem solving is an individualistic trait (Heppner, 1988; MacNair & Elliott, 1992). Previous research suggests that this perception is critical in shaping problem solving skills and thus has a deterministic power in problem solving (Heppner et al., 2004a; Larson et al., 1993). Perceptions of problem-solving skills can be described as a person's beliefs or judgements about their performance in the problem-solving process (Kaplan et al., 2016).

The "Problem-Solving Inventory" developed by Heppner & Petersen, (1982) and used in the current study consists of three factors, namely "(1) problem-solving confidence, (2) approach-avoidance style, and (3) personal control." These components show that each individual has a different perception of their problem-solving skills and a unique way of dealing with problems in everyday life (Heppner et al., 2004b). "Problem-solving confidence" assesses self-perceived confidence in solving problems when confronted with the problem for the first time. "Approach-avoidance style" assesses whether individuals tend to approach problems with alternative solutions, and "personal control" assesses elements of self-control, that is, how individuals manage emotions and behaviors in the face of unexpected problems (Heppner & Baker, 1997; Sahin et al., 1993; Taylan, 1990). When the factors of perceptions of problem-solving skills are evaluated together, it can be said that they may reflect the individual's perception of problem-solving skills in everyday life (Kaplan et al., 2016).

Metacognition is the awareness of an individual's cognitive processes (Flavell, 1979) and enables learners to understand and monitor their cognitive processes (Wengrowicz et al., 2018). Metacognition has been defined simply as thinking about thinking (Anderson, 1999; Jiménez-Aleixandre, 2007). Metacognition is being aware of one's thoughts and perceptions, monitoring one's cognitive processes, evaluating one's thoughts, and regulating one's cognitive processes in relation to recent learning (Hennessey, 1999; Wilson, 2001). Metacognition is examined in two dimensions, namely "metacognitive knowledge" and "metacognitive experience." "Metacognitive knowledge" refers to knowledge about oneself as a learner in terms of the cognitive processes one engages in, while "metacognitive experience" involves the regulation of one's cognition in the refinement of metacognitive knowledge (Flavell, 2000). Metacognition has an important impact on a person's knowledge of cognitive process activities such as monitoring and organizing learning, problem-solving, understanding, and reasoning (Chan & Mansoor, 2007; Öz, 2005). Metacognition is important because it is effective in the maintenance and implementation of learning, as well as in learning efficiency, critical thinking, and problem-solving (Hartman, 1998). Metacognition also provides the learners with skills such as being aware of the learning process, planning and choosing strategies, monitoring the learning process, correcting mistakes, checking whether the strategies used are working, and changing learning methods and strategies when necessary (Anderson, 1999). Kaplan et al., (2016) state that behaviors such as making full sense of a problem, choosing appropriate strategies after determining the action that will solve the problem, abandoning inappropriate strategies, and evaluating the results after putting the strategies into practice draw attention to metacognition. Metacognitive skills are believed to be closely related to educational activities such as problem-solving, inquiry, reading, and writing (Zohar & Dori, 2012). The literature suggests that metacognitive skills improve problem-solving and questioning skills and increase success and motivation (Kramarski, 2008; Teong, 2002; Vula et al., 2017). Previous research suggests that learning environments that encourage students to use metacognitive strategies promote problem-solving and higher-order thinking skills (Toth et al., 2000; White & Frederiksen, 1998).

Significance and purpose of the study

The term metacognition is often used in discussions about how to improve education and is an important component of educational reform that focuses focusing on inquiry and thinking (Wilson & Clarke, 2004; Zohar, 2006). It has been noted that the concept of metacognition, which influences the problem-solving process, should also be assessed within the perception of problem-solving skills (Butler & Meichenbaum, 1981; as cited in Kaplan et al., 2016). Inquiry-based learning is one of the most effective approaches to developing metacognitive and problem-solving skills in individuals (Carin & Bass, 2001; Llewellyn, 2005; Schraw et al., 2006). Studies have shown that inquiry-based learning activities have a positive impact on students' metacognitive skills or awareness (Raes et al., 2012; Yıldız, 2008; Yurdakul, 2004) and problem-solving skills (Dipasquale et al., 2003; Ibrahim, 2003; Lawson, 2010). In the same vein, studies in the field of chemistry education suggest that IBL environments enhance the use of metacognitive skills (Haidar & Al Naqabi, 2008; Sandi-Urena et al., 2011). IBLabs, by their very nature of promoting inquiry-type chemistry experiments, are crucial to the development of metacognitive skills (Kipnis & Hofstein, 2008). van Opstal & Daubenmire, (2015) identified several features of the learning environment that promote the use of metacognitive skills: a supportive social environment with a focus on reflective practice, as well as an inquiry-based approach (i.e., inductive learning). In this context, the SWH strategy, which promotes the use of metacognitive skills in chemistry laboratories, guides IBL practices, and constructs knowledge through collaborative work (Hand et al., 2004; van Opstal & Daubenmire, 2015), was preferred in this study. One of the reasons for preferring inquiry-based chemistry laboratory activities conjugated with the SWH approach is that it is the first laboratory teaching experience in which PCTs use the inquiry-based approach. In fact, as mentioned above, the teacher and student template of the SWH technique provides a guide to the process for prospective teachers. As an IBLab approach, SWH is designed to promote science achievement through a student-centered approach to collaborative learning. More specifically, as an argument-based inquiry approach, SWH helps students to use metacognitive strategies (Akkus et al., 2007) and thus contributes to their long-term problem-solving skills (Burke et al., 2006).

In their study, DiBiase & McDonald, (2015) show that science teachers consider the IBL approach as "an effective teaching tool, an important instructional strategy, as well as a motivating method to develop student problem-solving skills." It is well documented in previous studies that the use of IBL and SWH approaches contributes significantly to the development of students' problem-solving skills (Burke et al., 2006; DiBiase & McDonald, 2015; Rust, 2011) as well as metacognitive skills (Akkus et al., 2007; Haidar & Al Naqabi, 2008; Kipnis & Hofstein, 2008; van Opstal & Daubenmire, 2015). Despite its known benefits, IBL strategies have not been sufficiently implemented in teaching and learning, taking into account educational standards. A study by Deters, (2005) of 571 chemistry teachers found that 45.5% of teachers were not using IBLab practices. The reasons for the lack of emphasis on inquiry-based approach in science education have been the subject of many studies. Some of these drawbacks revolve around the fact that classes that implement IBL strategies tend to flow more slowly than traditional classes, and it takes more time to perform activities in these classes. In addition, lack of time for instructional materials, overcrowded classrooms, teachers' lack of pedagogical knowledge and skills, problems related to the implementation of these activities, and students' low motivation are some of the barriers related to the use of IBL approach in the classroom or argument-based inquiry instruction (Brown & Melear, 2006; Cheung, 2007; Choi et al., 2021; Duncan et al., 2010; Gao & Wang, 2014; Llewellyn, 2007; Ramnarain, 2014; Yoon et al., 2012). Among these reasons, the lack of teacher training is cited as the most important (Welch et al., 1981; Yoon et al., 2012; Zion et al., 2013). Based on two chemistry teachers' perceptions of inquiry, Gao & Wang, (2014) show that teachers lack experience and knowledge in translating the new curriculum expectations and content into inquiry-based instruction and in applying the approach in their classrooms. The role of teacher development in the IBL process is not clear-cut (Murphy et al., 2021). However, the literature indicates that there is a strong correlation between teachers' questioning skills and their ability to use the SWH approach and students' performance and conceptual development (Akkus et al., 2007; Gunel, 2006; McDermott, 2009; Mohammad, 2007; Poock, 2005). In addition, the willingness and readiness of teachers to implement new approaches are another crucial factor (Gunel, 2006; Promyod, 2013), as the time that teachers need to become proficient in applying a new approach (Gunel, 2006). The professional development of teachers begins during their undergraduate education and continues throughout their professional lives. Therefore, it is important to provide prospective teachers with opportunities to put into practice the theoretical knowledge they have acquired during their undergraduate education. The development of teacher competencies and practices has long been the focus of the teaching profession. Thus, supporting the development of teachers' competencies has been on the agenda of several countries, and Türkiye is no exception.

In the research in which the prospective teachers participated, it was found that the IBL activities had a positive impact on learners' metacognitive skills (Kipnis & Hofstein, 2008; Raes et al., 2012) and perceptions of problem-solving skills (Ibrahim, 2003; Lawson, 2010). Unlike other studies, the aim of this study is to examine the effects of PCTs' carrying out laboratory practices as teachers on their own development in terms of metacognitive thinking skills and perceptions of problem-solving skills variables. Therefore, the current study seeks to answer the following research questions:

1. Do teaching experiences relying on the inquiry-based chemistry laboratory activities conjugated with the SWH have significant and positive effects on PCTs' perceptions of problem-solving skills compared to traditional laboratory teaching experiences?
2. Do teaching experiences relying on the inquiry-based chemistry laboratory activities conjugated with the SWH have significant and positive effects on PCTs' metacognitive thinking skills compared to traditional laboratory teaching experiences?

Method

Research design

The current study was designed to provide PCTs with the opportunity to design and practice activities based on laboratory approaches and to explore the impact of these practices on their metacognitive thinking skills and perceptions of problem-solving skills. In the data collection phase, "the quasi-experimental non-equivalent pre-test/post-test control group research design" was utilized. In this design, comparison groups are randomly assigned to control and experimental groups; participants are not randomly assigned to these groups; preformed or intact groups are used; and two treatment groups are pre-tested, treated, and post-tested (Fraenkel & Wallen, 2006; Gay & Airasian, 2000). One group was randomly assigned to the experimental group, where the PCTs carried out teaching experiences relying on the inquiry-based chemistry laboratory activities conjugated with the SWH, and the other group was randomly assigned to the control group, where the PCTs carried out teaching experiences based on the traditional laboratory approach. The PCTs in both groups were administered the Problem-Solving Inventory and the Metacognitive Thinking Skills Scale as pre- and post-tests.

Participants

The study was conducted with 27 volunteer PCTs who were senior students in the Department of Chemistry Education at a public university in Ankara, Türkiye. There were 14 PCTs in the experimental group and 13 PCTs in the control group. The majority of subject-specific and professional teaching knowledge courses were completed by the PCTs. The age of the participants ranged from 23 to 25 years. PCTs have laboratory experience as students. They have no previous experience as a teacher using IBL, the SWH approach, or the traditional laboratory approach.

Instruments

The PCTs were given two instruments: *Problem-Solving Inventory* and *Metacognitive Thinking Skills Scale*. Each participant was given 40 min to complete the task.

Instrument 1: Problem-Solving Inventory (PSI)

The inventory, which measures an individual's self-perception of problem-solving skills, was developed by Heppner & Petersen, (1982) and first adapted to Turkish by Akkoyun and Öztan (as cited in Taylan, 1990), followed by Taylan, (1990), Sahin et al., (1993), Savaşır & Şahin, (1997), and Güçlü, (2003). The study of Güçlü, (2003) was taken into consideration in determining the perceived level of problem-solving skills of PCTs. Accordingly, the inventory consists of three factors and 28 items, including 10 items in the "Problem-Solving Confidence" (PSC) factor, 13 items in the "Approach-Avoidance Style" (AAS) factor, and 5 items in the "Personal Control" (PC) factor. PSC is described as confidence in one's ability to solve problems when engaging in a variety of problem-solving activities. PC is defined as the belief that one is in control of one's emotions and behavior during problem-solving, while AAS is described as a general tendency to approach or avoid various problem-solving activities (Heppner & Baker, 1997).

The sample items for each factor are presented in Table 1.

The Cronbach's alpha values of these factors were calculated as 0.81, 0.84, and 0.70, respectively (Güçlü, 2003).

A high score on this scale indicates that an individual feels incompetent in terms of problem-solving skills (Heppner & Petersen, 1982; Taylan, 1990). The inventory is a self-assessment questionnaire. The inventory does not determine an individual's problem-solving skills, but it does allow them to assess or notice their problem-solving skills or

Table 1 The sample items for each factor of PSI

PSC	I am usually able to think up creative and effective alternatives to solve a problem. When faced with a novel situation, I have confidence that I can handle problems that may arise
AAS	When a solution to a problem was unsuccessful, I do not examine why it didn't work. When I am confused by a problem, one of the first things I do is survey the situation and consider all the relevant pieces of information
PC	Even though I work on a problem, sometimes I feel like I am groping or wandering, and am not getting down to the real issue. Sometimes I get so charged up emotionally that I am unable to consider many ways of dealing with my problems

performance in the problem-solving process (Abaan & Altıntoprak, 2005). The PSI was administered to PCTs in both groups as a pre- and post-test to examine the effect of chemistry laboratory teaching experiences on PCTs' perceptions of problem-solving skills.

Instrument 2: Metacognitive Thinking Skills Scale (MTSS)

The scale developed by Tuncer & Kaysi, (2013) was used to determine the metacognitive thinking skills of PCTs. It is a 5-point Likert-type scale consisting of 18 items and four factors. The factors of the scale are as follows: "Thinking Skills (TS)," "Reflective Thinking Skills Towards Problem-Solving (RTSTPS)," "'Decision-Making Skills (DMS)," and "Alternative Skills of Evaluation (ASE)." The sample items for each factor are presented in Table 2.

The Cronbach's alpha reliability coefficient values of the scale were 0.881 for the whole scale, 0.786 for the TS factor, 0.767 for the RTSTPS factor, 0.784 for the DMS factor, and 0.704 for the ASE factor (Tuncer & Kaysi, 2013). To examine the effect of chemistry laboratory teaching experiences on PCTs' metacognitive thinking skills, the MTSS was administered to PCTs in both the experimental and control groups as a pre- and post-test.

Procedure

The research protocol was approved by the University Ethics Committee and informed consent was obtained from all participants. The research study covers a period of 14 weeks. The distribution of practices performed in the experimental and control groups during this process by week is as follows:

In the first week, the PCTs were briefed by the researcher on the content and procedures. The PSI and MTSS were administered as a pre-test.

In the second week, the PCTs were informed through visual materials about basic laboratory materials, cleaning and drying of glass materials, precautions to be taken while working in the laboratory, laboratory accidents, and first aid. The aim of this process was to refresh the forgotten information and to encourage the PCTs to take this information into account in their practices.

PCTs in the experimental group were provided with information and practical examples of the IBL and SWH approaches. The SWH, which is shown in the student template in Appendix Table 7 and consists of seven stages, was shared with the PCTs

Table 2 The sample items for each factor of MTSS

TS	I try different working methods to obtain the best solution. Before beginning a new task, I think of what I will need to learn the task
RTSTPS	After solving a problem, I think if I could find a better way. After I solve a problem, I compare my results with my friends' results and evaluate the solution
DMS	I think about how my decisions can affect others. Before I make a decision, I think carefully what, how and to whom my decision will address
ASE	I am aware of thinking techniques or strategies concerning the topic I am working on. I change my thinking technique or strategy of my work when necessary

for use in their laboratory practices. The PCTs were free to determine the topics and choose the experiments.

In determining the topic and selecting the experiments, it was pointed out that the chosen topic should be applicable to this approach, that the expected readiness of the students for the topics and experiments should be taken into consideration, that the directions to be used in the topics and the experiments should be planned, and that the issues to be considered in the experiments (the experiment should be interesting, intriguing; the materials used in the experiment should be available in laboratories or easily obtainable; the experiment should not have harmful effects, etc.) were indicated.

Once the information was provided, the dates of the practices were set primarily at the request of the PCTs.

PCTs in the control group were provided with information and practice samples on the traditional "cookbook" laboratories. They were also free to determine the topics and choose the experiments.

In the 3rd, 4th, 5th, and 6th weeks, the PCTs were given time to conduct their research, develop their plan, and complete their preparations. During this 4-week preparation period, the PCTs were guided by the researcher as needed.

According to the high school chemistry curriculum, the topics and grade levels of the topics used by the PCTs in the practices are as follows:

1. *9th Grade:* (1) States of Matter, (2) Periodic Specifications - Heat Conduction, (3) Surface Tension of Liquids, (4) Evaporation, Condensation, and Boiling
2. *10th Grade:* (5) Mixtures, (6) Mixtures - The Concept of Dissolution, (7) Law of Conservation of Mass, (8) Acids and Bases, (9) Acids and Bases in Our Lives
3. *11th Grade:* (10) Gases-Gas Pressure, (11) Ideal Gas Law, (12) Chemical Reactions-Combustion Reactions, (13) Exothermic and Endothermic Reaction Concepts, (14) Factors Affecting Solubility and Dissolution Rates

During the following 7 weeks, the PCTs in the experimental group carried out the laboratory teaching experiences they had prepared based on the IBLab activities conjugated with the SWH. The PCTs carried out their practices in a laboratory environment with 10–12 students, designed for an appropriate grade level (i.e., micro-teaching practices). The participating students were experienced with the IBL approach; more specifically, they were quite competent in using information sources and asking questions according to the grade level. During the implementation process, students worked in groups of 3 or 4 for one or two class periods, depending on the focus content.

During the following 7 weeks, the PCTs in the control group carried out the laboratory teaching experiences they had prepared using the traditional laboratory approach. They carried out their practices in a laboratory environment with 10–12 students, designed for an appropriate grade level (i.e., micro-teaching practices).

During the last week, the PSI and the MTSS were administered to the PCTs as a post-test. In addition, the PCTs in each group were brought together and asked to evaluate themselves for their development, briefly summarize their practices, share their experiences, and communicate their suggestions to each other. The researchers also made evaluations of the successful parts, the parts that could be improved, the parts that were defective, if any, and the parts that could be made differently.

Data analysis

The data obtained from the two groups were transferred to the electronic environment and prepared for the required statistical analysis. IBM SPSS 2023 statistical software was utilized for data analysis. Descriptive statistics and the results of the Shapiro-Wilk normality test were examined to obtain information about the general characteristics of the data and to determine whether or not they were normally distributed (see Appendix Table 8). The PSI and MTSS pre- and post-test total and factor scores of the PCTs show a normal distribution ($p > .05$). Therefore, it was decided that using the parametric test would be appropriate to answer the research questions. A dependent *t* test was used to test the significance of the difference between PSI and MTSS pre- and post-test total and factor scores within the groups. An independent *t* test was performed to determine the differences between the groups.

Results

Preliminary results

In order to better understand the effect of the PCTs' teaching experiences relying on the IBLab activities conjugated with the SWH on their perceptions of problem-solving skills and metacognitive thinking skills, the equivalence of the control and experimental groups was assessed.

For this reason, the mean pre-test scores for the control and the experimental groups were compared using an independent *t* test (see Appendix Table 9). The *t* test results indicated that there were no significant differences between the control and experimental group participants' mean pretest scores on the PSI and MTSS (p ˃ .05). According to these results, the PCTs' metacognitive thinking skills and perceptions of problem-solving skills were initially considered equal for both groups.

Results of the 1st research question

The first research question was as follows: "Do teaching experiences relying on the inquiry-based chemistry laboratory activities conjugated with the SWH have significant and positive effects on PCTs' perceptions of problem-solving skills compared to traditional laboratory teaching experiences?" In order to answer this question, a comparison was made between the perceptions of problem-solving skills of the PCTs in the experimental group and those in the control group. The results of the independent *t* test conducted to examine the mean PSI scores of the control and experimental groups are presented in Table 3.

The low scores obtained from the PSI are effective in solving problems refer to effectiveness in problem-solving, and high scores indicate an inability to find effective solutions to problems.

The results of the analysis show that there is no statistically significant difference between the mean PSI post-test total scores of the PCTs of the control and experimental groups ($p > .05$). Regarding the PSI factors, there was a statistically significant difference between the post-test scores of the control and experimental groups on the PSC ($p < .05$), but there was no statistically significant difference between the post-test scores of

Table 3 The *t* test results of the post-test scores of the PCTs on the PSI

PSI		*N*	*M*	SD	df	*t*	*p*
PSC	Control	13	23.46	4.57	25	−2.524	.018
	Experimental	14	18.85	4.88			
AAS	Control	13	34.23	7.16	25	−0.906	.374
	Experimental	14	31.92	6.03			
PC	Control	13	16.30	2.81	25	−0.790	.437
	Experimental	14	15.57	1.98			
Total score	Control	13	74.00	12.47	25	−1.787	.086
	Experimental	14	66.35	9.66			

the control and experimental groups on the AAS and PC factors ($p > .05$). The effect size (Cohen's *d*) of the PSC variable that had a statistically significant difference was calculated to be 0.97. For the calculated *d* value, 0.20 indicates a small effect size, 0.50 indicates a medium effect size, and 0.80 indicates a large effect size (Cohen, 1992). Accordingly, the effect size of the PSC variable is quite large.

Once these results were obtained, the differences between the pre- and post-test scores of the groups were also examined. The dependent *t* test was used (see Table 4).

Based on the results presented in Table 4, there was no statistically significant difference between the pre- and post-test scores of the PSC, AAS, PC factors and total scores of the control group PCTs. On the other hand, there was a statistically significant difference between the pre- and post-test scores of the PCTs in the experimental group in terms of total scores and all factor scores except the PC factor scores ($p < .05$). The mean PSI score of the PCTs in the experimental group was 76.92 before the practices and 66.35 after the practices. The mean PSC factor score of the PCTs was

Table 4 The *t* test results of the pre- and post-test scores of the PCTs on the PSI

PSI			*N*	*M*	SD	df	*t*	*p*
PSC	Control	Pre-test	13	23.92	8.59	12	−0.172	.866
		Post-test	13	23.46	4.57			
	Experimental	Pre-test	14	24.14	9.26	13	−2.422	.031
		Post-test	14	18.85	4.88			
AAS	Control	Pre-test	13	36.61	5.73	12	−0.753	.466
		Post-test	13	34.23	7.16			
	Experimental	Pre-test	14	37.00	6.07	13	−2.649	.020
		Post-test	14	31.92	6.03			
PC	Control	Pre-test	13	15.30	2.65	12	0.987	.343
		Post-test	13	16.30	2.81			
	Experimental	Pre-test	14	15.78	2.72	13	−0.291	.775
		Post-test	14	15.57	1.98			
Total score	Control	Pre-test	13	75.84	14.28	12	0.301	.769
		Post-test	13	74.00	12.47			
	Experimental	Pre-test	14	76.92	14.19	13	−3.201	.007
		Post-test	14	66.35	9.66			

calculated as 24.14 before the practices and 18.85 after the practices; the mean AAS factor score was calculated as 37.00 before the practices and 31.92 after the practices; and the mean PC factor score was calculated as 15.78 before the practices and 15.57 after the practices. When examined according to the factors, it can be seen that the teaching experiences relying on the IBLab activities conjugated with the SWH lead to a significant change in the improvement of the PSC and AAS factor scores of the PCTs but do not lead to a significant change in the PC factor scores (although there is a slight decrease in the scores).

Results of the 2nd research question

The second research question was as follows: "Do teaching experiences relying on the inquiry-based chemistry laboratory activities conjugated with the SWH have significant and positive effects on PCTs' metacognitive thinking skills compared to traditional laboratory teaching experiences?" In order to answer this question, a comparison was made between the metacognitive thinking skills of the PCTs in the experimental group and those in the control group. The results of the independent *t* test conducted to examine the mean scores of the control and experimental groups on the MTSS are presented in Table 5.

The results showed that there was a statistically significant difference between the mean scores on the MTSS total and factor post-tests scores of the PCTs of the two research groups in favor of the experimental group ($p < .05$). The effect sizes (Cohen's *d*) of the variables with statistically significant differences (TS, RTSTPS, DMS, ASE, and total score) were calculated as 1.71, 3.77, 1.92, 3.33, and 3.98, respectively. Accordingly, the effect size is quite large.

As a result of these findings, the differences between the pre- and post-test scores of the groups were also examined. The dependent *t* test was used (see Table 6).

The analysis results shown in Table 6 indicate that there was no statistically significant difference between the pre- and post-test scores of the TS, RTSTPS, ASE factors and the total scores of the control group PCTs ($p > .05$), but there was a statistically significant difference between the pre- and post-test scores of the DMS factor only ($p < .05$). On the other hand, there was a statistically significant difference between the pre- and post-test scores of the PCTs in the experimental group in terms of total scores and all factor scores ($p <$ .05), in favor of the post-test scores. It was found that total and factor mean MTSS scores

Table 5 The *t* test results of the post-test scores of the PCTs on the MTSS

MTSS		*N*	*M*	*SD*	df	*t*	*p*
TS	Control	13	18.77	1.69	25	4.457	.00
	Experimental	14	22.21	2.25			
RTSTPS	Control	13	15.92	1.44	25	9.814	.00
	Experimental	14	21.50	1.50			
DMS	Control	13	14.30	1.31	25	4.992	.00
	Experimental	14	17.21	1.67			
ASE	Control	13	12.77	1.73	25	8.651	.00
	Experimental	14	17.78	1.25			
Total score	Control	13	61.77	3.08	25	10.356	.00
	Experimental	14	78.71	5.09			

Table 6 The *t* test results of the pre- and post-test scores of the PCTs on the MTSS

MTSS			*N*	*M*	*SD*	df	*t*	*p*
TS	Control	Pre-test	13	18.15	1.67	12	-1.979	.071
		Post-test	13	18.77	1.69			
	Experimental	Pre-test	14	18.35	2.13	13	4.880	.000
		Post-test	14	22.21	2.25			
RTSTPS	Control	Pre-test	13	15.30	1.79	12	-1.860	.088
		Post-test	13	15.92	1.44			
	Experimental	Pre-test	14	15.92	1.43	13	9.438	.000
		Post-test	14	21.50	1.50			
DMS	Control	Pre-test	13	13.61	1.85	12	-2.920	.013
		Post-test	13	14.30	1.31			
	Experimental	Pre-test	14	13.50	1.45	13	5.316	.000
		Post-test	14	17.21	1.67			
ASE	Control	Pre-test	13	12.46	1.66	12	-1.477	.165
		Post-test	13	12.77	1.73			
	Experimental	Pre-test	14	12.92	1.26	13	14.062	.000
		Post-test	14	17.78	1.25			
Total score	Control	Pre-test	13	60.23	3.26	12	-2.187	.05
		Post-test	13	61.77	3.08			
	Experimental	Pre-test	14	61.07	3.70	13	11.012	.000
		Post-test	14	78.71	5.09			

increased after the practices (see Table 6). From the data obtained, it can be concluded that the teaching experiences relying on the IBLab activities conjugated with the SWH have a significant effect on the increase of the factor scores and the total scores of the metacognitive thinking skills of the PCTs.

Discussion

In terms of the professional development of prospective teachers, it is important that they put into practice the theoretical knowledge they have acquired during their undergraduate education through their teaching experiences. The present study primarily provided PCTs with an opportunity to translate their theoretical knowledge of IBLabs, SWH, and the traditional laboratory approach into practical action. This study aimed to examine the effects of PCTs' teaching experiences relying on the inquiry-based chemistry laboratory activities conjugated with the SWH approach on their "perceptions of problem-solving skills" and "metacognitive thinking skills." This was done by comparing the data from two groups in the presence of a control group performing traditional laboratory activities.

The results showed that there was a more positive improvement in the perceptions of problem-solving skills of the PCTs in the experimental group compared to the PCTs in the control group on the total score and all factor scores (see Table 4). While there was no significant difference between the pre- and post-test in the control group for PSI total and factor scores, the positive improvements in the experimental group were found to be significant, except for the PC factor. The results also show that there was a significant difference in favor of the experimental group in terms of total scores in these improvements (see Table 4). When the mean post-test scores of the factors were examined, it was found that there was a significant change in the scores of the PSC factor in favor of the experimental group; however, the improvement in the scores of the AAS and PC factors and the PSI total scores did not result in a significant change (see Table 3). When the statements provided in the factors were examined, it was seen that the factor of PSC includes the items related to finding creative and effective solutions to solve problems, ability to solve problems, ability to solve new and difficult problems, confidence in understanding problems and making plans to solve the problem, and being able to carry out the plan. In other words, this factor reveals PCTs' confidence in their problem-solving skills. In contrast to the control group, the PCTs in the experimental group prepared for the application of the laboratory approach, which was new to them, by planning the process by thinking like a student, thinking of additional applications to guide the students, evaluating the possibilities by trying the experiments themselves before the lesson, and making plans to reach the end of the process despite possible problems in the application process. In this regard, it is thought that the significant increase in confidence in problem-solving skills (i.e., PSC factor score) of the PCTs in the experimental group is closely related to the preparation process for laboratory applications. The AAS factor includes expressions such as evaluating the options or generating many options in the problem-solving process, evaluating the success rates of each of the options, evaluating the effect of external factors in solving the problem, and evaluating the information related to the issue. The PC factor includes statements about making personal decisions, personal problems and solutions, and making immediate or emotional decisions. Although there is some improvement, the lack of a significant difference in the AAS factor, which indicates the individual's behavior to face the problem or escape, and the PC factor, which expresses the individual's sense of being able to control the problem situation, can be explained by the fact that they did only one laboratory application and did not encounter enough situations related to these variables during the application process. It has been found that the development of higher-order skills is more likely to occur through inquiry or problem-based experiments in laboratories (Hofstein et al., 2005; Seery et al., 2019). In contrast to the other studies, the present research examined the impact of teaching experiences (designing and practicing laboratory activities) based on the IBLab activities conjugated with SWH on prospective teachers' perceptions of problem-solving skills. The PCTs went through different stages of preparation to carry out practices with their students using IBL activities conjugated with SWH as the teacher. They created different plans they could use to think about the problems or situations they might face and to guide their students through the problems they might encounter. In addition, during the implementation process, they were faced with situations that they had not anticipated during the preparation phase and, as teachers, created appropriate solutions. The researcher guided the PCTs both during the preparation phase and by conducting post-practice evaluations. Suggested solutions for situations they might encounter during practice were discussed. It can be said that all of these processes are more effective in their perception of problem-solving skills compared to the control group. This study did not focus on improving PCTs' problem-solving skills. In the problem-solving process, the perception of the individual's problem-solving ability is crucial (Wismath et al., 2014). How individuals perceive themselves in terms of their problem-solving skills is an important aspect of how they think and behave in the problem-solving process (Larson et al., 1993). In developing problem-solving skills, it is important to provide guidance and feedback to individuals by introducing strategic methods and modeling their use (Jeon et al., 2005). Göktepe Yıldız & Göktepe Körpeoğlu, (2023) found that there is a relationship between students' creative problem-solving characteristics and their perceptions of problem-solving skills. While individuals with a high perception of problem-solving skills are able to deal with the events they encounter in a calm and decisive manner, individuals with a low perception of problem-solving skills are anxious and insecure in the face of events and failure to understand the expectations of others (Dixon et al., 1991; Rosenberg, 1989). From this point of view, teachers who have high perceptions of problem-solving skills will be effective in their school life and in the processes of coping with the problems they will encounter in the learning environment.

Another result of the current study showed that there were differences in the PCTs' total metacognitive thinking skills scores and the scores of TS, RTSTPS, DMS, and ASE when the groups were compared to each other. The results showed that there was a more positive increase in the metacognitive thinking skills of the PCTs in the experimental group compared to the PCTs in the control group on the total score and all factor scores. While there was no significant difference between the pre- and post-test in the control group for MTSS total and factor scores except for the DMS factor score, all positive improvements in the experimental group were found to be significant. The literature found that IBL activities positively developed learners' metacognitive thinking skills/awareness (Raes et al., 2012; Yıldız, 2008; Yurdakul, 2004). To date, there is no research on the impact of prospective teachers' designing and practicing activities based on the IBLab activities conjugated with the SWH approach as a teacher on their metacognitive thinking skills. In SWH-based practices, students engage in metacognitive activities. The positive impact of SWH practices used in science courses on the development of students' metacognitive knowledge and skills has been highlighted in several studies (Hand et al., 2004; Hohenshell & Hand, 2006; Keys et al., 1999). Wallace et al., (2004) stated that learners are expected to have metacognitive skills to acquire skills such as making explanations, providing evidence to support their knowledge, making claims using data they have obtained, and interpreting the data in relation to their research questions by making evaluations. Chemistry teachers are expected to be aware of and develop their own metacognitive skills and to create learning environments that enhance students' cognitive, affective, and metacognitive skills. Several studies have emphasized the importance of metacognition for problem-solving skills and understanding of chemistry topics (Cooper & Sandi-Urena, 2009; Kaberman & Dori, 2009; Tsai, 2001). In addition, as part of this study, prospective teachers also reflected on their preparation, practices, and experiences and rated them as positive-negative, successful-unsuccessful, incomplete-exaggerated, or other. This is consistent with the function of developing metacognitive skills. Zion et al., (2005) also claim that the development of metacognitive skills is usually provided by asking students to monitor and reflect on their learning performance.

Conclusion

In summary, the results of this study show that PCTs' teaching experiences relying on the IBL activities conjugated with the SWH had a positive effect on their perceptions of problem-solving skills and metacognitive thinking skills, compared to traditional laboratory teaching experiences. The current study differs from previous studies in that it focuses on design activities and experiments of PCTs through IBL activities conjugated with SWH. Although the IBL and SWH approaches have been well documented in previous research, prospective teachers participate in these studies as students, not in the role of teachers as in the current study. This study provides new insights into the impact of variables (i.e., students' questions and challenges) in the laboratory practice preparation and practice processes on the development of PCTs. In addition, the impact of these processes was quantitatively evaluated using scales compared to the tradition in existing research.

As a necessity of our age, we aim to educate our students to be scientifically literate, responsible learners, curious, entrepreneurial, explorers, and problem solvers. To achieve this goal, it is necessary to train future teachers to design learning environments based on constructivist approach so that learners can acquire these skills. Therefore, it is essential to provide opportunities for prospective teachers to put into practice the theoretical knowledge they have acquired during their education, to experience the process of teaching, and to practice and gain experience.

Appendix

Table 7 SWH teacher template and student template

Teacher template		
Exploration of pre-instructional understanding through individual or group concept mapping.		
Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.		
Participation in laboratory activity.		
Negotiation phase I—writing personal meanings for laboratory activity (e.g., writing journals).		
Negotiation phase II—sharing and comparing data interpretations in small groups (e.g. making a group chart).		
Negotiation phase III—comparing science ideas to textbooks or other printed resources (e.g. writing group notes in response to focus questions).		
Negotiation phase IV—individual reflection and writing (e.g., creating a presentation such as a poster or report for a larger audience).		
Exploration of post instruction understanding through concept mapping.		
Student template		
Beginning ideas	-----	What are my questions?
Tests	-----	What did I do?
Observations	-----	What did I see?
Claims	-----	What can I claim?
Evidence	-----	How do I know? Why am I making these claims?
Reading	-----	How do my ideas compare with other ideas?
Reflection	-----	How have my ideas changed?

Table 8 Normality test results of groups for the PSI and MTSS pre-test and post-test

Shapiro-Wilk					
Variables		Groups	Statistic	df	Sig. (p)
PSI pre-test	PSC	Experimental	0.935	14	.354
		Control	0.929	13	.333
	AAS	Experimental	0.969	14	.867
		Control	0.970	13	.891
	PC	Experimental	0.961	14	.740
		Control	0.971	13	.905
	Total	Experimental	0.943	14	.453
		Control	0.970	13	.892
PSI post-test	PSC	Experimental	0.964	14	.781
		Control	0.970	13	.891
	AAS	Experimental	0.945	14	.491
		Control	0.890	13	.097
	PC	Experimental	0.942	14	.449
		Control	0.955	13	.676
	Total	Experimental	0.965	14	.808
		Control	0.953	13	.643
MTSS pre-test	TS	Experimental	0.918	14	.204
		Control	0.927	13	.313
	RTSTPS	Experimental	0.890	14	.080
		Control	0.904	13	.154
	DMS	Experimental	0.897	14	.102
		Control	0.913	13	.203
	ASE	Experimental	0.901	14	.116
		Control	0.917	13	.226
	Total	Experimental	0.975	14	.935
		Control	0.975	13	.946
MTSS post-test	TS	Experimental	0.914	14	.177
		Control	0.917	13	.230
	RTSTPS	Experimental	0.900	14	.114
		Control	0.914	13	.207
	DMS	Experimental	0.951	14	.576
		Control	0.919	13	.246
	ASE	Experimental	0.907	14	.142
		Control	0.918	13	.237
	Total	Experimental	0.971	14	.894
		Control	0.973	13	.930

Table 9 The *t* test results of the PCTs in the control and experimental groups on the PSI and MTSS pre-test scores

Variables		Groups	*N*	$\overline{X}$	SD	df	*t*	*p*
PSI	PSC	Control	13	23.92	8.59	25	0.064	.950
		Experimental	14	24.14	9.26			
	AAS	Control	13	36.61	5.73	25	0.169	.867
		Experimental	14	37.00	6.07			
	PC	Control	13	15.30	2.65	25	0.461	.649
		Experimental	14	15.78	2.72			
	Total score	Control	13	75.84	14.28	25	0.197	.845
		Experimental	14	76.92	14.19			
MTSS	TS	Control	13	18.15	1.67	25	0.274	.786
		Experimental	14	18.35	2.13			
	RTSTPS	Control	13	15.30	1.79	25	0.994	.330
		Experimental	14	15.92	1.43			
	DMS	Control	13	13.61	1.85	25	−0.181	.858
		Experimental	14	13.50	1.45			
	ASE	Control	13	12.46	1.66	25	0.824	.418
		Experimental	14	12.92	1.26			
	Total score	Control	13	60.23	3.26	25	0.623	.539
		Experimental	14	61.07	3.70			

Abbreviations *IBL*: Inquiry-based learning; *IBLab*: Inquiry-based laboratory; *IBLabs*: Inquiry-based laboratories; *SWH*: Science writing heuristic; *PCTs*: Prospective chemistry teachers

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Data Availability The data sets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate Ethical approval and necessary permissions were obtained from respective authorities to carry out this research. Also, informed consent was obtained from all individual participants included in this research.

Conflict of interest The author declares no competing interests.

References

Abaan, D. S., & Altıntoprak, U. A. (2005). Hemşirelerde problem çözme becerileri: Öz değerlendirme sonuçlarının analizi [Nurses' perceptions of their problem solving ability: Analysis of self apprasials]. *Hacettepe Üniversitesi Hemşirelik Fakültesi Dergisi, 12*(1), 62–76.

Açıkgöz, K. Ü. (2008). *Aktif öğrenme*. Biliş Eğitim.

Aguirre-Mendez, C., Chen, Y.-C., Terada, T., & Techawitthayachinda, R. (2020). Predicting components of argumentative writing and achievement gains in a general chemistry course for nonmajor college students. *Journal of Chemical Education, 97*, 2045–2056. https://doi.org/10.1021/acs.jchemed.0c00042
Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the science writing heuristic to traditional science teaching practices: are there differences? *International Journal of Science Education, 29*(14), 1745–1765. https://doi.org/10.1080/09500690601075629
Aldahmash, A. H., & Omar, S. H. (2021). Analysis of activities included in Saudi Arabian chemistry textbooks for the inclusion of argumentation-driven inquiry skills. *Studies in Educational Evaluation, 68*, 100968. https://doi.org/10.1016/j.stueduc.2020.100968
Anderson, N. J. (1999). *Exploring second language reading: issues and strategies*. Heinle & Heinle.
Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and Children, 46*(2), 26–29.
Beerenwinkel, A., Parchmann, I., & Gräsel, C. (2011). Conceptual change texts in chemistry teaching: a study on the particle model of matter. *International Journal of Science and Mathematics Education, 9*(5), 1235–1259. https://doi.org/10.1007/s10763-010-9257-9
Bicak, B. E., Borchert, C. E., & Höner, K. (2021). Measuring and fostering preservice chemistry teachers' scientific reasoning competency. *Education Sciences, 11*(9), 496. https://doi.org/10.3390/educsci11090496
Bingham, A. (1998). *Improving problem-solving skills of children (A. F. Oğuzhan, Trans.)*. Milli Eğitim Basımevi.
Bretz, S. L. (2019). Evidence for the importance of laboratory courses. *Journal of Chemical Education, 96*, 193–195. https://doi.org/10.1021/acs.jchemed.8b00874
Brown, S. L., & Melear, C. T. (2006). Investigation of secondary science teachers' beliefs and practices after authentic inquiry-based experiences. *Journal of Research in Science Teaching, 43*(9), 938–962. https://doi.org/10.1002/tea.20110
Butler, L., & Meichenbaum, D. (1981). The assessment of interpersonal problem-solving skills. In: P. Kendall, C., & Hollon, S.D. (eds.) *Assessment strategies for cognitive-behavioral interventions* (pp. 197–225). New York: Academic Press.
Burke, K. A., Greenbowe, T. J., & Hand, B. M. (2006). Implementing the science writing heuristic in the chemistry laboratory. *Journal of Chemical Education, 83*(7), 1032–1038. https://doi.org/10.1021/ed083p1032
Carin, A. A., & Bass, J. E. (2001). *Teaching science as inquiry*. Merrill/Prentice-Hall.
Chan, E. C.M., & Mansoor, N. (2007). Metacognitive behaviours of primary 6 students in mathematical problem solving in a problem-based learning setting. In *Proceedings of the Redesigning pedagogy: culture, knowledge and understanding conference, Singapore, May 2007, Centre for Research in Pedagogy and Practice- Conference Papers*. http://hdl.handle.net/10497/234
Cheung, D. (2007). Facilitating chemistry teachers to implement inquiry-based laboratory work. *International Journal of Science and Mathematics Education, 6*, 107–130. https://doi.org/10.1007/s10763-007-9102-y
Cohen, J. (1992). Statistical power analysis. *Current Directions in Psychological Science, 1*(3), 98–101. https://doi.org/10.1111/1467-8721.ep10768783
Choi, A., Notebaert, A., Diaz, J., & Hand, B. (2010). Examining arguments generated by year 5, 7, and 10 students in science classrooms. *Research in Science Education, 40*, 149–169. https://doi.org/10.1007/s11165-008-9105-x
Choi, A., Seung, E., & Kim, D. (2021). Science teachers' views of argument in scientific inquiry and argument-based science instruction. *Research in Science Education, 51*(1), 251–268. https://doi.org/10.1007/s11165-019-9861-9
Colburn, A. (2000). An inquiry primer. *Science Scope, 23*(6), 42–44.
Cooper, M. M., & Sandi-Urena, S. (2009). Design and validation of an ınstrument to assess metacognitive skillfulness in chemistry problem-solving. *Journal of Chemical Education, 86*(2), 240–245. https://doi.org/10.1021/ed086p240
Deters, K. M. (2005). Student opinions regarding inquiry-based labs. *Journal of Chemical Education, 82*, 1178–1180. https://doi.org/10.1021/ed082p1178
DiBiase, W., & McDonald, J. R. (2015). Science teacher attitudes toward inquiry-based teaching and learning. *The Clearing House: A Journal of Educational Strategies, Issues, and Ideas, 88*(2), 29–38. https://doi.org/10.1080/00098655.2014.987717
Dipasquale, D. M., Mason, C. L., & Kolkhorst, F. W. (2003). Exercise in inquiry: critical thinking in an inquiry-based exercise physiology laboratory course. *Journal of College Science Teaching, 32*(6), 388–393.

Dixon, W. A., Heppner, P. P., & Anderson, W. P. (1991). Problem-solving appraisal, stress, hopelessness, and suicide ideation in a college population. *Journal of Counseling Psychology, 38*(1), 51–56. https://doi.org/10.1037/0022-0167.38.1.51

Duncan, R. G., Pilitsis, V., & Piegaro, M. (2010). Development of preservice teachers' ability to critique and adapt inquiry-based instructional materials. *Journal of Science Teacher Education, 20*(1), 81–102. https://doi.org/10.1007/s10972-009-9153-8

Flavell, J. H. (1979). Metacognition and cognitive monitoring: a new area of cognitive-developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

Flavell, J. H. (2000). Development of children's knowledge about the mental world. *International Journal of Behavioral Development, 24*(1), 15–23. https://doi.org/10.1080/016502500383421

Fraenkel, J. R., & Wallen, N. E. (2006). *How to design and evaluate research in education*. McGraw-Hill.

Furtak, E. M. (2006). The problem with answers: an exploration of guided scientific inquiry teaching. *Science Education, 90*(3), 453–467. https://doi.org/10.1002/sce.20130

Gao, S., & Wang, J. (2014). Teaching transformation under centralized curriculum and teacher learning community: two Chinese chemistry teachers' experiences in developing inquiry-based instruction. *Teaching and Teacher Education, Education, 44*, 1–11. https://doi.org/10.1016/j.tate.2014.07.008

Gay, L. R., & Airasian, P. (2000). *Educational research: competencies for analysis and application.* .

Göktepe Yıldız, S., & Göktepe Körpeoğlu, S. (2023). Prediction of students' perceptions of problem solving skills with a neuro-fuzzy model and hierarchical regression method: a quantitative study. *Education and Information Technologies, 28*, 8879–8917. https://doi.org/10.1007/s10639-022-11446-1

Gunel, M. (2006). Investigating the impact of teachers' implementation practices on academic achievement in science during a long-term professional development program on the science writing heuristic (Publication No. 305315993) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/investigating-impact-teachers-implementation/docview/305315993/se-2?accountid=11248

Gupta, T. (2012). Guided-inquiry-based laboratory instruction: Investigation of critical thinking skills, problem-solving skills, and implementing student roles in chemistry (Publication No. 1022645439) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/guided-inquiry-based-laboratory-instruction/docview/1022645439/se-2?accountid=11248

Güçlü, N. (2003). Lise müdürlerinin problem çözme becerileri [Problem solving skills of high school principals]. *Milli Eğitim Dergisi, 160*, 1–14.

Haidar, A. H., & Al Naqabi, A. K. (2008). Emiratii high school students' understandings of stoichiometry and the influence of metacognition on their understanding. *Research in Science & Technological Education, 26*(2), 2015–2237. https://doi.org/10.1080/02635140802037393

Hand, B., Hohenshell, L., & Prain, V. (2004). Exploring students' responses to conceptual questions when engaged with planned writing experiences: a study with year 10 science students. *Journal of Research in Science Teaching, 41*(2), 186–210. https://doi.org/10.1002/tea.10128

Hand, B., Shelley, M. C., Laugerman, M., Fostvedt, L., & Therrien, W. (2018). Improving critical thinking growth for disadvantaged groups within elementary school science: a randomized controlled trial using the science writing heuristic approach. *Science Education, 102*(4), 693–710. https://doi.org/10.1002/sce.21341

Hand, B., Chen, Y. C., & Suh, J. K. (2021). Does a knowledge generation approach to learning benefit students? A systematic review of research on the science writing heuristic approach. *Educational Psychology Review, 33*, 535–577. https://doi.org/10.1007/s10648-020-09550-0

Hartman, H. J. (1998). Metacognition in teaching and learning: an introduction. *Instructional Science, 26*, 1–3. https://doi.org/10.1023/A:1003023628307

Hennessey, M. G. (1999). Probing the dimensions of metacognition: Implications for conceptual change teaching-learning. *Annual Meeting of the National Association for Research in Science Teaching (NARST) Boston, MA. March 28-31, 1999).* https://files.eric.ed.gov/fulltext/ED446921.pdf

Heppner, P. P., & Petersen, C. H. (1982). The development and implications of a personal problem-solving inventory. *Journal of Counseling Psychology, 29*(1), 66–75. https://doi.org/10.1037/0022-0167.29.1.66

Heppner, P. P. (1988). *The Problem-Solving Inventory (PSI): research manual*. Consulting Psychologists Press.

Heppner, P. P., & Baker, C. E. (1997). Application of problem-solving inventory. *Measurement and Evaluation in Counseling and Development, 29*(4), 229–241. https://doi.org/10.1080/07481756.1997.12068907

Heppner, P. P., Witty, T. E., & Dixon, W. A. (2004a). Problem-solving appraisal and human adjustment: a review of 20 years of research using the problem-solving inventory. *The Counseling Psychologist, 32*(3), 344–428. https://doi.org/10.1177/0011000003262793

Heppner, P. P., Witty, T. E., & Dixon, W. A. (2004b). Problem-solving appraisal: helping normal people lead better lives. *The Counseling Psychologist, 32*(3), 466–472. https://doi.org/10.1177/0011000003262794

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching, 42*(7), 791–806. https://doi.org/10.1002/tea.20072

Hofstein, A., & Mamlok-Naaman, R. (2007). The laboratory in science education: the state of the art. *Chemistry Education Research and Practice, 8*(2), 105–107. https://doi.org/10.1039/B7RP90003A

Hohenshell, L. M., & Hand, B. (2006). Writing-to-learn strategies in secondary school cell biology: a mixed method study. *International Journal of Science Education, 28*(2-3), 261–289. https://doi.org/10.1080/09500690500336965

Ibrahim, A. I. (2003). Design and initial validation of an instrument for measuring teacher beliefs and experiences related to inquiry teaching and learning and scientific inquiry (Publication No. 305303141). [Doctoral Dissertation, The Ohio State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/design-initial-validation-instrument-measuring/docview/305303141/se-2

Irwanto Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K. (2018). Promoting critical thinking and problem-solving skills of preservice elementary teachers through process-oriented guided-inquiry learning (POGIL). *International Journal of Instruction, 11*(4), 777–794. https://doi.org/10.12973/iji.2018.11449a

Jeon, K., Huffman, D., & Noh, T. (2005). The effects of thinking aloud pair problem-solving on high school students' chemistry problem-solving performance and verbal interactions. *Journal of Chemical Education, 85*(10), 1558–1564. https://doi.org/10.1021/ed082p1558

Jiménez-Aleixandre, M. P. (2007). Designing argumentation learning environments. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education. Science & Technology Education Library* (Vol. 35). Springer. https://doi.org/10.1007/978-1-4020-6670-2_5

Kaberman, Z., & Dori, Y. J. (2009). Metacognition in chemical education: question posing in the case-based computerized learning environment. *Instructional Science, 37*(5), 403–436. https://doi.org/10.1007/s11251-008-9054-9

Kaplan, A., Duran, M., & Baş, G. (2016). Examination with the structural equation modeling of the relationship between mathematical metacognition awareness with skill perception of problem solving of secondary school students. *The Inonu University Journal of the Faculty of Education, 17*(1), 01–16. https://doi.org/10.17679/iuefd.17119785

Katchevich, D., Hofstein, A., & Mamlok-Naaman, R. (2013). Argumentation in the chemistry laboratory: inquiry and confirmatory experiments. *Research in Science Education, 43*, 317–345. https://doi.org/10.1007/s11165-011-9267-9

Keys, C., Hand, B., Prain, V., & Collins, S. (1999). Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching, 36*, 1065–1084. https://doi.org/10.1002/(SICI)1098-2736(199912)36:10<1065::AID-TEA2>3.0.CO;2-I

Kipnis, M., & Hofstein, A. (2008). The inquiry laboratory is a source for the development of metacognitive skills. *International Journal of Science and Mathematics Education, 6*, 601–627. https://doi.org/10.1007/s10763-007-9066-y

Kramarski, B. (2008). Promoting teachers algebraic reasoning and self-regulation with metacognitive guidance. *Metacognition and Learning, 3*(2), 83–99. https://doi.org/10.1007/s11409-008-9020-6

Larson, L. M., Allen, S. J., Imao, R. A. K., & Piersel, W. C. (1993). Self-perceived effective and ineffective problem solvers' differential views of their partners' problem solving styles. *Journal of Counseling and Development, 71*(5), 528–532. https://doi.org/10.1002/j.1556-6676.1993.tb02236.x

Lawson, A. E. (2010). *Teaching inquiry science in middle and secondary schools*. Sage Publications.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 138–147.

Lim, B. R. (2001). Guidelines for designing inquiry-based learning on the web: Online professional development of educators (Publication No. 275734380) [Doctoral dissertation, Indiana University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/guidelines-designing-inquiry-based-learning-on/docview/275734380/se-2?accountid=11248

Llewellyn, D. (2005). *Teaching high school science through inquiry: a case study approach*. Corwin Press.

Llewellyn, D. (2007). *Inquire within: implementing inquiry-based science standards in grades 3-8*. Corwin Press.

MacNair, R. R., & Elliott, T. R. (1992). Self-perceived problem-solving ability, stress appraisal, and coping over time. *Journal of Research in Personality, 26*(2), 150–164. https://doi.org/10.1016/0092-6566(92)90051-5
McDermott, M. A. (2009). The impact of embedding multiple modes of representation on student construction of chemistry knowledge (Publication No. 304904352) [Doctoral dissertation, The University of Iowa]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/impact-embedding-multiple-modes-representation-on/docview/304904352/se-2?accountid=11248
Millar, R., Osborne, J., & Nott, M. (1998). Science education for the future. *School Science Review, 80*(291), 19–24.
Miller, M., & Nunn, G. D. (2001). Using group discussion to improve social problem solving and learning. *Education, 121*(3), 470–475.
Mistry, N., & Gorman, S. G. (2020). What laboratory skills do students think they possess at the start of university? *Chemistry Education Research and Practice, 21*, 823–838. https://doi.org/10.1039/c9rp00104b
Mohammad, E. G. (2007). Using the science writing heuristic approach as a tool for assessing and promoting students' conceptual understanding and perceptions in the general chemistry laboratory (Publication No. 304860732) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/using-science-writing-heuristic-approach-as-tool/docview/304860732/se-2?accountid=11248
Morgan, C. T. (2000). *Introduction to psychology.* (H. Arıcı, Trans.). Hacettepe Üniversitesi Psikoloji Bölümü Yayınları.
Murphy, C., Abu-Tineh, A., Calder, N., & Mansour, N. (2021). Teachers' and students' views before introducing inquiry-based learning in Qatari science and mathematics classrooms. *Teaching and Teacher Education, 104*, 103367. https://doi.org/10.1016/j.tate.2021.103367
Nakhleh, M. B. (1992). Why some students do not learn chemistry: chemical misconceptions. *Journal of Chemical Education, 69*(3), 191–196. https://doi.org/10.1021/ed069p191
Orgill, M., & Bodner, G. (2004). What research tells us about using analogies to teach chemistry. *Chemistry Education: Research and Practice, 5*(1), 15–32. https://doi.org/10.1039/B3RP90028B
Öz, H. (2005). Metacognition in foreign/second language learning and teaching. *Hacettepe University Journal of Education, 29*, 147–156.
Poock, J. R. (2005). Investigating the effectiveness of implementing the science writing heuristic on student performance in general chemistry (Publication No. 304989615) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/investigating-effectiveness-implementing-science/docview/304989615/se-2?accountid=11248
Pratt, H., & Hackett, J. (1998). Teaching science: the inquiry approach. *Principal, 78*(2), 2–20.
Promyod, N. (2013). Investigating the shifts in Thai teachers' views of learning and pedagogical practices while adopting an argument-based inquiry approach (Publication No. 1443852628) [Doctoral dissertation, The University of Iowa]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/investigating-shifts-thai-teachers-views-learning/docview/1443852628/se-2?accountid=11248
Raes, A., Schellens, T., De Wever, B., & Vanderhoven, E. (2012). Scaffolding information problem-solving in web-based collaborative inquiry learning. *Computers & Education, 59*(1), 82–94. https://doi.org/10.1016/j.compedu.2011.11.010
Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: the context-specificity of science curriculum implementation in South Africa. *Teaching and Teacher Education, 38*, 65–75. https://doi.org/10.1016/j.tate.2013.11.003
Rickey, D., & Stacy, A. M. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education, 77*(7), 915–920. https://doi.org/10.1021/ed077p915
Rosenberg, M. (1989). *Society and the adolescent self-image*. Wesleyan University Press.
Roth, W.-M. (1994). Experimenting in a constructivist high school physics laboratory. *Journal of Research in Science Teaching, 31*(2), 197–223. https://doi.org/10.1002/tea.3660310209
Rust, P. M. H. (2011). The effects of inquiry instruction on problem-solving and conceptual knowledge in ninth-grade physics class [Master's thesis, Montana State University]. https://scholarworks.montana.edu/xmlui/handle/1/2169?show=full
Sadeh, I., & Zion, M. (2012). Which type of inquiry project do high school biology students prefer: open or guided? *Research in Science Education, 42*(5), 831–848. https://doi.org/10.1007/s11165-011-9222-9
Sahin, N., & H., Sahin, N.N., & Heppner P.P. (1993). Psychometric Properties of the problem-solving inventory in a group of Turkish university students. *Cognitive Therapy and Research, 17*(3), 379–385. https://doi.org/10.1007/BF01177661

Sandi-Urena, S., Cooper, M. M., & Stevens, R. H. (2011). Enhancement of metacognition use and awareness using the collaborative intervention. *International Journal of Science Education, 33*(3), 323–340. https://doi.org/10.1080/09500690903452922

Savaşır, İ., & Şahin, N. H. (1997). *Bilişsel-davranışçı terapilerde değerlendirme: Sık kullanılan ölçekler [Evaluation in cognitive-behavioral therapies: Frequently used scales]*. Türk Psikologlar Derneği Yayınları.

Schoerning, E., Hand, B., Shelley, M., & Therrien, W. (2015). Language, access, and power in the elementary science classroom. *Science Education, 99*(2), 238–259. https://doi.org/10.1002/sce.21154

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: metacognition as part of a broader perspective on learning. *Research in Science Education, 36*, 111–139. https://doi.org/10.1007/s11165-005-3917-8

Seery, M. K., Jones, A. B., Kew, W., & Mein, T. (2019). Unfinished recipes: structuring upper-division laboratory work to scaffold experimental design skills. *Journal of Chemical Education, 96*(1), 53–59. https://doi.org/10.1021/acs.jchemed.8b00511

Smith, L. E., Blakeslee, T. D., & Anderson, C. W. (1993). Teaching strategies associated with conceptual change learning in science. *Journal of Research on Science Teaching, 30*(2), 111–126. https://doi.org/10.1002/tea.3660300202

Sönmez, E., Kabataş Memiş, E., & Yerlikaya, Z. (2021). The effect of practices based on argumentation-based inquiry approach on teacher candidates' critical thinking. *Educational Studies, 47*(1), 59–83. https://doi.org/10.1080/03055698.2019.1654364

Spaulding, D. T. (2001). Stakeholder perceptions of inquiry-based instructional practices (Publication No. 287875172) [Doctoral dissertation, Albany State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/stakeholder-perceptions-inquiry-based/docview/287875172/se-2

Szalay, L., & Toth, Z. (2016). An inquiry-based approach of traditional 'step-by-step' experiments. *Chemistry Education Research and Practice, 17*, 923–961. https://doi.org/10.1039/C6RP00044D

Talanquer, V. (2018). Chemical rationales: another triplet for chemical thinking. *International Journal of Science Education, 40*(15), 1874–1890. https://doi.org/10.1080/09500693.2018.1513671

Taylan, S. (1990). Heppner's problem-solving inventory adjustment, validity and reliability studies (Thesis No. 11910) [Master's thesis, Ankara University]. Council of Higher Education Thesis Center. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Teong, S. K. (2002). The effect of metacognitive training on mathematical word-problem solving. *Journal of Computer Assisted Learning, 19*, 46–45. https://doi.org/10.1046/j.0266-4909.2003.00005.x

Tho, S. W., Yeung, Y. Y., Wei, R., Chan, K. W., & So, W. W.-M. (2017). A systematic review of remote laboratory work in science education with the support of visualizing its structure through the HistCite and CiteSpace software. *International Journal of Science and Mathematics Education, 15*, 1217–1236. https://doi.org/10.1007/s10763-016-9740-z

Toth, E. E., Klahr, D., & Chen, Z. (2000). Bridging research and practice: a cognitively based classroom intervention for teaching experimentation skills to elementary school children. *Cognition and Instruction, 18*(4), 423–459. https://doi.org/10.1207/S1532690XCI1804_1

Tsai, C. (2001). A review and discussion of epistemological commitments, metacognition, and critical thinking with suggestions on their enhancement in internet-assisted chemistry classrooms. *Journal of Chemical Education, 78*(7), 970–974. https://doi.org/10.1021/ed078p970

Tuncer, M., & Kaysi, F. (2013). The development of the metacognitive thinking skills scale. *International Journal of Learning & Development, 3*(2), 70–76.

van Opstal, M. T., & Daubenmire, P. L. (2015). Extending students' practice of metacognitive regulation skills with the science writing heuristic. *International Journal of Science Education, 37*(7), 1089–1112. https://doi.org/10.1080/09500693.2015.1019385

Vula, E., Avdyli, R., Berisha, V., Saqipi, B., & Elezi, S. (2017). The impact of metacognitive strategies and self-regulating processes of solving math word problems. *International Electronic Journal of Elementary Education, 10*(1), 49–59. https://doi.org/10.26822/iejee.2017131886

Wallace, C. S., Prain, V., & Hand, B. (2004). Does writing promote learning in science? In C. S. Wallace, B. Hand, & V. Prain (Eds.), *Writing and learning in the science classroom* (pp. 1–10). Kluiwer Academic Publishers.

Wang, J., & Jou, M. (2016). Qualitative investigation on the views of inquiry teaching based upon the cloud learning environment of high school physics teachers from Beijing, Taipei, and Chicago. *Computers in Human Behavior, 60*, 212–222. https://doi.org/10.1016/j.chb.2016.02.003

Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T. (1981). The role of inquiry in science education: analysis and recommendations. *Science Education, 65*(1), 33–50. https://doi.org/10.1002/sce.3730650106

Wengrowicz, N., Dori, Y. J., & Dori, D. (2018). Metacognition and meta-assessment in engineering education. In Y. J. Dori, Z. R. Mevarech, & D. R. Baker (Eds.), *Cognition, metacognition, and culture in STEM education. Innovations in Science Education and Technology* (Vol. 24). Springer. https://doi.org/10.1007/978-3-319-66659-4_9

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: making science accessible to all students. *Cognition and Instruction, 16*(1), 3–118. https://doi.org/10.1207/s1532690xci1601_2

Williams, M. E. (2007). Teacher change during a professional development program for implementation of the science writing heuristic approach (Publication No. 304856277) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global. https://www.proquest.com/dissertations-theses/teacher-change-during-professional-development/docview/304856277/se-2

Wilson, J. (2001). Methodological difficulties for assessing metacognition: A new approach. *Annual Meeting of the Australian Association for Research in Education, Fremantle, Western Australia, December 2-6, 2001, Reports- Research*. https://www.aare.edu.au/data/publications/2001/wil01001.pdf

Wilson, J., & Clarke, D. (2004). Towards the modelling of mathematical metacognition. *Mathematics Education Research Journal, 16*(2), 25–48. https://doi.org/10.1007/BF03217394

Wismath, S., Orr, D., & Zhong, M. (2014). Student perception of problem solving skills. *Transformative Dialogues: Teaching and Learning Journal, 7*(3), 1–17.

Yaman, F. (2018). Effects of the science writing heuristic approach on the quality of prospective science teachers' argumentative writing and their understanding of scientific argumentation. *International Journal of Science and Mathematics Education, 16*, 421–442. https://doi.org/10.1007/s10763-016-9788-9

Yıldız, E. (2008). The effects of metacognition during the instruction based on conceptual change used with 5E model: An application regarding the force and motion subject in the 7th grade (Thesis No. 231557) [Doctoral dissertation, Dokuz Eylül University]. Council of Higher Education Thesis Center. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Yoon, H.-G., Joung, Y. J., & Kim, M. (2012). The challenges of scientific inquiry teaching for pre-service teachers in elementary classrooms: difficulties on and under the scene. *Research in Science Education, 42*, 589–608. https://doi.org/10.1007/s11165-011-9212-y

Yurdakul, B. (2004). The effects of the constructivist learning approach on learners' problem-solving skills, metacognitive awareness, and attitudes towards the course, and contributions to the learning process (Thesis No. 144332) [Doctoral dissertation, Hacettepe University]. Council of Higher Education Thesis Center. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Zion, M., Michalsky, T., & Mevarech, Z. R. (2005). The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills. *International Journal of Science Education, 27*(8), 959–983. https://doi.org/10.1080/09500690500068626

Zion, M., Schanin, I., & Shmueli, E. R. (2013). Teachers' performances during a practical dynamic open inquiry process. *Teachers and Teaching, 19*(6), 695–716. https://doi.org/10.1080/13540602.2013.827457

Zohar, A. (2006). The nature and development of teachers' metastrategic knowledge in the context of teaching higher-order thinking. *Journal of the Learning Science, 15*(3), 331–377. https://doi.org/10.1207/s15327809jls1503_2

Zohar, A., & Dori, Y. J. (2012). *Metacognition in science education: trends in current research*. Springer.

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Current themes of research:

Learning styles/approaches, inquiry-based learning, metacognitive skills, self-efficacy

Most relevant publications in the field of Psychology of Education:

Dinçol Özgür, S. & Yılmaz, A. (2017). The effect of inquiry-based learning on gifted and talented students' understanding of acids-bases concepts and motivation. *Journal of Baltic Science Education*, 16 (6), 994-1008.

Dinçol Özgür, S. (2018). Effect of learning styles on prospective teachers' self-regulated learning skills.*Cypriot Journal of Educational Sciences*, 13 (4), 521-528.

Dinçol Özgür, S. & Yılmaz, A. (2020). Proje tabanlı öğrenme yaklaşımının öğretmen adaylarının tercih ettikleri öğrenme yaklaşımına, özyeterlik ve bilgi düzeyine etkisi [The effect of project-based learning approach on prospective teachers' adopted learning approach, self-efficacy and level of knowledge] Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 14 (1),761-786. https://doi.org/10.17522/balikesirnef.673060

Ozgur, S. D. (2021). Chemistry self-efficacy beliefs as predictors of students' metacognitive skills when solving chemistry problems. *International Online Journal of Education and Teaching (IOJET)*, 8(1), 132-147.