# Pre-service Physics Teachers' Metacognitive Knowledge about Their Instructional Practices

Sevda Yerdelen-Damar
*Yüzüncü Yıl University, TURKEY*
Ömer Faruk Özdemir
*Middle East Technical University, TURKEY*
Cezmi Ünal
*Gaziosmanpaşa University, TURKEY*

This study aims to investigate pre-service physics teachers' metacognitive knowledge about their teaching practices. The participants included six pre-service physics teachers. A taxonomy of metacognition for teaching was developed to analyze the level of pre-service physics teachers' metacognitive knowledge about their teaching practices. Analysis of data showed that pre-service physics teachers' metacognitive knowledge about their content knowledge was quite satisfactory; however, their metacognitive knowledge about instructional methods, students' pre-instructional knowledge, and the task of teaching needs to be improved. The results of the study provided evidence that metacognitive knowledge on teaching is a fruitful framework to generate interpretations about the participants' instructional processes.

*Keywords*: metacognition, metacognitive knowledge, science education, teacher education

## INTRODUCTION

Metacognition has been one of the most studied constructs in the literature on educational research since it was proposed as a theoretical construct by Flavell (1979). Metacognition often refers to individuals' awareness, judgments, and beliefs about their cognitive potentials and conscious act of cognitive operations. Metacognition is usually associated with students' learning and academic performances (Adey & Shayer, 1993; Baker, 1991; Blank, 2000; Carr, Kurtz, Schneider, Turner, & Borkowski, 1989; White & Frederiksen, 1998). An extensive body of literature collected since the 1980s has indicated that there is a relationship between metacognition and several output variables such as academic achievement (Yerdelen-Damar & Pesman, 2013; Everson & Tobias, 1998; Young & Fry, 2008), retention of learning (Georghiades, 2004; Blank, 2000; Yuruk, Beeth, & Andersen,

2009), and problem solving (Desoete, Roeyers, & Buysse, 2001; Desoete, Roeyers, & Clercq, 2003).

A brief review of literature easily reveals that the cognitive phenomena taken into account by the literature on metacognition has been mostly limited to students' learning or problem solving performances and a little emphasis has been devoted to teaching processes. Furthermore, it is not unusual to see the definition of metacognition as knowledge and cognition about learning processes (Georghiades, 2000). This is probably because the term, cognition, is usually associated with learning and problem solving processes. Instructional practices are mainly cognitive processes and it seems legitimate to argue that instructional practices supported with instructors' metacognition can help improve the quality of instruction. Stimulated by similar arguments, some studies have initiated the inquiries about instructional practices enriched with instructors' metacognition. For example, reflection practices in teaching and teacher education have put some light on the possible implications of metacognition on instructional practices (e.g., Jay & Johnson, 2002; Parsons & Stephenson, 2005). The major components of reflection practices were proposed as setting goals, planning, and evaluation of instructional practices (McAlpine, Weston, Beauchamp, Wiseman, & Beauchamp, 1999). According to several researchers, reflection practices were prerequisites of quality teaching (Kreber & Castleden, 2009; Ottesen, 2007). In addition to reflection practices, several researchers have focused on directly adapting metacognition on learning to the teaching situations (Leou, Abder, Riordan, & Zoller, 2006; Artzt & Armour-Thomas, 1998; Hartman, 2001; Lin, Schwartz, & Hatano, 2005; Peterson, 1988; Zohar, 1999). For example, Artzt and Armour-Thomas (1998) conducted an exploratory study to investigate the role of metacognition on the instructional practices of

### State of the literature

- Metacognition literature has mainly addressed students' learning or problem solving activities while metacognition related to teaching is limitedly studied.
- Some instructional problems observed in teachers' practices can be due to deficiencies in their metacognition about instructional processes. The applications in which instructional practices enriched with teachers' metacognition improved the quality of teaching.
- Metacognition includes two components: knowledge and process base. The research studying teacher metacognition has generally focused on process component; however, there has been little known about metacognitive knowledge of teachers regarding their instructional practices and decisions.

### Contribution of this paper to the literature

- This study provides a theoretical framework for metacognition for teaching to analyze the level of teachers' metacognitive knowledge about their teaching practices. This framework can be used by other researchers and teacher educators.
- The current study provided evidences that pre-service teachers' problems and decisions regarding instructional practices can be explained in the perspective of metacognition.
- Compared to other research studies investigating teacher metacognition in the process base, this study focused on knowledge base of metacognition related to teaching.

secondary school mathematics teachers. They analyzed three stages of teaching: pre-active (planning), interactive (monitoring and regulating), and post-active (assessing and revising). The researchers argued that teachers' metacognition had important influences on classroom practices. Their analysis of classroom data supported this argument by revealing that the teachers who were good at metacognition organized well-designed instructions, and the learning environment created by these instructions was intellectually and socially improved. However, the teachers who had deficiencies in terms of using metacognitive processes had also deficiencies in their instructions such as poorly-designed tasks and unproductive learning environments.

Although Artzt and Armour-Thomas' (1998) study has demonstrated the fruitfulness of adapting metacognition to teaching processes on locating some instructional problems, Lin, Schwartz, and Hatano (2005) have argued that

"conventional applications of metacognition fall short when it comes to the challenges teachers often face. Teaching has some unique qualities that differentiate it from many of the tasks that metacognitive interventions have supported." (p.245). Teaching is a multifaceted process which cannot be isolated from either the cognitive processes of learners or the learning environment created by learners, teachers, and instructional tools.

The major argument of this study is quite parallel to those of Lin et al. (2005) that conventional applications of metacognition are limited when it comes to the teaching situations. However, we also believe that the limitation of conventional applications is not due to the limitation of metacognition as a theoretical construct but due to that the whole breath of metacognition is not used or adapted to the teaching situations. There are two major components of metacognition. One is knowledge base and the other is process base of metacognition. Flavell (1979), in his leading article, categorized these components as metacognitive knowledge and metacognitive experiences. While metacognitive knowledge refers to individuals' awareness about her/his knowledge and cognitive potentials, metacognitive experience refers to active planning, monitoring, and evaluating the cognitive processes during the execution of a cognitive task. Although the process base of metacognition has attracted considerable attention, the knowledge base of metacognition seems to be ignored in the literature of teacher education. There is a reciprocal causation between metacognitive knowledge and metacognitive processes - both components feed and manipulate each other. For example, an instructional planning is directly affected by the repertoires of instructional strategies held by instructors. Similarly, evaluation of an instructional process gives feedback about the appropriateness and power of a specific instructional strategy for a particular concept. The unique qualities of any cognitive task can actually be observed in the knowledge base of metacognition. Therefore, detailing the knowledge base of metacognition for teaching situations can provide important implications for the challenges teachers often face during their practices.

Based on these arguments, this study aims to analyze the performances of pre-service physics teachers in terms of metacognitive knowledge. In the following sections, we first provide a taxonomy of metacognition and then explain the methodology used to inquire pre-service teachers' metacognition. Finally, we present the analysis of the data and discuss the results.

## TAXONOMY OF METACOGNITION

Flavell(1979) categorized metacognition into metacognitive knowledge and metacognitive experiences. Metacognitive knowledge involves knowledge and beliefs about the variables influencing the courses and outcomes of cognitive processes. Flavell discussed the metacognitive knowledge in three categories which were labeled as person, task, and strategy variable. Person variable refers to one's belief about the nature of oneself and other people as cognitive processors. For example, someone can believe that s/he learns something better by taking notes than by just listening or s/he believes that her/his friend is more competent in electricity than in mechanics. Task variable includes knowledge and judgments about task goals and demands such as an individual's conceptualization of the task in terms of whether a specific task is easy or hard to achieve or knowledge about the sources (cognitive as well as outside help) required to accomplish a task. The strategy variable refers to knowledge about strategies useful for certain goals or sub-goals as well as knowing the necessary strategies for specific cognitive tasks.

Another interpretation about the knowledge base of metacognition was proposed by Schraw and Moshman (1995) as knowledge about cognition which refers to one's knowledge about her/his own cognition. It consists of three subcomponents; (i)

declarative, (ii) procedural, and (iii) conditional knowledge. Declarative knowledge is defined as one's knowledge about oneself as a cognitive processor. Procedural knowledge involves knowledge about execution of procedures for a specific cognitive task. The last component, conditional knowledge, refers to knowledge of why and when to use a particular strategy for a particular cognitive task.

The process base of metacognition has attracted more attention than the knowledge base of metacognition in the literature of education. Flavell (1979) described the process base of metacognition as 'any conscious or affective experiences that accompany and pertained to any intellectual enterprise' (p. 906). Flavell labeled the process base of metacognition as "metacognitive experiences". Metacognitive process can be performed before, during, or after the cognitive processes about a specific task. More detailed accounts about the process base of metacognition were provided by Brown (1987) and Kluwe (1987). Both researchers interpreted the process base of metacognition in terms of executive control. While doing so, they focused on checking, evaluating, and regulating the cognitive processes during a cognitive performance. Further elaboration and operationalization of the process base of metacognition was explored in terms of regulatory skills (Schraw & Dennison, 1994). In the most general sense, the regulatory skills can be categorized as planning, monitoring, and evaluation (Schraw & Moshman, 1995). Planning requires the selection of suitable strategies and the allocation of relevant resources to perform a cognitive task. It consists of goal setting, activating relevant background knowledge, and regulating time. Monitoring involves self-testing of the cognitive processes required for a specific cognitive task. Evaluation involves assessment and regulation of the cognitive processes after the accomplishment of a cognitive task (Schraw, Crippen & Hartley, 2006).

## The taxonomy of metacognition for teaching

The brief review of theoretical arguments about metacognition provided in the previous section reveals that there seems to be a consensus about the process base of metacognition, which is interpreted in terms of regulatory skills (i.e., planning, monitoring, and evaluation). The literature of teacher education on metacognition seems to be following the same pattern and focusing on the regulatory skills of teachers during their instructional practices.

The knowledge base of metacognition seems to be more controversial than the process base of metacognition. While Flavell (1979) was focusing on specific variables such as person, task, and strategy during his arguments about the knowledge base of metacognition, Schraw and Moshman (1995) took a more general position by interpreting knowledge as a theoretical construct and focusing on three aspects of knowledge. These aspects are declarative, procedural, and conditional knowledge and the literature of metacognition on learning and problem solving mostly followed these aspects during the interpretations of students' metacognitive knowledge. Although these two approaches differ in terms of categorizing knowledge base of metacognition, neither of them ignores the aspects proposed by the other. For example, it is not possible to generate arguments about conditional knowledge without referring to particular strategies. Similarly, it is not possible to argue about strategies without referring to conditional knowledge. In this study, we preferred to use Flavell's categorization for the analysis of pre-service teachers' metacognitive knowledge because it refers to some explicit variables, directly related to teaching situations such as task, strategy, and person variables. Especially, person variable is important because this variable is not limited to oneself but also the others. In a teaching situation, teachers' awareness about her/his students as cognitive processors is as important as his/her awareness about

her/himself. Similarly, task and strategy variables can easily find their places in a teaching process; the task of teaching a specific concept.

The major argument of this study and the others studying metacognition on teaching is that metacognition can be expanded to any situation which requires cognitive processes because the essence of metacognition is all about knowledge and regulatory skills about a particular cognitive task. A particular cognitive task can be "teaching" as well as problem solving or learning. Therefore, the adaptation of metacognition to the teaching situation is not more than defining the cognitive task as teaching and redefining the components of metacognition accordingly. As we discussed before, the process component of metacognition for teaching has already been developed and studied in the literature of teacher education. Therefore, in this study, we will particularly focus on the knowledge base of metacognition. For the knowledge component of metacognition for teaching, we used Flavell's categories, classified in terms of person, strategy, and task variables. We will further define and operationalize these constructs for teaching in the following section.

## METHODOLOGY

The purpose of the study is to understand pre-service teachers' metacognitive knowledge related to their teaching practices. While generating research questions, we narrowed down the scope of the study by focusing on some particular aspects of teaching practices because of the feasibility concerns. For example, while we were generating research questions about person variable, we only focused on pre-service teachers' awareness about their content knowledge, their instructional method knowledge, and students' pre-instructional knowledge/reasoning; although this variable can be extended to the awareness about any knowledge related to an instructional practice such as knowledge about instructional materials, students' cognitive styles, or students' learning strategies. After we set the limits about the scope of the study, the following research questions were formulated.

- What is the level of pre-service physics teachers' metacognitive knowledge about their content knowledge?
- What is the level of pre-service physics teachers' metacognitive knowledge about their instructional method knowledge?
- What is the level of pre-service physics teachers' metacognitive knowledge about students' pre-instructional knowledge and reasoning?
- What is the level of pre-service physics teachers' strategic knowledge about instructional methods?
- How do pre-service physics teachers define their task for an instructional practice?

In order to respond to the research questions, the framework of metacognition for teaching was used. Metacognition is one of the most difficult and sensitive theoretical constructs when it comes to making observations about it. Metacognition is directly related to awareness of subjects and it is highly possible to make subjects be aware when the researchers probe subjects about their awareness. Consequently, what we observe can be easily affected by how we observe it. Because of this concern, we relied on participants' instructional performances and their reflections about their performances to make inferences about their metacognitive knowledge rather than asking direct questions about their awareness. We preferred to follow an interpretivist qualitative methodology to respond to the research questions. The research design of the study was case study (Yin, 1984). The case consisted of six pre-service teachers who were seeking a degree to become physics teacher.

## Participants and setting

This study was conducted with 6 pre-service teachers (one female and 5 male) in an "instructional methods" course designed for pre-service teachers who were seeking a degree to become physics teachers. The major objective of the course was to help pre-service teachers realize the nature and the role of students' pre-instructional knowledge during learning and gain basic knowledge and skills on the implementation of several instructional methods in physics classrooms, such as cognitive conflict, anchoring/bridging analogies, learning cycle, and modeling. The instructional process of the course mainly consists of the reading assignments of some articles about the instructional methods and techniques, classroom discussions about them, video analysis of some instructional practices, practice teachings of pre-service teachers, and discussions about them. Students took this course at the final year of pre-service teacher education program. Before this course, they completed the core physics courses. Students' ages ranged from 20 to 26 with a mean of approximately 23 years.

## Data sources

The main source of data used in this study was observations collected through pre-service teachers' instructional practices. Students' instructional practices were video-taped and the observations were based on the analysis of the tapes. However, we also referred to other sources to support and detail the analysis emerging from our observations of the instructional practices. Supplementary data were collected through lesson plans, reflection papers, and interviews with pre-service teachers about their instructional practices.

*Lesson Plans*. Pre-service physics teachers (PST) were requested to prepare a lesson plan for their instructions. They were let free on the choice of the format of the plan and were not requested for any specific information. They were just asked to write anything they thought important to think about before and useful during the instructional practice.

*Microteaching.* To understand the pre-service teachers' metacognitive knowledge related to their teaching practices, we requested them to give an instruction about a specific physics topic. They were let free to choose any topic they wanted to teach during their practices. They were just advised to choose a topic that they felt competent and comfortable to instruct. They were not forced to choose a specific instructional method either; however, they were informed that they were expected not to ignore students' pre-instructional knowledge during their instructions. The PSTs' provided the instructions to their classmates. All the instructions were video recorded for further analysis. The durations of microteachings performed by students ranged from 21 minutes to 46 minutes.

*Interviews.* Interviews were conducted immediately after the pre-service teachers' instructional practices. During the interviews, we asked them to provide a general evaluation of their performances. The interviews were also video recorded for further analysis.

*Reflection Papers*. After the instruction, the PSTs were requested to write a reflection about their instructional practices. They were asked to evaluate their instructional practices anyway they wanted but they were also requested to include the information about the difficulties they met, the problems they encountered, and the situations that did not go as they planned.

## Data analysis

The analysis of data consists of our interpretations about pre-service teachers' metacognitive knowledge and experiences. To generate reliable interpretations, we first defined and operationalized the theoretical constructs of metacognitive knowledge related to teaching practices in the following sections. The following

components were developed by the researchers of the present study based on Flavell's (1979) metacognitive knowledge for learning.

## Operational definitions for metacognitive knowledge

### *Person variable*

While analyzing pre-service teachers' metacognitive knowledge about person variable, we focused on three sub-variables labeled as metacognitive content knowledge, metacognitive method knowledge, and metacognitive knowledge about students' knowledge. These sub-variables are operationalized as follows.

- Metacognitive Content Knowledge (MCK): MCK was defined as one's awareness of the level of her/his content knowledge on a specific topic. This knowledge was interpreted by comparing pre-service teachers' judgments and our own judgments about their content knowledge. We judged the pre-service teachers' content knowledge as "good", "average", or "poor" based on the analysis of students' video-taped microteaching. Pre-service teachers' judgments about their content knowledge were obtained from their reflection papers and interviews. Pre-service teachers' content knowledge was labeled as good if the core concepts and their relations were covered and student questions were responded by the pre-service teachers without a conceptual error during the instruction. Content knowledge was labeled as average when the core concepts and their relations were covered without a conceptual error but some erroneous knowledge was observed while the pre-service teacher was solving problems or responding to students' questions. Poor was used if the pre-service teacher had conceptual problems about the core concepts and their relations among them. Pre-service teachers' MCK was interpreted based on the consistency between the researchers' judgments and pre-service teachers' own judgments about their content knowledge.
- Metacognitive Method Knowledge (MMK): MMK was defined as one's awareness of the level of her/his knowledge about a specific instructional method. The procedure followed while making interpretation about MMK was similar to that of MCK. In this case, our judgments about pre-service teachers' method knowledge were based on the PSTs' recorded instructional practices. To make judgments about the pre-service teachers' method knowledge, we prepared rubrics for each method that participants would use during their instructional methods. The rubrics consist of the questions about the essential steps that a pre-service teacher should follow during the implementation of an instructional method. For example, the following questions were included to the rubric for the method of cognitive conflict: Did the instructor use conceptual questions as an exposing event? Did the instructor give enough time to students to think and respond to the questions? Did the instructor present anomalous data? When we made judgments about the pre-service teachers' method knowledge, we compared our judgments with the judgments of pre-service teachers about their method knowledge. The PSTs provided the judgments about their method knowledge in their reflection papers and during interviews.
- Metacognitive Knowledge about Students' Knowledge: Student knowledge can be analyzed in different dimensions such as cognitive styles, learning styles, or intelligence types; however, because of the feasibility concerns (the major feasibility concern was the observability of the related constructs during instructional process), we narrowed down our focus on students' pre-instructional knowledge and reasoning about

the instructed phenomena. Therefore, when we referred to MSK, we refer to the pre-service teachers' metacognitive knowledge about students' pre-instructional knowledge and reasoning. While making interpretations on pre-service teachers' MSK, we focused on three observable actions which were "explicit reference to pre-instructional knowledge," "prompts used to reveal possible pre-instructional knowledge," and "requests for elaboration for a particular pre-instructional knowledge." The data sources used for MSK were the PSTs' video-taped instructional practices and reflection papers.

### Strategy variable

Strategy variable is defined as awareness of what strategies are useful for certain goals or sub-goals. In the context of this study, strategy refers to instructional methods and techniques used during the instruction of a topic. We should make a distinction between methods and techniques at this point. What we mean by a method is simply the instructional process which consists of well-defined steps from beginning to an end to cover the instruction of a topic lasting one or several class hours according to the nature of the topic. Learning cycle, problem based learning, or expository teaching can be provided as examples of instructional methods (Peşman & Özdemir, 2012). On the other hand, techniques are defined as specific instructional processes used to overcome a particular difficulty related to a specific concept. Using analogies, demonstrations, simulations, or questioning are some examples of techniques frequently used during instructional practices. The use of instructional techniques takes not more than a few minutes during an instruction and they are used to support an instructional method (Anthony, 1963, as cited in Celce-Murcia, 1991). While we were making interpretations about strategy variable, we focused on whether the pre-service teachers used methods and techniques appropriately. The data source for those interpretations was the PSTs' recorded instructional practices. Students' judgments about their strategy knowledge were obtained from their reflections papers.

### Task variable

Task variable refers to how pre-service teachers' conceptualize their task of teaching. To generate interpretations about task variable, we focused on the pre-service teachers' arguments in reflections papers, plans about their instructional practices, and their video-taped instructional practices. We first tried to understand the common themes shaping the pre-service teachers' interpretations about their task of teaching using their plans and instructional practices. Then, we outlined their major concerns about their teaching task and their interpretations about the difficulty of the task using their reflection papers and interviews.

### Trustworthiness and Limitations

This study is qualitative in nature and the results generated through this study depend on the researchers' interpretations. Therefore, several issues should be discussed about the trustworthiness of the study. One issue is that the researchers are also the instructors of the class in which the data was collected. This situation has advantages as well as disadvantages for the trustworthiness of the study. The major disadvantage could be that the researchers could easily manipulate or lead students to their preconceived expectations emerging from particular theory or theories. Our argument against this issue is that the researchers have not any preconceived expectations about the results of this study. As the research questions reveal the study is not searching for a causal relation or trying to test a theoretical hypothesis. This study is descriptive in nature and trying to give a picture of the pre-service teachers' metacognition as detailed as possible. Therefore leading or

manipulation is hardly an issue in for this study. On the advantages side of being also the instructor, it can be claimed that the participants' natural environment was not disturbed and the participants' possible unusual reactions due to the existence of an outsider were prevented. Another advantage is that the researchers engaged with the participants for several months although the interactions during the data collection were limited. This engagement enabled construction of mutual trust between the researchers and the participants.

In terms of the trustworthiness of the analysis, it should be stated that the researchers did not base their interpretations on a single data source. The pre-service teachers' instructional plans, micro teaching practices, reflection papers, and interviews were used to elaborate and insure the performance of specific processes of the pre-service teachers. It is also worth to mention that the whole data was analyzed by three researchers and the final decisions about a measure or a code were always taken through a consensus of all three researchers. In spite of these arguments, eventually, this study is qualitative in nature and highly depends on the researchers' interpretations.

## RESULTS

### Person Variable

#### *Metacognitive knowledge about content*

The analysis of the pre-service teachers' instructional practices showed that most of the PSTs' knowledge about the content that they instructed was either good or average. Except for one PST (PST4), all the PSTs covered the core concepts without a substantial error or inconsistency with scientific knowledge. Their judgments about the level of their content knowledge were also mostly consistent with our judgments. Table 1 shows the PSTs' judgments and our judgments about the specific content knowledge that they instructed. The high level of consistency between the PSTs' judgments and our judgments reveals that the pre-service teachers' metacognitive knowledge about their content knowledge is quite satisfactory. When we focus on the PSTs whose judgments are not consistent with ours, we see that they exaggerated their content knowledge. One question about this result is that why someone would try to teach a topic that she/he does not know much about it. PST4's response to this question helps us make sense of the issue:

> I thought that I knew the topic but I realized during the instruction that I do not know much about it. Actually, I knew quite a lot about mechanical waves but somehow the topic went to a quite different direction during the instruction that I did not think about them in details before...

Before the instruction, PST4 thought that she knew the topic that she would teach. In Table 1, it seems that PST4's MCK was satisfactory. This is because observations about PST4's MCK were taken after the instruction. In actuality, the instructional process helped her be aware of the limits of her content knowledge.

**Table 1.** The contents the PSTs instructed, their judgments and the researchers' judgments about those content knowledge

| PSTs | Content | PSTs' judgments about their content knowledge | Our judgments about PSTs' content knowledge |
|------|---------|-----------------------------------------------|---------------------------------------------|
| PST1 | Momentum-Collision | Good | Average |
| PST2 | Photoelectric | Good | Good |
| PST3 | Projectile Motion | Good | Good |
| PST4 | Waves | Poor | Poor |
| PST5 | Motion in one dimension | Good | Good |
| PST6 | Circular Motion | Good | Good |

**Table 2.** The instructional methods implemented by the PSTs, the PSTs' and the researchers' judgments about the use of the instructional methods

| PSTs | Instructional Method | PSTs' judgments about their methodological knowledge | Our judgments about PSTs' methodological knowledge |
|---|---|---|---|
| PST1 | Expository Instruction | Poor | Poor |
| PST2 | Learning Cycle | Average | Poor |
| PST3 | Expository Instruction | Poor | Poor |
| PST4 | Expository Instruction | Good | Poor |
| PST5 | Learning cycle | Good | Average |
| PST6 | Cognitive Conflict | Good | Average |

Another inconsistency occurred between our judgment and PST1's judgment. PST1 argued in his reflection paper that he did not have any difficulties when he explained the subject matter. PST1 aimed in his instructional practice to explain conservation of momentum in non-isolated systems. He specifically asked whether it was realistic that an actor flied backward when a bullet hit him. After he applied his strategy, students were not convinced why the person hit by the bullet should not fly, and requested further explanation for the phenomenon. However, PST1 failed to explain why the law of conservation of momentum was not valid in non-isolated systems (the effect of frictional forces).

### *Metacognitive knowledge about instructional method*

The researchers' judgments about the PSTs' implementation of the instructional methods were mostly poor. However, the PSTs' judgments about their performances were usually good. Table 2 shows the discrepancies between the PSTs' and the researchers' judgments about the appropriate use of instructional methods. The table shows that the consistency level is quite low.

The most common problem related to the implementation of the inquiry oriented instructions (the learning cycle) was that the PSTs could not provide enough guidance to let students make a conclusion for the explanation phase. They did not try different prompts to get students' ideas. For example, during the interview with PST2, we addressed this issue:

> Researcher: You did not let students provide their own explanations. Why?
> PST2: I asked but they were silent, I asked again they were silent again. Then, I started to explain the topic by myself.

Another problem was encountered during the exploration phase of inquiry. Instead of providing appropriate guidance and let the students do their own explorations, the PSTs were preferred to do the exploration by themselves when students get stuck during the inquiry process. The following excerpt taken from the interviews exemplifies how the PSTs were not aware of their own knowledge about the instructional methods. For example, PST2 had planned to teach the subject matter using the learning cycle method. Nevertheless, he implemented a teacher-centered instruction without having students do their own investigations.

> Researcher: What method did you chose to perform?
> PST2: The learning cycle
> Researcher: Did you appropriately implement it?
> PST2: Yes, I think so. I started with the engagement phase, and then, I implemented explain and explore phases together. In the explain phase, I asked questions to the students and I waited their explanations based on their daily life experiences or knowledge on their mind.
> Researcher: Did you do those before exploration?
> PST2: Yes.
> Researcher: With those, you tried to elicit what they had known, didn't you?

PST2: Yes. In the explore phase, I again asked questions and waited explanations from the students. After the explain phase, in the extend phase, I explained the subject further.

Researchers: What did you do in the explore phase?

PST2: I asked questions and made a demonstration.

During the interview and in the reflection paper, PST2 reported that he knew and implemented the learning cycle method, appropriately. However, our observations and PST2's own explanations of what he did during the instruction indicated that he was not aware of his knowledge about the instructional method. He was not aware that students should do their own exploration to respond to the specific questions during the implementation of the learning cycle. Instead, he preferred to do his own demonstration to respond to do the specific questions.

The major problem on the implementation of the cognitive conflict strategy (only PST6 used the strategy) was that the PST selected an inappropriate demonstration to create a conflict and his effort to generate a conflict was too ambiguous. PST6 had planned to use the cognitive conflict method to deal with one of the common misconceptions, centrifugal force. To understand whether students believe that there was a centrifugal force, he asked students to identify the forces acting on a body rotating in a circular path. Most of the students stated that there was a centrifugal force on the body. Then, he made a demonstration to create conflict in the students' minds who believed that there was a centrifugal force. He rotated a mass connected to a string around himself. While the mass was rotating, he cut the string and asked the students what they observed and what direction the mass moved. However, students could not clearly see which direction the mass went. Nevertheless, PST6 assumed that the students saw the direction of the motion and began to explain why there was no centrifugal force. Thus, the demonstration did not serve the purpose of creating conflict between the students' pre-instructional knowledge and their observation.

During the implementation of the expository instruction, the main problem was that the instructional techniques used by the PSTs were not productive to help the students understand the targeted concepts. Especially the use of analogies was problematic - either the analogies were not familiar to the students or did not match with the targeted concepts.

Beside these specific problems, the general problem experienced by the PSTs, during their instructional practices, was lack of a coherent logical structure of the instruction. Independent from any specific instructional method, the PSTs frequently jumped from one concept to another by skipping some of the very important logical links between them. Interestingly, during the interviews, it was revealed that the PSTs were not aware of these jumps. Only when we explicitly showed these missing links, the PSTs realized them. For example, while giving an instruction about the properties of waves, PST4 began to talk about the electromagnetic waves and wrote a formula on the board ($E = Bc$; $E$ is for electric field, $B$ is for magnetic field and $c$ is for speed of light) and then turned back to talking about the properties of waves without explaining the relations between wave properties and the formula she wrote on the board. During the interview, this situation was asked:

Researcher: You wrote $E = Bc$ on the board while you were explaining the properties of waves. What is it related to?

PST4: The relation of magnetic field to electric field.

Researcher: You wrote it and went on (without explaining what it means).

PST4: You are right. I could not make connections among what I explained. I guess I did not care much whether students understood

what I explained. I tried to immediately explain what I had in my mind at that time.

### Metacognitive knowledge about students' knowledge

In their reflection papers, all PSTs argued that they considered students' pre-instructional knowledge in their instructional practices. They also reported that teachers should take into consideration students' pre-instructional knowledge when they plan their lessons. The pre-service teachers' references to students' knowledge during the instructional practices were mostly about the knowledge that students were supposed to gain during previous instructions. The PSTs asked several questions such as "what did we learn last meeting" or "what was the definition of force" to check whether the students could retrieve the information provided during the previous lessons rather than understanding students' own conceptualizations about the related concepts.

Table 3 shows that the number of pre-instructional knowledge explicitly addressed by the PSTs during their instructions was very limited. The pre-instructional knowledge explicitly addressed by the PSTs was as follows:

- If an object was hit by a bullet, it flies backwards.
- The object dropped from a particular height hits the ground faster than the object projected horizontally at the same height.
- Circular motion creates a centrifugal force.

Nevertheless, the PSTs used quite a number of prompts to get students' pre-instructional knowledge during their instructional practices as shown on Table 3. During these prompts the PSTs asked several questions. Some of the questions were directly related to a specific misconception. For example one of the PSTs asked "If I release two plastic bottles, one is full and the other one is empty, from the same height which one falls faster?" Some other questions were related to students' conceptualizations of a specific concept such as "how do you think about the force concept?"

Upon asking a question, no PSTs requested elaboration – asked students to explain their reasoning to understand why they answered in such ways. For instance, PST4 asked several questions such as "what have we learned last meeting?" and "what is wave?" However, her questions did not aim at exploring or eliciting what the students thought or knew about the topic. She seemed to ask question to herself rather than to the students. She answered the questions immediately after asking them. She used the questions as a guide for herself to start explaining the new knowledge rather than understanding students' own conceptualizations.

**Table 3.** The number of the PSTs' prompts to elicit students' pre-instructional knowledge, requests for elaboration and pre-instructional knowledge explicitly addressed

| PSTs | The number of pre-instructional knowledge explicitly addressed by the PSTs | The number of prompts used by the PSTs to get students' pre-instructional knowledge | The number of requests for elaboration of reasoning |
|---|---|---|---|
| PST1 | 1 | 1 | Never |
| PST2 | Never | 3 | Never |
| PST3 | 1 | 2 | Never |
| PST4 | Never | 1 | Never |
| PST5 | Never | 1 | Never |
| PST6 | 1 | 3 | Never |

**Table 4.** The instructional methods and techniques used by the PSTs and whether these methods and techniques appropriately were used or not

| PSTs | Instructional method used by the PSTs | Appropriateness of the method | Instructional techniques used by the PSTs | Appropriateness of techniques |
|---|---|---|---|---|
| PST1 | Expository Instruction | Yes | Analogy, Questioning Demonstration | Not appropriate |
| PST2 | Learning Cycle | Yes | Questioning | Not appropriate |
| PST3 | Expository Instruction | Yes | Analogy, Visualization, Questioning | Not appropriate |
| PST4 | Expository Instruction | Yes | Analogy Questioning | Not appropriate |
| PST5 | Learning Cycle | Yes | Questioning Experiment | Partially appropriate |
| PST6 | Cognitive Conflict | Yes | Demonstration Video, Analogy Visualization Verbal arguments | Partially appropriate |

### Strategy variable

While we were analyzing the PSTs' knowledge about their instructional methods, we observed that their knowledge about instructional methods was not at the expected level. Furthermore, they were not aware of the problematic aspects of their instructions while they were implementing the methods. Strategy variable was defined as the PSTs' awareness of what strategies (i.e., instructional methods and techniques) are useful for certain goals or sub-goals. While selecting an instructional strategy, the PSTs need to focus on the content they intend to teach, the level of students, and the available resources they can use during the instruction. For example, while implementing the learning cycle, the content should be appropriate for students to conduct their own explorations during the instruction. Similarly, while implementing the cognitive conflict, students should have common misconceptions related to the content that the PST aimed to teach. In this section of the analysis, we focused on whether the PSTs' choice of instructional methods and techniques were appropriate or not by considering the content that the PSTs planned to teach, the PSTs' competence to apply instructional methods and techniques, and the resources available to the PSTs.

Table 4 shows the instructional methods and techniques used by the PSTs and whether or not these methods and techniques were appropriately used or not. In spite of the problems experienced by the PSTs during the implementation of the methods, the choice of the methods is usually appropriate. However, the number of the techniques used by the PSTs and the appropriateness of the use of the techniques seem to be problematic. The major result in terms of the use of the techniques was that very limited number of the techniques was used. The most widely used technique was analogy. However, in some situations, the use of analogy was not appropriate because either the use of analogy was not necessary or an inappropriate analogy was used. For example, PST3 planned to teach a basic physics principle that "the horizontal velocity of an object is not influenced by gravity". For this purpose, he asked the following question:

> A man fires a bullet from a gun held parallel to the ground. At the same time, he drops another identical bullet at the same height. Which bullet hits the ground first?

After taking students' ideas, PST3 used the following phenomenon, as indicated in Figure 1, as an analogy to the gun phenomenon. When a Car A falls from the edge
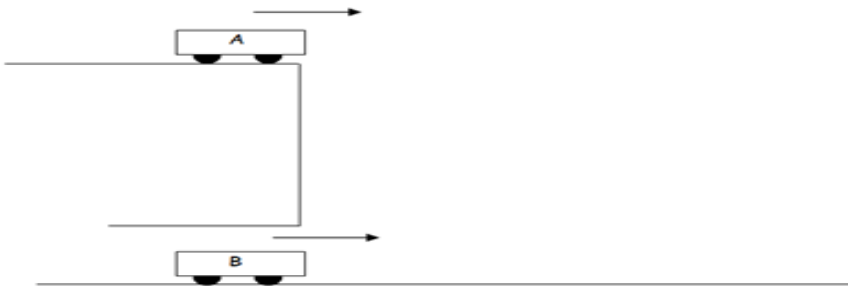
**Figure 1.** The example used by PST3 for an analogy

of a cliff with velocity V, the Car B with velocity V exits from a tunnel in the base of the cliff. Both cars have the same constant velocity before. Where does Car A land? PST3 expected that with this example, the students could easily see that Car A lands on Car B. Consequently, the similarity between the gun and cars situations could help the students to understand the principle that the horizontal velocity of a body is not affected by gravity. However, it was not a realistic expectation that the students were familiar to the cars' situation. Thus, this example did not serve as an analogy to help students to understand the targeted concept.

Other techniques frequently used by the PSTs were demonstrations and questioning which were mostly used appropriately. However, sometimes, the PSTs did not use some of the techniques even though the instructional method required them. For example, during the implementation of the learning cycle, PSTs usually needed to guide students through questioning but the PSTs hardly used this technique; instead, they preferred to give direct instructions about the inquiry processes of the learning cycle. Similarly, while the PSTs were using the cognitive conflict method, they preferred to create a conflict by verbal arguments even though a demonstration would be more powerful to create a conflict.

In short, the PSTs' strategic knowledge about the use of instructional method was mostly satisfactory in spite of the problems during the implementation of the method; nevertheless, their strategic knowledge about the use of the instructional techniques needs to be improved.

## Task variable

Task variable refers to how the pre-service teachers' conceptualize their task of teaching. The major source of data revealing the task knowledge was the PSTs' instructional plans, reflection papers, and videotaped instructional practices.

The data allowed us to generate interpretations about the task knowledge into three categories: focus of the task, major concerns about the task, and difficulty of the task. Table 5 summarizes the emerging subcategories for each category. In the first category, how the PSTs formulated the task of teaching in terms of students' and their roles in the instruction was examined. The task knowledge held by the pre-service teachers in this category was quite general and it was usually formulated in terms of what will be done by the teacher during the instruction. The PSTs seemed to define the subject of the instruction as themselves and focused on their activities independent from the students. Only one pre-service teacher (PST5) took a student centered perspective while designing his instruction. PST5 used the learning cycle to teach "motion in one dimension". Although he ignored to engage students at the beginning and elaborate the targeted concepts at the end of the instruction, he took a student-centered perspective during the exploration phase of the learning cycle.

**Table 5.** The PSTs' knowledge about the task of teaching

| PSTs | Focus of the task | PSTs' major concerns about the task | PSTs' judgments about the difficulty of the task |
|---|---|---|---|
| **PST1** | Teacher-centered | Following all steps of a method | Not difficult in terms of the content, but difficult with respect to the instructional method |
| **PST2** | Teacher-centered | Finding materials used in the instruction | Not difficult in terms of the content and instructional method |
| **PST3** | Teacher-centered | Matching method to subject matter, understanding the stage of the method | Not difficult in terms of the content, but difficult with respect to the instructional method |
| **PST4** | Teacher-centered | Teaching subject matter, Studying method and subject matter, | Not difficult in terms of the instructional method, but difficult with respect to the content |
| **PST5** | Student-centered | Integrating subject matter with the method | Not difficult in terms of the content and instructional method |
| **PST6** | Teacher-centered | Matching method to subject matter, and himself | Not difficult in terms of the content and instructional method |

He divided students into small groups, and let them conduct their own investigations. He also provided the students opportunities to explain their findings.

The second category included the PSTs' major concerns about the task. The PSTs' concerns about the task were mostly technical in nature such as following the necessary steps of a particular method or integrating subject matter into the teaching strategy. For example, PST6 reported the following arguments in his reflection paper:

> When I was getting prepared for my instructional practices, the first thing I focused was whether the instructional method I chose was suitable to the subject I would plan to teach in micro-teaching. For example, the selection of a particular misconception, creating conflict and matching it to the method are vital.

In the following quotation, another PST (PST3) defined his major concern as following the required steps of the instructional methods.

> When I was preparing to my practice in lesson, my big concern was about if I can do all steps of instruction well. That is, when using any method, there are some steps. In order to make a good teaching in a given method, I have to follow all the steps in classroom. However, when I am teaching, because of the atmosphere there, I could pass some of the important points. And that could affect the whole instruction. Actually, I did not make a big mistake in classroom, may be, but it was my big concern.

As seen from the table, no PST mentioned concerns related to students such as students' difficulties, motivation, or readiness. The PSTs' judgments about the difficulty of the task indicated that they generally did not find the task of teaching difficult. Studying subject matter and application of instructional method were two difficulties reported by the PSTs.

## DISCUSSION AND CONCLUSION

In this study, the PSTs' metacognitive knowledge about their teaching practices was investigated. To determine the level of the PSTs' metacognitive knowledge

about teaching practices, a framework was developed by adapting Flavell's framework of metacognitive knowledge.

The major argument of this study was that metacognition seems to have a potential to put some light on instructors' difficulties related to instructional practices. The analysis of the data provided evidence that metacognitive knowledge on teaching is a fruitful framework to generate interpretations about the instructional processes. This result of the current study complements the results of several studies that focused on the process base of teacher metacognition (Artzt & Armour-Thomas, 1998; Hartman, 2001; Lin, Schwartz, & Hatano, 2005; Peterson, 1988; Zohar, 1999). The analysis indicated that the PSTs' metacognitive knowledge about their content knowledge was quite satisfactory. They were mostly aware of their weaknesses and strengths regarding the level of their content knowledge they had planned to teach. However, the PSTs demonstrated poor judgments on the other components of metacognitive knowledge. In terms of the metacognitive knowledge about their instructional method, our judgments generally conflicted with the PSTs' judgments. Zohar (1999) reported parallel results for science teachers. He found that teachers' metacognitive knowledge about teaching of higher order thinking skills was not adequate. Similarly, the PSTs' metacognitive knowledge about students' pre-instructional knowledge and reasoning was poor. Similar results were reported in the literature. For example, Gullberg, Kellner , Attorps , Thorén, & Tärneberg (2008) investigated pre-service teachers' awareness of students' understandings in science and mathematics. They found that a third of pre-service teachers did not pay attention to students' knowledge when they were planning their lessons. Furthermore, Bukova-Güzel (2010) reported that pre-service mathematics teachers did not address students' pre-instructional ideas during their instructional practices.

The analysis related to strategy variable showed that the PSTs chose the instructional methods appropriately. However, they had some problems related to the techniques required for the implementation of the instructional methods. The major problem that the PSTs were experiencing about their instructional practices seems to be related to how they interpreted their task of teaching. The PSTs' major concerns about the task of teaching were mostly limited to the method of teaching. This is an expected result because the data were collected during an instructional method course. However, the implementation of an instructional method was reduced to "following some pre-defined steps." The PSTs focused on some surface features of instructional method and ignored the essential elements of instruction during the implementation. They were not aware that the implementation of an instructional method is a dynamic process and requires the use of broad range of instructional tools and students' knowledge/reasoning. The PSTs' narrow view about the instructional method is probably due to overemphasis on the specific steps of instructional methods and ignorance on the elaboration of instructional methods as a dynamic process during instructional method courses.

Another issue that the PSTs experienced during the implementation of instructional methods was the PSTs' inclination towards direct instruction. Even though they were trying to implement alternative instructional methods, it was common to observe the PSTs giving direct instructions about the targeted concepts. The literature of teacher education has also provided evidence that even though the PSTs have strong beliefs on the success of student-centered instructional practices they may fail to reflect these beliefs on their teaching approaches (Cheng, Chan, Tang, & Cheng, 2009). PSTs' persistence on direct instruction usually sabotaged the true nature of alternative instructional methods especially the inquiry oriented ones. Unfortunately, the PSTs were not aware that they were not implementing the instructional methods that they were intended to teach.

In conclusion, the results of the study has showed that metacognition on teaching is as important as metacognition on learning in terms of locating and understanding some of the instructional problems. In this study, we focused on very limited elements of teacher knowledge. However, instruction is a multifaceted process and requires multiple sources of knowledge which is referred as pedagogical content knowledge. We believe that focusing on different elements of teacher knowledge and instructional processes with metacognitive lenses help the researchers further understand the difficulties related to instructional processes.

## REFERENCES

Adey, O., & Shayer, M. (1993). An explanation long- term far transfer effects following and extended intervention program in the high school science curriculum. *Cognition and Instruction, 11*(1), 1-29. doi**:** 10.1207/s1532690xci1101_1

Artzt, A. F., & Armour-Thomas, E. (1998). Mathematics teaching as problem solving: A framework for studying teacher metacognition underlying instructional practice in mathematics. *Instructional Science*, *26*(1-2), 5-25. doi: 10.1023/A:1003083812378

Baker, L. (1991). Metacognition, reading, and science education. In C.M. Santa and D.E. Alvermann (Eds.), *Science learning: Processes and applications* (pp. 2-13). Newark, DE: International Reading Association.

Blank, L. M. (2000). Metacognitive learning cycle: A better warranty for students understanding. *Science Education, 84*, 486- 506. doi:10.1002/1098-237X(200007)84:4<486::AID-SCE4>3.0.CO;2-U

Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert and R. H. Kluwe (Eds), *Metacognition, Motivation, and Understanding* (pp. 65-116). Hillsdale, NJ: Lawrence Erlbaum.

Bukova-Güzel, E. (2010). An investigation of pre-service mathematics teachers' pedagogical content knowledge, using solid objects. *Scientific Research and Essays*, *5*(14), 1872-1880.

Carr, M., Kurtz, B. E., Schneider, W., Turner, L. A., & Borkowski, J. G. (1989). Strategy acquisition and transfer among German and American children: Environmental influences on metacognitive development. *Developmental Psychology*, 25, 765-771. doi: 10.1037/0012-1649.25.5.765

Celce-Murcia, M. (1991). Language teaching approaches: An overview. In M. Celce-Murcia (Ed.), *Teaching English as a second or foreign language* (pp. 3-11). New York, NY: Newbury House.

Cheng, M.H, Chan, K., Tang, S.Y.F., & Cheng, A.Y.N. (2009). Pre-service teacher education students' epistemological beliefs and their conceptions of teaching. *Teaching and Teacher Education*, 25, 319-327. doi:10.1016/j.tate.2008.09.018

Desoete, A., Roeyers, H., & Buysse, A. (2001). Metacognition and mathematical problem solving in grade 3. *Journal of Learning Disabilities, 34,* 435–449. doi: 10.1177/002221940103400505

Desoete, A., Roeyers, H., & De Clercq, A. (2003). Can offline metacognition enhance mathematical problem solving? *Journal of Educational Psychology, 95,* 188–200. doi: 10.1037/0022-0663.95.1.188

Everson , H.T, Tobias, S (1998). The ability to estimate knowledge and performance in college: A metacognitive analysis*. Instructional Science*, 26: 65-79. doi: 10.1023/A:1003040130125

Flavell, J.H. (1979). Metacognition and Cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologists, 34,* 906- 911. doi: 10.1037/0003-066X.34.10.906

Georghiades, P. (2000). Beyond conceptual change learning in science education: focusing on transfer, durability and metacognition. *Educational Research*, *42*(2), 119–139. doi: 10.1080/001318800363773

Georghiades, P. (2004). Making pupils' conceptions of electricity more durable by means of situated metacognition. *International Journal of Science Education*, *26*(1), 85-99. doi: 10.1080/0950069032000119401

Gullberg, A., Kellner, E., Attorps, I., Thorén, I., & Tärneberg, R. (2008). Prospective teachers' initial conceptions about pupils' understanding of science and mathematics. *European Journal of Teacher Education*, *31*(3), 257-278. doi: 10.1080/02619760802208429

Hartman, H. J. (2001). Teaching metacognitively. In H. J. Hartman (Ed.), *Metacognition in Learning and Instruction: Theory, Research and Practice* (pp. 149-172)). Boston: Kluwer.

Jay, J. K., & Johnson, K. L. (2002). Capturing complexity: A typology of reflective practice for teacher education. *Teaching and Teacher Education*, *18*(1), 73-85. doi:10.1016/S0742-051X(01)00051-8

Kluwe, R. H. (1987). Executive decisions and regulation of problem solving behavior. In F. E. Weinert and R. H. Kluwe (Eds), *Metacognition, Motivation, and Understanding* (pp. 1-19). Hillsdale, NJ: Lawrence Erlbaum.

Kreber, C., and Castleden, H. (2009). Reflection on teaching and epistemological structure: Reflective and critically reflective processes in 'pure/soft' and 'pure/hard' fields. *Higher Education, 57*, 509–531. doi: 10.1007/s10734-008-9158-9

Leou, M., Abder, P., Riordan, M., & Zoller, U. (2006). Using 'HOCS-centered learning as a pathway to promote science teachers' metacognitive development. *Research in Science Education*, *36*(1-2), 69-84. doi: 10.1007/s11165-005-3916-9

Lin, X., Schwartz, D. L., & Hatano, G. (2005). Toward teachers' adaptive metacognition. *Educational Psychologist*, *40*(4), 245-255. doi: 10.1207/s15326985ep4004_6

McAlpine, L., Weston, C., Beauchamp, J., Wiseman, C. & Beauchamp, C. (1999). Building a metacognitive model of reflection. *Higher Education 37*, 105–131. doi: 10.1023/A:1003548425626

Ottesen, E. (2007). Reflection in teacher education. *Reflective Practice, 8*(1), 31–46. doi: 10.1080/14623940601138899

Parsons, M., & Stephenson, M. (2005). Developing reflective practice in student teachers: Collaboration and critical partnerships. *Teachers and Teaching*, *11*(1), 95-116. doi: 10.1080/1354060042000337110

Peşman, H., & Özdemir, Ö. F. (2012). Approach– method interaction: The role of teaching method on the effect of context-based approach in physics instruction. *International Journal of Science Education*, 34(14), 2127-2145. doi: 10.1080/09500693.2012.700530

Peterson, P. L. (1988). Teachers' and students' cognitional knowledge for classroom teaching and learning. *Educational Researcher*, *17*(5), 5-14. doi: 10.3102/0013189X017005005

Schraw, G. & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*: 460–475. doi: 10.1006/ceps.1994.1033

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*(1-2), 111-139. doi: 10.1007/s11165-005-3917-8

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7*(4), 351-371. doi: 10.1007/BF02212307

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

Yerdelen-Damar, S., & Peşman, H. (2013). Relations of gender and socioeconomic status to physics through metacognition and self-efficacy. *The Journal of Educational Research*, *106*(4), 280-289. doi: 10.1080/00220671.2012.692729

Yin, R. K. (1984). *Case study research: Design and methods*. Newbury Park, CA: Sage.

Young, A., & Fry, J. (2008). Metacognitive awareness and academic achievement in college students. *Journal of the Scholarship of Teaching and Learning*, *8*(2), 1-10.

Yuruk, N., Beeth, M. E., & Andersen, C. (2009). Analyzing the effect of metaconceptual teaching practices on students' understanding of force and motion concepts. *Research in Science Education*, *39*(4), 449-475. doi: 10.1007/s11165-008-9089-6

Zohar, A. (1999). Teachers' metacognitive knowledge and the instruction of higher order thinking. *Teaching and Teacher Education*, *15*(4), 413-429. doi:10.1016/S0742-051X(98)00063-8

◈ ◇ ◈