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**Integrating Video Analysis of Teacher and Student Behaviors**

**to Promote Preservice Teachers' Teaching Meta-Strategic Knowledge**

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**Abstract**

Using a quasi-experimental design, our study integrated systematic learning from teachers’ behaviors and students’ behaviors preparatory programs and examined how such learning affected preservice physics teachers’ capacity to teach meta-strategy knowledge (MSK). Results indicated that pre-service teachers who contemplated both teachers' and students' behaviors improved their teaching of MSK to a greater extent and their students had more MSK achievements compared to pre-service teachers who contemplated the process of learning only from the perspective of the teachers’ behaviors. The current study suggests the need to integrate systematic approaches that analyze both teachers’ and students’ behaviors into teacher preparation programs as a means for developing pre-service teachers’ capacity to promote students' MSK.

**Keywords**: learning from teachers’ behaviors, learning from students' behaviors, meta strategy knowledge, teacher education, teaching control of variable strategy

**Introduction**

Metacognition is made up of a number of components. The following study focuses on one component in particular: meta-strategic knowledge (MSK). Meta-strategic knowledge is defined as the general and explicit knowledge of the manipulated cognitive procedures (Kuhn, Katz & Dean 2004; Zohar & Ben David, 2008). In particular, this study focused on the cognitive processes that are involved in higher-order thinking strategies. For example, higher-order thinking strategies are utilized when constructing good arguments; solving problems; classifying, establishing, and analyzing causal relationships; formulating research questions, testing hypotheses, drawing valid conclusions, and deciding which variables to control (Kuhn, 2000, 2002). The vast amount of traditional scientific inquiry about thinking strategies utilizes these cognitive methods (National Academies of Sciences, Engineering, and Medicine, 2016; Zoller, 2000). The metacognitive knowledge that is relevant to the current study is the awareness of the particular thinking strategy used in a specific situation. Although this type of knowledge can be both implicit and explicit, it is always taught explicitly in school settings; in other words, metacognitive knowledge is openly discussed in the classroom (Kuhn et al, 2004; Zohar & Ben David, 2008). Metacognitive knowledge consists of different cognitive methods: (1) utilizing generalizations to decipher the rules about a thinking strategy and naming the thinking strategy; (2) clarifying why and when the strategy would be used, and the manner in which it is used; (3) listing the task characteristics needed to use the strategy; and (4) naming the disadvantages of failing to use the correct strategy (Kuhn, 2000a, 2002).

The meta-strategic knowledge focused on in this study is the control of variables strategy (CVS). This strategy is considered to be a core skill in scientific reasoning. An understanding of CVS helps to build interpretable research, as it involves the researcher’s manipulation of only the variables of interest while, at the same time, keeping all other variables constant (Chen & Klahr, 1999). In addition, CVS can be used to deduce logical inferences from research studies, as one compares the outcomes of the different conditions that differ only in one manipulated variable (Ross, 1988; Zohar & Ben David, 2008).

This study argues that a useful way to enhance students’ reasoning abilities is by maintaining general cognitive structures, as well as teaching specific contexts. This can be achieved using a number of pedagogical strategies that teach MSK. For example, such strategies can include reflecting on others’ performance on an assignment or engaging in multiple meta-level written tasks (e.g., Kuhn et al. 2004; Pearsall, 1999).

Popular educational notions suggest that in order for learning to be meaningful and useful, the learner must actively construct the knowledge. This belief mainly refers to the learning of concepts and strategies, but is also relevant to learning meta-strategies. In our study, the teaching of MSK is explicit and does not include instruction by “transmission learning” or rote learning (Tan, Chua & Goh, 2015; Zohar, 2004; Zohar & Peled, 2007). Rather, the instruction involved in teaching MSK utilizes explicit and verbal communication that focuses on encouraging the learner to engage in active thinking and to form a deep understanding of the material (Author, 2013).

The teaching and learning of MSK in schools includes two main features. The first feature refers to the linguistic element of constructing statements to be discussed both in a social and individual context. The second feature is that, because of the abstractness of MSK, many students will not be able to understand this sort of knowledge if they do not have personal experience with it (Dean and Kuhn, 2007; Zohar & Peled 2007; Zohar & Ben David, 2008). Given these features, we can conclude that when teaching concepts such as addressing rules, generalizations, and good thinking principles, the best strategy is to eliminate abstractness by connecting the material to students’ personal experiences (Kuhn, 1999, 2000b, 2001; Kuhn et al. 2004).

One problem that prevents teachers from incorporating MSK teaching is that they lack the knowledge on how to implement it practically in a classroom setting (e.g., Perry, Brenner & Fusaro, 2015; Zohar & Lustov, 2018). Teachers, especially those who have not had prior experience as reflective practitioners, struggle in choosing the best methods to help students develop MSK skills (Author, 2014; Perry et al, 2008). To ensure students’ MSK learning progress, teachers must make sure to maintain constant awareness of their students’ development and asses and reflect on their work, as well as simultaneously using supported tactics that encourage metacognitive activity (Perry et al., 2002; Veenman et al., 2006).

To enhance teachers’ MSK teaching abilities, the present study suggests a model for integrating a professional vision for MSK into pre-service teachers’ training through the utilization of a video-based laboratory learning environment. Our study explored the value of pre-service physics teachers’ systematic reflection on *students' classroom behavior* during the practicum phase of their preparatory programs, as a complementary approach to the more traditional systematic reflection on *teachers' classroom behavior.* Both reflective approaches – learning from student behavior (LFSB) and learning from teacher behavior (LFTB) – are conceptualized as professional vision (PV) processes. Our study examined the differential contribution of either LFTB or LFTB + LFSB to the dependent variables: the actual teaching of MSK, measured both implicitly and explicitly, and students’ application of MSK.

Prior to describing the present exploratory study’s design, we introduce a brief overview of MSK teaching and PV, as well as present a model for integrating PV for MSK into pre-service teachers’ training programs for teaching MSK.

**Theoretical background**

The goals of science education and the methods used to achieve these goals must be changed to meet the challenges of the world today, in particular the rapid and dynamic changes in the fields of science and technology. The emphasis in the classroom is shifting from a focus on learning large amounts of information and acquiring basic skills, to prioritizing the development of higher-order and reasoning skills as well as acquiring deep understandings in order for students to gain and process new information (National Academies of Sciences, Engineering, and Medicine, 2016; National Research Council, 2012; Organisation for Economic Co-operation and Development – OECD, 2017).

Metacognition – an individual’s awareness and control over their own thinking and learning strategies – is one of the main components of effective science learning, which consists of both higher-order thinking and self-regulated learning (Brown, 1987; Flavell, 1979; Schraw & Moshman, 1995). Since the innovative writings of Flavell (1979) and Brown (1987), the development of students’ metacognition has become a primary educational goal (Flavell, 1979; Garner & Alexander, 1989). Flavell et al. (2002) have separated the term metacognition into three main components. The first component, metacognitive knowledge, was further separated into another three sub-components: strategies, tasks, and knowledge about persons. The first two of these sub-components are connected to MSK, as they focus on the nature of the tasks and strategies which aim at learning specific cognitive goals. Another perspective, introduced by Schraw (1998), concerns the separation between regulation of cognition and knowledge of cognition. Knowledge of cognition specifically consists of declarative, procedural, and conditional knowledge. Both regulation and knowledge of cognition are related to MSK because they refer to the effective use of strategies, including knowing when and why to use particular strategies.

The current study, in contrast, uses the definition constructed by Kuhn, who dedicated a considerable amount of time to the study of MSK (Kuhn 1999, 2000, 2001a, b; Kuhn & Dean, 2004). Kuhn’s procedural meta-level knowing, which this study’s perception of MSK is largely based on, focuses on what one can accomplish while using knowing strategies, as well as when, why and in what manner the strategies should be used. According to Kuhn, meta-strategic understanding includes two main elements: (1) being aware of and understanding both the nature and necessities of the task; (2) being aware of and understanding the way in which one can use the strategies in one’s repertoire in order to effectively accomplish the task. The combination of these two components –understanding the task and understanding the strategies – is what Kuhn sees as the challenge of effective meta-strategic thinking (Kuhn & Pearsall, 1998).

Researchers agree that teachers have a great deal of influence over students’ MSK development (Schraw, Crippen & Hartley, 2006; Schunk & Zimmerman, 1997). Therefore, a number of pedagogical models for teaching MSK have been developed (Cleary & Zimmerman, 2004; Perry, VandeKamp, Mercer, & Carla, 2002; Schunk & Zimmerman, 1997; Zimmerman, 1998). These models can be organized into three complementary approaches (Dignath et al., 2008): (a) providing key contextual elements or learning conditions that facilitate MSK (e.g., giving students choices, opportunities for control, and peer collaboration; Perry et al., 2002); (b) modeling to facilitate learners’ movement from emulator (an individual who imitates a more experienced other) to self-regulator (an individual who independently adapts learning strategies to meet new contextual demands; e.g., Schunk & Zimmerman, 1997); and (c) engaging in direct MSK strategy instruction (e.g., Dignath& Büttner, 2008). The third pedagogical approach entails giving students *explicit directions* on how to use strategies, when to use them, what goals to set, how to pursue those goals, and how to monitor strategies and movement toward goal achievement. Additionally, it includes providing students with *explicit information* about the meaning and importance of those strategies, as well as information to help them explicitly understand the goal of the learning task, which may offer students a metacognitive understanding that can lead to applying the learned strategies in the future. Direct MSK instruction contrasts with teachers' mere modeling of a strategy’s use and verbalization of thought processes, which can implicitly induce students to engage in certain behaviors, but it does not inform students about the activity’s significance.

Despite the considerable literature on pedagogical strategies and learning environments for promoting MSK, more empirical research is sorely needed to analyze authentic pedagogical situations in which pre-service teachers attempt to promote their students’ MSK. Such research efforts would address several questions raised in the literature: How do pre-service teachers actually inculcate MSK in various teaching and learning contexts (Randi & Corno, 2000)? How can teacher educators help pre-service teachers design tasks and engage in practices that promote their students’ MSK (Perry et al., 2006)?

Butler, Schnellert, and Perry (2017) highlight the importance of training pre-service teachers how to define the explicit teaching of MSK, monitor student successes, and interpret outcomes with implications for practice. To meet the growing call to create a cadre of flexible, yet effective, MSK-promoting teachers, the present study focused on facilitating pre-service teachers' development of professional vision (PV) for MSK explicit teaching, while comparing two scaffolding methods to determine which best promotes MSK teaching.

*Pre-service Teachers’ Professional Vision (PV)*

The PV concept (Goodwin, 1994) refers to teachers’ ability to notice features of classroom events that are relevant for student learning, and to analyze and interpret those events using prior content knowledge and prior pedagogical content knowledge, namely, domain-related pedagogical principles and concepts (Sherin, 2007; van Es & Sherin, 2002). PV is conceptualized as a complex “dynamic interplay of top-down and bottom-up processes” (Sherin, 2007, p. 384) that should be guided by teachers’ timely application of higher-order thinking skills before and during multifaceted classroom situations, as well as after making decisions and taking actions (Kunter, 2013; Kunter & Baumert, 2006; Seidel, 2012). PV expertise allows teachers to perceive and respond flexibly to students’ understanding and reasoning at any given moment (Berliner, 2000), thereby helping teachers provide effective learning opportunities.

Research has identified two component processes of teachers’ PV. *Noticing* refers to teachers’ ability to direct their attention to relevant classroom situations (van Es & Sherin, 2002). *Knowledge-based reasoning* describes teachers’ cognitive processing of the noticed events, which is grounded in their knowledge about effective teaching and learning (Borko, 2004; Sherin, 2007; van Es & Sherin, 2002), and their ability to transfer that knowledge to authentic instructional situations (Palmeri, Wong, & Gauthier, 2004; Seidel, Schwindt, Stürmer, & Blomberg, 2008).

A qualitative empirical analysis of teachers’ reflections while observing videotaped classroom situations yielded three qualitatively distinct, but highly interrelated levels of reasoning – description, explanation, and prediction (Blomberg, Stürmer, & Seidel, 2011; Seidel & Stürmer, 2014; Stürmer, Könings, & Seidel, 2013). *Description* is defined as identifying and differentiating particular classroom events based on teaching knowledge. *Explanation* refers to classifying a noticed classroom event based on teaching knowledge while bridging between theories and classroom practice. *Prediction* is the pedagogical knowledge of how to forecast future classroom practice based on noticed events impacting student learning processes. Unsurprisingly, in contrast to experienced teachers, pre-service teachers tended to identify fewer critical classroom events, described classroom situations in more limited and naïve terms (Carter, Sabers, Cushing, Pinnegar, & Berliner, 1987; Seidel, 2011), explained and predicted fewer classroom events and practices (Seidel, 2012; Seidel & Prenzel, 2007), and applied theoretical knowledge less effectively to authentic classroom situations (Gruber, 2001; Putnam & Borko, 2000; Shulman, 1987). Educators agree that equipping pre-service teachers with PV skills would allow them to continuously reflect on their teaching processes as they mature professionally, as well to generate knowledge that would guide their gradual acquisition of expertise (Hiebert, Morris, Berk, & Jansen, 2007; Santagata & Angelici, 2010). Nevertheless, little is known about the connections between pre-service PV skills and actual MSK-teaching, which is the question at hand in the present study.

*Video-Based PV Training for MSK-Mapping*

Video observation and analysis of classroom situations has been shown to promote teachers’ application of PV abilities, such as noticing and reasoning about students’ learning and thinking behaviors (Franke, Carpenter, Levi, & Fennema, 2001; Santagata et al., 2007; van Es & Sherin, 2010; Yea & Santagata, 2013), as well as predicting alternative instructional strategies (Kersting et al., 2009; van Es & Sherin, 2002). Although the educational potential of video analysis has largely been recognized, the simple provision of opportunities to analyze video cases is not sufficient to enhance pre-service teachers' PV skills; rather, the analysis needs to be an accompanied by specific instruction and guidance (Santagata & Angelici, 2010; Seidel & Prenzel, 2007). Yet, what counts as effective PV guidance, or PV scaffolding, for video-analysis remains an open question.

Moreover, based on science education reforms that call for an inquiry into student-centered teaching and learning, van Es and Sherin (2008) appealed to teacher educators to help pre-service teachers go beyond analyzing and interpreting teachers' classroom behaviors by using scaffolding techniques with teacher trainees that emphasize students as the main actors in classroom interactions. Researchers have argued that learning from students’ behavior (LFSB) is imperative for the successful development of students’ MSK (Ganda & Boruchovitch, 2018; Kuhn & Dean, 2004; Randi & Corno, 2000; Sabourin, Shores, Mott, & Lester, 2013; Santagata & Angelici, 2010). These appeals call for a more specific inquiry into how pre-service teachers can optimally capitalize on reflective analysis, with a complementary focus on all major actors in classrooms today (Perry, Phillips, & Hutchinson, 2006). Analyzing not only teacher behavior, but also student behavior in authentic pedagogical situations should help develop pre-service teachers’ professional vision skills for mapping MSK-teaching by engaging in effective practices and creating appropriate environments that promote students’ MSK (COLLEAGUES & AUTHOR, 2009; Randi & Corno, 2000; Randi, 2004).

*The present study*

Education reforms call for teacher education programs to shift the emphasis of MSK pedagogical knowledge from teacher regulation of students’ learning to students’ regulation of their own learning. As such, this study examined a new conceptual PV approach for teachers, which blends learning from student behaviors (LFSB) with learning from teacher behaviors (LFTB), while analyzing MSK-teaching modes as portrayed in videotaped lessons (National Research Council, 2012; van Es & Sherin, 2008).

*Learning from teacher behavior (LFTB).*University-based teacher education has been criticized for not bridging the gap between theory and practice (Borko, 2004; Seidel, 2011; van Es & Sherin, 2008). Many pre-service teachers struggle with applying their basic knowledge of pedagogy to dynamic real-time teaching situations. To bridge the gap between pedagogical knowledge and actual classroom practices, preparatory programs utilize video observation to critically reflect on pre-service teachers' behavior (Borko, 2004; Seidel, 2011, van Es & Sherin, 2008). Video observation elicits conscious post-action reviews (noticing, describing, explaining, predicting) and stimulates a process of sense-making (Hastie, 1984; Lau & Russell, 1980; Mahenswaran & Chaiken, 1991). The effectiveness of video observation in promoting teacher reflection and change has led to a consensus recommendation among leaders in educational programs and teaching professionals to incorporate LFTB into organizational practices.

*Learning from student behavior (LFSB).* The recommended shift to a student-centered view of teaching and learning, including an emphasis on knowledge construction (National Research Council, 2012), emphasizes the necessity for teachers to carefully observe student behavior. Teachers are expected to, at least in part, make appropriate pedagogical decisions while adapting MSK-instructional practices and learning environments in a manner that meets their students’ diverse needs (van Es & Sherin, 2008). For example, if a teacher notices two students whispering about how to solve a problem under discussion, she can approach the situation in multiple ways. She can decide to ask the pair to share their dilemma aloud with the class in order to elicit class interest, she can provide more data on the problem to prevent misconceptions about the task, or she can divide the class into small groups for peer discussion to encourage the learner-centered practice of building problem-solving skills. In the more specific case of inquiry-based science projects, teachers are encouraged to analyze and interpret students’ behavior in order to promote students’ MSK and science understanding while giving students the opportunity to independently investigate authentic questions (Hammer, 2000; National Research Council, 2012; van Zee & Minstrell, 1997).

This learner-centered view of teaching and learning requires teachers to develop new ways of noticing and interpreting classroom interactions (e.g., Blomberg et al., 2011; Seidel & Stürmer, 2014; Stürmer et al., 2013). Prior research has shown that some experienced teachers may already engage in these practices (Berliner, 2000; Heyd-Metzuyanim & Shabtay, 2019). However, current teacher education programs do not explicitly focus on helping pre-service teachers learn to analyze and interpret *student behavior*. In particular, preparatory programs do not address the topic of how *student behavior* can trigger *teachers’ MSK-teaching behavior* and thus affectstudents' thinking. Instead, programs usually focus on helping teachers analyze *their own MSK-teaching behavior* and provide frequent instruction concerning new pedagogical techniques or activities (Berliner, 2000; Day, 1999; Huling, Resta, & Rainwater, 2001; Niess, 2001; Putnam & Borko, 2000; Zohar & Lustov, 2018). Teacher-focused activities are certainly important, but they do not necessarily ensure pre-service teachers gain PV expertise in noticing, describing, explaining, and predicting students’ verbal and nonverbal behaviors.

Understanding students’ MSK learning behavior has been the subject of increasing attention (Sabourin, Shores, Mott, & Lester, 2013). Unfortunately, monitoring this behavior in real-time has proven to be challenging. However, understanding and scaffolding students’ MSK learning behavior is especially important in open-ended learning environments where goals may be less clear, and students do not necessarily receive clear indications of their progress. In particular, in the context of science teaching and learning (e.g., laboratory research learning and Project Based Learning), open learning environments offer students opportunities to develop and practice their MSK learning processes. Such environments provide students with active learning tasks and a set of tools for exploring, hypothesizing, and building solutions to authentic and complex problems. In order to be successful in this type of learning environment, students must actively identify and select their own goals and evaluate their progress accordingly. However, research has shown that students do not consistently demonstrate sufficient MSK behaviors during interactions with these environments, which may reduce the potential contributions to learning (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Kirschner, Sweller, & Clark 2006). Consequently, further investigation of the role of MSK in open-ended learning environments is necessary to understand how the teaching and learning of MSK can be incorporated most effectively in these environments.

**A complementary approach.** The present study draws on the increasing value attributed to student-centered teaching for promoting effective teaching practices, as well as students’ MSK acquisition and domain-specific academic achievements (Dignath & Büttner, 2008). Moreover, there is a widespread call to systematically analyze teacher behavior, with the goal of developing teachers’ PV and building their pedagogical knowledge (Seidel, 2011). Therefore, the quasi-experimental study aims in the current research were to examine the possible added benefit of incorporating the LFSB-reflective approach with the LFTB-reflective approach during pre-service science teachers’ practicum phase. This study is innovative as it expands pre-service teachers’ perspective during video analysis to include both teacher-centered as well as student-centered behavior. Further, the study advances the field by examining how pre-service teachers' actual teaching in schools may benefit from PV development via an explicit model that scaffolds mapping of MSK-teaching based on these different foci (see Table 1).

**Research Questions and Hypotheses**

The goals of this study were threefold. The first goal was to design the two reflective PV for MSK-instructional approaches for mapping direct/indirect MSK-teaching modes from videotaped science-teaching vignettes, viewed during pre-service university-based workshops. Trainings were based either (a) solely on traditional LFTB or (b) on two complementary approaches (LFSB + LFTB). The second goal was to compare the effectiveness of LFTB vs. LFTB + LFSB for pre-service teachers’ actual MSK teaching of their students (Q1). Lastly, the third goal was to examine the contribution of pre-service teachers’ LFTB vs. LFTB + LFSB reflective approaches for students’ MSK (Q2).

Research hypotheses were based on: (a) researchers’ assertions that pre-service teachers will likely need more explicit, systematic reflective support during their training (Pintrich 2002; Veenman et al. 2006); (b) several prior claims that systematic, bottom-up specific prompts might foster pre-service teachers’ use of MSK in ill-defined domains such as pedagogy education (Davis 2003; Ifenthaler 2012; Koedinger and Aleven 2007; AUTHOR & COLLEAGUE, 2015); and (c) initial studies that point to the benefit of specific prompts emphasizing student behavior for developing PV for teaching (Seidel et al. 2014; Kramarski & Choen, 2017). In regard to Q1, which examined group differences in the actual teaching of MSK, we expected that the group of participants exposed to the LFTB + LFSB-prompts condition would be more effective than the group exposed only to the LFTB- prompts condition. In regard to Q2, which examined group differences in students’ MSK, we expected that the students’ MSK in the group exposed to LFTB + LFSB prompts would yield better outcomes than the group exposed only to LFTB. This hypothesis reflects previous research, which indicates that the utilization of both LFTB + LFSB prompts hold merit for transferring knowledge to new contexts using different thinking paths (Aleven et al. 2006; Davis 2003; Ifenthaler 2012; Michalsky and Kramarski 2015; McNeill and Krajcik 2008; Salomon and Perkins 1989; Wu and Looi 2012).

**Method**

*Participants*

Participants included 82 second-year pre-service physics teachers who were enrolled in a practicum teacher education course at one of two major Israeli research universities (65% females, 35% males; 88% Jewish, 12% Arab). The average age of participants and acceptance criteria were similar across the two programs (age: M *=* 26.3 years, SD = 6.1; GPA: M *=* 85 out of 100, SD = 5.6). Each university was assigned to one of the two intervention procedures. Responses to ten open-ended questions from the standard Israeli high-school physics curriculum found no significant differences in physics content knowledge across participants from the two university programs, (F (1, 81) = 2.1, p > 0.17). For their practicum field training, the pre-service teachers were assigned to teach 10th grade physics in fourteen high schools (4-5 pre-service teachers from each university were assigned to each school).

**Intervention procedure.** As seen in Table 2, both reflective groups shared the same training structure, but had different instructor training content. All participating pre-service teachers attended the same two academic courses at a separate university for each group – the Science Teaching and Learning Methods video-analysis course (in which they viewed the same eight authentic video vignettes) and the Practical Teaching fieldwork practicum training course. All teachers and students were administered the same assessments in both groups. The only component distinguishing between the two intervention groups was the reflective approach used for theoretical instruction and for video-analysis in the Science Teaching and Learning Methods course: in the LFTB-only group, the emphasis was solely on how MSK-teaching behavior affects student thinking/behavior, and in the LFTB + LFSB group, the emphasis was on how student behavior influences teachers’ MSK-teaching behavior, which in turn impacts students’ MSK and science achievements (see components highlighted in bold in Table 2).

**Measures.** Two dependent variables were measured at three different time points: at the beginning, middle, and end of the year-semester practicum course.

***Pre-service teachers’ actual MSK teaching* (*N =* 82)*.***

To assess the possible differential effects of the two reflective methods on actual MSK-promoting teaching skills among pre-service physics teachers, participants’ teaching of MSK was examined at three time points during the practicum. The time points chosen for administering the measures were based on research that indicated that pre-service teachers’ reflection skills develop predominantly through practicing the reflection process in various teaching situations (Schön, 1983), and on research that shows that the more opportunities there are to practice reflection, the better the development of pre-service teachers’ reflection skills (Zeichner & Liston, 1987).

**Data collection.** Videotapes were collected from all pre-service teachers’ actual teaching experiences with high school students. Each pre-service teacher was videotaped giving three different lessons in his/her practicum classroom (each lesson lasted approximately 45 minutes). These lessons took place on the first, middle, and last day of the pre-service teaching period. The lessons dealt with the solar system (Time 1), global warming (Time 2), and electromagnetism (Time 3), and were in line with the standard Israeli Ministry of Education high school physics curriculum. Videotaping began as soon as the teacher started the lesson and continued until the lesson ended. The high school students and pre-service teachers were informed that the videotaping was part of a research study that aimed to determine the effectiveness of pre-service training. Moreover, the study was approved by the chief scientist in the Israeli Ministry of Education and parental consent was obtained.

**Data coding.** Each videotape was coded by two trained observers using the ATES observation instrument (**A**ssessing How **T**eachers **E**nhance Metacognition; Dignath, Dickhäuser & Büttner, 2013). This observation instrument consisted a low-inferent coding system, which was used to assess the quantity and quality of MSK teaching. The videos were coded in one minute increments, because briefer units of time turned out to be impractical, and longer units of time increased the risk of losing information. This produced approximately 45 segments per lesson; however, not all observed lessons were exactly the same length as they ranged from 35 to 45 minutes. For coding purposes, the observed amount of time per each strategy was standardized to 45 minutes, and a standardized average frequency related to the total length of each lesson was computed.

***Coding of pre-service teachers’ actual teaching of MSK.*** The low-inferent coding system, based on Kuhn’s (1999) MSK model, was used to assess small-unit features of pre-service teachers’ actual instruction of specific MSK. The observers coded, minute-by-minute, whether the teacher instructed with cognitive strategies; for example, meta strategy (naming the thinking strategy, clarifying why and when a particular strategy would be used and how to use it), meta task (naming the task characteristics needed to use the strategy) and, lastly, naming the disadvantages of failing to use the correct strategy. Teachers' verbal statements, as well as nonverbal behavior, were taken into account. Table 3 provides some examples of teachers’ statements that were coded as instruction of MSK in the classroom. If the teacher instructed with different components within the same minute, each component was coded for in that minute.

As seen in Table 3, to account for the quality of strategy instruction, for each coded strategy, observers specified whether the pre-service teacher promoted the strategy implicitly (prompting students to use a certain strategy without directly referring to it) or explicitly (telling students directly to use a certain strategy). For example, if, while students tackled a physics task, a teacher stated, “the goal of the task is knowing/understanding that variables need to be controlled in science experiments…applying CVS, whenever we need to establish the existence of causal relationships,” it would be coded as an explicit instruction of an meta task component according to Kuhn’s (1999) MSK model (i.e., naming that thinking strategy; clarifying why and when such a strategy would be used and how to use it; naming the task characteristics needed to use the strategy; naming the disadvantages of failing to use the correct strategy). In contrast, the following teacher's statement would be coded as an implicit instruction of the same meta task component: “The goal is to find out how fast the ball would drop down in the different cases.”

***Coders’ training and interrater reliability*.** A total of 246 videos were observed and coded (82 participants X 3 videotaped lessons). Before starting the coding procedure, eight observers underwent 50 hours of observation training, during which they were introduced to the ATES observation instrument and practiced coding of videotaped lessons that were collected from an unrelated sample of pre-service teachers. After training, all eight observers then independently coded the same 20 videos that were randomly selected from the current dataset of 246 videos, to test for interrater reliability. For the low-inferent coding system measuring participants’ actual teaching of MSK (which yielded nominal data), Cohen’s kappa was computed. Disputable ratings and/or disagreements in the coding of MSK processes were resolved through discussion. In the rare cases in which coders did not reach consensus, an external coder (a university professor with expertise in teacher education) was summoned until an agreement could be reached. After the coding of the first 10 videos, Cohen’s kappa was .78 and generalizability coefficients ranged between .76 and 1.00. After the coding of all 20 videos, Cohen’s kappa was .74 and generalizability coefficients ranged between .77 and .94.

***High school students' Levels of Metastrategic Understanding/knowledge?***

### **Metastrategic knowledge interview:** The rationale behind the design of the MSK interview was to provide students with multiple opportunities to externalize their MSK and their understanding of it. The interview consisted of four parts. Part 1 was an adaptation of the interview protocol designed by Kuhn and Pearsall (1998). Students were presented with a fictitious story about a classmate who had been absent from the lessons in which the students engaged in a solar system task. The interviewer then asked students to explain to their classmate what they were supposed to do in the solar system task (i.e., a question designed to assess the understanding of the task component of MSK) and how they had decided which features to investigate (i.e., a question designed to assess the understanding of the strategic component of MSK). Parts 2 and 3 consisted of fictitious stories about children who planned an experiment in order to find out which features made a difference in the solar system. The interviewees were asked to explain the goal of the experiments (i.e., task component) and to evaluate their conclusions (i.e., strategic component). The difference between Part 2 and Part 3 was that the children in the stories of Part 2 failed to control variables, whereas the children in Part 3 did control variables. Part 4 of the interview consisted of explicit questions about MSK: ‘‘Why is it important to control variables?’” “How do you control variables?” (i.e., strategic components of MSK), or “In what cases is it important to control variables?” (i.e., task components of MSK).

## *Data analysis*

Interview transcripts were analyzed using the coding scheme developed and validated by Kuhn and Pearsall (1998), adapted to the specific details of the four parts of the MSK interview described earlier. Subsequently, we designed detailed categories to assess students’ level of MSK in each of the interview’s four parts. Following Kuhn and Pearsall’s (1998) guidelines, scores for each part of the interview were between 0 and 5 for the task component and between 0 and 6 for the strategy component. An example of the coding categories and scoring for the first part of the metastrategic interview is provided in Table 4.

To establish interrater reliability, a sample of 30 responses for each part of the interview was coded independently by two different coders. The percentage of agreement between the two coders was at least 90% for each of the four parts of the interview. The categories were then used to code all students’ replies for the two metastrategic components of the interview (i.e., the task component and the strategy component) (see Kuhn & Pearsall, 1998). Consequently, each student in each session received an average total score for MSK (computed by averaging the each student’s score for the task and the strategy component), which was then used to compute a mean MSK score for each of the two PV instruction groups (LFTB and IFTB + LFSB).

**Results**

To address the research questions and hypotheses, multivariate analysis of variance (MANOVA) was performed. Prior to carrying out the MANOVA, we confirmed that the data satisfied its three conditions (Weinfurt, 1995): (a) multivariate normality, (b) homogeneity of the covariance matrices, and (c) independence of observations. Learning condition (group) was the between-subjects factor and time was the within-subjects factor. Follow-up ANOVAs with repeated measures were conducted.

To compare the MSK teaching processes of the two PV instruction groups (LFTB and LFTB + LFSB), our study examined actual MSK teaching in Time 1, 2, and 3 in the four subgroups; LFTB + LFSB explicit, LFTB + LFSB implicit, LFTB explicit, and LFTB implicit. We used a 2 (treatment) by 2 (teaching explicit/implicit) by 3 (time) design. The mean scores of MSK (strategy and task component) are presented in Fig. 1.

Insert Fig 1

To examine initial differences between the four subgroups, we performed a 2 X 2 ANOVA on the pretest scores (Time 1). There was no main effect for treatment, suggesting that there were no significant differences between the LFTB + LFSB and LFTB only groups. There was a main effect for MSK teaching groups, such that the implicit teaching group received a higher mean score (measured by the proportion of valid inferences) than the explicit teaching group, *F*(1, 78) = 7.81, *p* < 0.01, partial *η²*= 0.19. There was also a statistically significant interaction between group and teaching level, *F*(1, 78) = 9.23, *p* < 0.01, partial *η²*=0.17, which resulted from a larger difference (between explicit and implicit MSK teaching) in the LFTB + LFSB group than in the LFTB only group. An examination of Fig. 1 reveals that MSK teaching across all teaching levels improved in all groups across time. The largest improvement was observed for explicit teaching MSK in the LFTB + LFSB group, who had low scores similar to the LFTB group in the pre-test, but whose scores in the post-test (Time 3) were almost as high as the scores of MSK implicit teaching in the two groups (see Fig. 1).

To determine the effects of the PV instruction intervention, a repeated measures ANOVA was performed with time as the within-subjects factor and treatment and teaching level (explicit/implicit) as the between-subjects factors. The analysis revealed a main effect of time, *F*(2, 74) = 32.17, p < 0.001, partial *η²*= 0.61, indicating that pre-service teachers improved their teaching MSK performance over the course of the three sessions. There was also a main effect of treatment (LFTB vs. LFTB + LFSB), F(1, 77) = 21.36, p < 0.001, partial η²= 0.41, indicating that students in the LFTB + LFSB group outperformed students in the LFTB group, and a main effect of MSK teaching level, F(1, 77) = 6.11, p < 0.05, partial *η²* = 0.19, indicating differences between students who were taught implicitly and students who were taught explicitly. The interaction between treatment and time was also significant, *F*(4, 72) = 3.18, p < 0.01, partial *η²* = 0.27, indicating differences between the pre-service teachers in LFTB + LFSB group and the LFTB group in terms of the changes that took place across time.

In addition, the analysis revealed a significant three-way interaction between treatment, teaching level (explicit/implicit), and time, *F*(2, 74) = 5.21, p < 0.01, partial *η²*= 0.31. To determine the source of the three-way interaction, a simple main effect analysis was performed, with separate 2 (teaching level: explicit vs. implicit) by 3 (time) ANOVAs for each group. The results of the ANOVA in the LFTB + LFSB group showed a significant interaction between teaching level and time, *F*(2, 39) = 4.33, p < 0.01, partial *η²*=0.15, indicating that in the LFTB + LFSB group, there were significant differences between explicit and implicit MSK teaching in terms of the changes in their performance across time. These findings support the pattern observed in Fig. 1 regarding the large improvement in MSK teaching across the three time points when using an explicit teaching strategy in the LFTB + LFSB group (as compared to explicit teaching in the LFTB only group). The respective interaction in the LFTB group was not significant.

As noted, significant changes in performance over time were found for explicit teaching in the LFTB + LFSB group. To identify the stages in which these changes took place, we performed a repeated measures contrast analysis using the mean scores of the various sessions for the LFTB + LFSB group. The contrast analysis showed significant differences in the LFTB + LFSB group’s mean scores between Time 1 and 2, F(1, 41) = 29.25, p < 0.001, partial *η²* =0.56, and between Time 2 and 3, F(1, 41) = 9.26, p < 0.01, partial *η²* = 0.31. Combined with an examination of Fig. 1, these results suggest that between Time 1 and 2, both explicit and implicit teaching in the LFTB + LFSB group significantly improved the frequency of the students’ valid inferences; however, the additional gain between Time 2 and 3 came from the explicit teaching. Therefore, the data suggest that, in the LFTB + LFSB group, explicit teaching required a more prolonged period of time to have an impact on scores than implicit teaching.

*Students development of MSK*

Students’ metastrategic level was assessed with the MSK interviews that took place during time points 1 (pretest), 2, and, 3. To examine differences between the groups prior to the intervention, our study compared students’ mean scores on the pretest, MLFTB= 2.3, SD = 1.48 and MLFTB + LFSB= 1.91, SD = 1.28. A t-test for independent groups showed that the differences between the two groups in the pretest were non-significant, *t*(80) = 0.79, *p* > 0.05.

To determine the effects of the MSK intervention, a repeated measures ANOVA was performed with time as the within-subjects factor and treatment (LFTB + LFSB vs. LFTB) as the between-subjects factor. The mean scores of the LFTB + LFSB group were considerably higher than those of the LFTB group in both Time 2 (MLFTB +LFSB= 5.48, SD = 1.46 and MLFTB= 3.56, SD = 1.39) and Time 3 (MLFTB +LFSB= 5.72, SD = 1.12 and MLFTB= 3.27, SD = 1.12). The ANOVA revealed a main effect of time, *F*(2, 78) = 35.16, *p* < 0.001, partial *η²*= 0.59, indicating that students improved their MSK performance over the course of the instructional sessions, as well as a main effect of treatment, *F*(1, 77) = 14.31, p < 0.001, partial *η²*= 0.27, indicating that children in the LFTB + LFSB group outperformed students in the LFTB group. The interaction between time and treatment was also significant, *F*(2, 78) = 12.51, *p* < 0.01, partial *η²*= 0.40.

**Discussion**

The discussion section focuses on the contribution of the study to the literature, suggests implications for practice and research, and concludes with an acknowledgement of several limitations of this study.

*Contribution to the literature*

Guided video analysis pairs specific video analysis procedures with guidance in the form of a self-evaluation rubric and written feedback (Nagro, deBettencourt, Rosenberg, Carran, & Weiss, 2017). In combination with high-quality professional development programs, guided video analysis helps teachers analyze teaching strategies, and thus change their teaching practices in ways that meet their students’ needs (Osipova, Prichard, Bordman, Kiely, & Caroll, 2011). In particular, this guidance gives teachers a clear purpose and focus for viewing the videos, which promotes active engagement (Rosean, Carlisle, Mihocko, Melnick, & Johnson, 2013).

In a similar fashion, video technology has also prompted the design of video-enhanced teacher professional development programs. Incorporating close analyses of student learning into broader goals (e.g., structured analysis of teaching effectiveness and the development of teacher professional vision and judgment) (Blomberg, Renkl, Sherin, Borko, & Seidel, 2013; Borko, Jacobs, Eiteljorg, & Pittman, 2008; Santagata, 2009; Seago, 2004; Stürmer, Seidel, & Schäfer, 2013), re-focuses teaching as an activity in which student learning is at the center of the process (Santagata & Taylor, 2018).

In accordance with our study expectations, the LFTB + LFSB group outperformed the LFTB group on the actual teaching of MSK by pre-service teachers and on the students' MSK achievements. These results suggest that developing PV for MSK from both teachers and students behaviors events, pre-service intensify their performance (see also Hong & Van Riper, 2016). More specifically, the stronger effect observed in the dual PV prompts/instruction group (LFTB + LFSB) emerged not only for pre-service teachers’ actual MSK teaching skills, but also for their students’ MSK achievements. This finding is important in light of the research that indicates that pre-service teachers havedifficulties implementing a meaningful understanding of the subject matter into their planning for instruction and ultimately into their teaching (e.g., Parkison, 2009). In this regard, R. F. Peterson and Treagust (1998) argued that pre-service teachers should not only “develop their knowledge base for teaching, which extends beyond just a knowledge of the subject matter, but they also need to begin developing the ability to make reasoned decisions when using this knowledge and applying it to a teaching situation” (p. 217). This quote implies that pre-service teachers require experience using various methods to develop the capacity to alternate between the conceptual and practical dimensions of the MSK construct. In that light, can systematically developing PV of both teacher and students behavior bridge between the theoretical knowledge (comprehension and lesson design) with the necessary practical wisdom (teaching)?

Why did the LFTB + LFSB group outperform the LFTB group in teaching MSK? Our study findings suggested that although both groups were actively exposed to the same video analysis activities, the additional element of being engaged with PV instruction that also focused on students’ behaviors, may have helped the pre-service teachers in the LFTB + LFSB group to teach and adapt to their students’ needs more effectively. Williams and Baumann (2008) conducted a research synthesis on expert elementary teachers. They, too, found that excellent teachers demonstrated adaptability, as captured by this quote: “An ability to adjust their instructional practices to meet individual student needs” (p. 367). The standards that define teacher quality also reflect this attention to teacher adaptability. For example, the Interstate Teacher Assessment and Support Consortium (Council of Chief State School Officers, 2011) —a nonpartisan, nationwide, nonprofit organization of public officials who lead departments of elementary and secondary education in the United States — emphasizes adaptability as an essential factor for quality teaching, as outlined in the following standard: “The teacher continuously monitors student learning, engages learners in assessing their progress, and adjusts instruction in response to student learning needs” (Council of Chief State School Officers, 2011, p. 17).

As described in the current literature, teachers need to notice and interpret student behavior as part of their everyday classroom work (e.g., Blomberg et al., 2013, 2014; Stürmer et al., 2013). Prior research has shown that some experienced teachers may engage in these practices already (Berliner, 2000), and these practices are reflected in the achievements of their students. As shown in the present study, the students in the LFTB + LFSB group outperformed the LFTB group in terms of showcasing higher MSK achievements. However, current teacher education programs often do not explicitly focus on helping pre-service teachers learn to analyze and interpret *student behavior* and understand how it may influence *teachers’ MSK-teaching behaviors*, which in turn may affect students’ thinking and achievements. Instead, programs usually explicitly focus only on helping teachers analyze *teachers’ MSK-teaching behaviors* and how they may impact student thinking or behavior, while frequently providing instruction concerning new pedagogical techniques or activities (Berliner, 2000; Day, 1999; Huling, Resta, & Rainwater, 2001; Niess, 2001; Putnam & Borko, 2000; Taylor, 2000).

To promote students’ MSK, teachers can teach using two kinds of instruction: implicit and explicit. Study findings indicate that pre-service teachers in the two groups taught MSK in a much more implicit than explicitmanner before the study began. This conclusion is in line with previous studies on science education (Dignath-van Ewijk, 2016). One of the unique contributions of our study is that we were able to show that, in comparison to the LFTB only group, incorporating LFSB into teaching training contributed to a significant increase in explicit instruction of MSK which, in turn, affected the development of students’ MSK achievements. These findings are in line with other research that found a relationship between teaching explicit MSK and students’ MSK achievements (Zohar & Peled, 2008; Ben David & Zohar, 2008; Kuhn & Pearsall, 1998).

*Implications for Practice and Research*

At the practical level, our study contributes added value to the existing tools for developing MSK teaching. The clear instructions provided for analyzing teachers’ and students' behaviors in video lessons may help in developing pre-service teachers’ PV levels. Furthermore, developing PV can contribute to teachers’ MSK-teaching abilities and their students MSK achievements. The PV model in our study can offer a platform for improving teacher education and for constructing intervention programs that promote teachers’ capacities to maintain MSK. Utilization of this PV model in teacher education programs may also have the potential to deepen teachers’ understanding of the dynamic interplay between the two MSK teaching delivery modes and their subcomponents, guide teachers in simultaneously adapting each of the two knowledge bases, and help teachers infuse MSK into the required material by using student-centered learning pedagogies. We suggest that program planners explicitly embed formal structures or tools within the curriculum to help pre-service teachers enrich their PV and evaluate information derived from teachers’ and students’ behaviors, practices which are often otherwise ignored.

Second, the findings described above suggest that teacher preparatory programs should consider “switching cognitive gears” between LFTB and LFSB. For example, LFTB may be a more conducive approach when the goal is to learn already validated instructional strategies or skills. However, the LFSB approach may be more appropriate when aiming to develop a professional identity, thus fostering awareness through adaptive teaching processes. The integration of the two approaches can provide a better link between inductive and deductive methods of teaching in science education. It may be the case that, in science education, deductive reasoning would be an appropriate goal for both pre-service science teachers and students, especially when integrated with inductive reasoning.

To conclude, the traditional instructional approach to teacher education, based on the technical-rational model of knowledge generation, has been criticized as being inappropriate for developing pre-service teachers’ understanding of how theory unfolds in the practical world (e.g., Korthagen, 2001). To bridge this theory-practice gap, LFTB has been applied quite extensively in teacher preparatory programs around the world, especially in North America (Dean, 1999; Edens, 2000; Edwards & Hammer, 2006; Goodnough, 2003). The current study’s findings reframe the learning-from-teacher behavior focus to an instructional framework of teacher education programs that additionally include learning from student behavior. Although learning from students’ behaviors has been perceived as the enemy of experimentation and innovation (Levitt & March, 1996), the deliberate choice to integrate learning from student and teacher behavior may nurture the practical wisdom necessary to work in dynamic school contexts.

*Study* *Limitations*

The limitations of this work need to be acknowledged. First, we could not test the contribution of learning solely from students’ behaviors (as compared to learning solely from teachers’ behaviors) to the improvement in the two dependent constructs (MSK teaching and students MSK achievements). As teacher education programs in Israel have been primarily centered on LFTB, testing the contribution of learning solely from students’ behaviors was not permitted by the higher education institutions.

Second, the present study did not include a control group of pre-service teachers who did not use any reflective method. Instead, we assessed the dependent constructs (pre-service teachers’ teaching of MSK and their students’ MSK) at the beginning of the practical teaching period and found no significant differences between the two PV groups. Third, in the two groups that integrated PV prompts/instruction of both teachers’ and students’ behaviors into the lesson, the PV process was conducted by probing teachers’ behaviors first and students’ behaviors second. We did not include groups that analyzed students’ behaviors first, followed by teachers’ behaviors. Thus, the current findings cannot be used to describe the patterns of interaction and mutual influences between LFTB and LFSB. Fourth, in this quasi-experimental design, the relatively small sample of participants, in addition to the logistical requirements, limited the randomization process, enabling only random assignment of each location to one of the two conditions instead of random assignment of participants to conditions.

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**Table 1:**

|  |  |
| --- | --- |
| **The instruction for the LFTB** group | **The instruction for the LFTB+LFSB** group |
| *You have one and a half hours to analyze an expert teacher's videotaped lesson given to high-school students on the topic of derivatives of a polynomial function. Please specify the 4 time stamps (4 situations) in the lesson when you notice that the teacher taught explicit/implicit MSK.* ***Describe*** *what was done at each marked time to develop students’ MSK. What do you think were the teacher’s considerations?* ***Explain*** *and* ***predict*** *how and why the events you describe will develop students’ MSK.* | *You have one and a half hours to analyze an expert teacher's videotaped lesson given to high-school students on the topic of derivatives of a polynomial function.*   1. *Please specify the 2 time stamps (2 situations) in the lesson when you notice that the teacher initiates instruction of MSK* [referring to explicit or implicit events]*.* ***Describe*** *what was done at each marked time to develop students’ MSK. What do you think were the teacher’s considerations?* ***Explain*** *and* ***predict*** *how and why the events you describe will develop students’ MSK.* 2. *Please specify the 2 time stamps in the lesson when you notice that a student’s behavior* triggers the *teacher’s explicit MSK instruction* [referring to direct or indirect events]*.* ***Describe*** *what was the student's behavior at each marked time to trigger the teacher’s MSK instruction. What do you think were the teacher’s considerations?* ***Explain*** *and* ***predict*** *how and why the events you describe will develop students’ MSK.* |

**Table 2**

*Summary of the Practical Teaching Course and the two Reflective Groups*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Time** | **Activity** | **Procedure** | **Condition** | |
| Sept. | Instructors’training | Training was led by two female university professors, each with a Ph.D. in education and over ten years of teaching experience and expertise in science teacher education. Training was accompanied by filmed demonstrations. | Same structure, but different content for each reflective approach | |
| Oct. | Trainees’ group assignment | Random assignment of two universities/professors, one to each research group.  Eighty-two second-year pre-service science teachers for secondary schools (*n* = 40/42 per group). | LFTB-only group or LFTB+LFSB group | |
| Oct. - Jan. | Video-analysis course | Participants participated in a single-semester*Teaching and Learning Methods* academic course, comprised of twelve weekly workshops (four hours each, totaling 48 hours) and held in university computer labs. The course was based on pre-service training programs reported in prior studies (AUTHOR, 2012; AUTHOR & COLLEUGE, 2013; Seidel, 2011; Stürmer et al., 2013).   * Materials: Eight 30-minute filmed vignettes, each of an authentic tenth grade science lesson taught by an expert teacher. Each vignette contained multifaceted ill-structured MSK-teaching events. Videos were taken from the Ministry of Education’s video stockpile of expert science teachers collected as part of the Third International Mathematics and Science Video 2012 study (Center for Educational Technology, 2013). Vignettes were uploaded onto the course’s [e-learning](http://en.wikipedia.org/wiki/E-learning" \o "E-learning) platform to enable repeated and/or interrupted viewing while participants completed tasks. * Teacher vs. student focus:LFTB-only group - participants were instructed to focus on the filmed teacher's explicit/implicit MSK-teaching behavior and the impact on students' behavior and thinking, while using the four-step approach. LFTB + LFSB group - participants were instructed to first focus on the filmed teacher's explicit or implicit MSK-teaching behavior and the impact on students’ behavior and thinking while using the four-step approach, and then to focus on students’ behavior as a trigger for the teacher’s explicit/implicit MSK-teaching behavior, while using the four-step approach. * Structure: * *Workshops 1-2:* Participants were exposed to the theoretical background and instructional foundation (**either LFTB-only or LFTB + LFSB**), high-school science lesson comprehension/design, modification of teaching practices via mapping PV skills, and MSK-teaching modes. * *Workshops 3-4:* Participants viewed two vignettes (one per workshop), followed by an explicit training in the four-step video-analysis approach for mapping PV skills and MSK-teaching modes, with instructor in the whole class, while focusing on **one of two** reflective approaches (**either LFTB-only or LFTB + LFSB**). * *Workshops 5-12: Participants* viewed eight vignettes (one per workshop), followed by an active reflective four-step video-analysis approach for mapping PV skills and MSK-teaching modes, performed individually (**either LFTB-only or LFTB + LFSB**) and submitted online to the course's [e-learning](http://en.wikipedia.org/wiki/E-learning" \o "E-learning) platform ([Modular](http://en.wikipedia.org/wiki/Modular" \o "Modular) [Object-Oriented](http://en.wikipedia.org/wiki/Object-oriented_programming" \o "Object-oriented programming) [Dynamic](http://en.wikipedia.org/wiki/Dynamic_programming" \o "Dynamic programming) [Learning Environment](http://en.wikipedia.org/wiki/Virtual_learning_environment" \o "Virtual learning environment) – Moodle). Next, with oral prompts from the instructor about time allotments, as well as written manuals so that participants could proceed autonomously, pairs collaborated to reflect and give feedback on prior thinking processes and answers, interpret pedagogical events, predict difficulties, and raise solutions for the problems those events presented. Pairs submitted their responses to Moodle. * Four-Step Video-Analysis Approach: Steps were presented linearly, but were interrelated and interdependent. The steps were as follows: (1) Notice**teacher/student** behavior during the filmed lesson (identify a relevant situation), according to the participant’s study condition. (2) Describethe event in detail(discern and depict relevant **teacher/student** behavior that effectively impacts student thinking). (3) Explain(classify a noticed situation, drawing on prior theoretical knowledge about effective teaching-learning components and their links to classroom reality). (4) Predict(suggest how the noticed **teacher/student** behaviorwill impact student thinking, drawing on broader generic pedagogical knowledge and transferring this to classroom practice). * Fidelity: The research team conducted monthly observations to ensure each group's fidelity to its **LFTB-only or LFTB + LFSB** reflection focus. | | Same workshop structure, materials, and four-step approach in both groups  Different focus of PV reflective approach for theoretical background and video-analysis in each group |
| Oct. - May | Fieldwork practicum training course | Participants participated in a two-semester *Practical Teaching* fieldwork course, comprised of 24 weekly practical workshops (four hours each, totaling 96 hours), which were held in high schools and based on the Israeli Ministry of Education‘s standard curriculum.   * Structure: Trainees' provided LFTB reflections in small groups (3-4 pre-service teachers) with a mentor, reflected on lesson design before teaching tenth grade science lessons and then reflected on lesson implementation after teaching. The research team conducted monthly observations to ensure fidelity to the LFTB reflection focus. * Mentors: Mentors had a mentoring diploma from the Israeli Ministry of Education as expert, experienced (6+ years), secondary school science teachers who had previously completed mentor training (eight 3-hour workshops). All mentors were faculty members and were part of their respective university's mentor pool at the time of the study. | Same for both groups | |

Table 3

*Examples of Low-Inferent Coding for MSK Instruction*

|  |  |  |  |
| --- | --- | --- | --- |
| **MSK** | | **Teacher statements** | |
| **Implicit** | **Explicit** |
| **Meta-Strategy**  **component** | **Naming** | *“We are going to ﬁnd out which features can affect the ball’s run.*” | *“I took one feature whose effect I wanted to examine, and I left all other features the same. I changed only this variable from one experiment to the next. This process is called control of variables.”* |
| **When** | *“What is different between the ramps now? Now is this a good or bad test for the Length of Run? If the ball went different distances, would I know for sure it was because of the Length of Run?”* | *“The goal of the CVS is to find the feature we want to test. There is a different feature that influences the ball’s run, we want to see whether this feature makes the main difference*?” |
| **Why** | *“Students compare between experiments when only one variable has been changed across experiments, but make no* *reference to other variables.”* | *“When you get to such a problem with the vector first, ask yourself: What is my plan for solving the problem? What is my first step to solve the problem? And why? To choose the base? How? To find the height? How?”* |
| **How** | *“We will proceed with this problem; in this step ….”* | *“To* *move forward* *in solving the problem,* it is very useful to *build a table* *to organize which variables are different or equal in the different research groups.”* |
| **Meta-Task component** | Goal | *"The goal of the learning task is to help us find out the weight of the ball…."*  (Find out which features make a difference in outcome) | *“The learning task we use in our lesson was chosen carefully because the task includes characteristics like: different independent variables that call for the use of the CVS.”* |
|  | Not be used | *“In this task we can't assess how the weight of the ball is affecting the time of the ball….”* | *“The current task is not designed to assess the CVS. This is because there are no differences in any of the independent variables.”* |

**Table 4**

Coding categories and examples of scoring in the metastrategic level (based on Kuhn and Pearsall, 1998)

|  |  |  |
| --- | --- | --- |
| Level | Task component, Part 1: Tell a student who has been absent from the lesson what s/he was supposed to do. | Strategy component, Part 1: How did you decide which feature to investigate? |
| 0 | The student reports that s/he does not know the answer or provides a meaningless reply (‘‘I don’t know’’; ‘‘We are doing an experiment about electromagnetism.”). | The student reports that s/he does not know the answer or provides a meaningless reply (“It depends on what I want”; “I decided to have an electric field because electric field is important for magnetic attraction.”). |
| 1 | Attain a good outcome (“The goal of the task is to find out how the electromagnetism would succeed to achieve the highest attraction.”). | Plan experiments believed to yield a good outcome (“I will tell him that I decided to try each time and see what would be more, that it would be the best.”). |
| 2 | The student refers in a general way to the fact that the experiment consists of a factor we want to test and an outcome. (“The goal of the experiment is to see, to check materials…how the distance between the magnets affects their attraction.”). | Try out various experiments and observe outcomes (“Each time I tried out various things and saw how they affected the magnets’ attraction.”). |
| 3 | The student’s goal is to find out which features make a difference, but s/he talks about features in general, making no differentiation and reference to individual factors (“To find out which features can affect magnets’ attraction.”). | Make comparisons between various conditions, but do not attend to the control-of-variables rule (“In the beginning, I changed the electric field strength and I changed the size of the magnets and later I changed the distance and the magnetic field force was 5.3 Tesla.”). |
| 4 | The student’s goal is to find out which of several specific features make a difference, but they make reference to multiple features at the same time (“The goal is to find out whether the size of the magnets or the distance cause the difference in the magnets’ attraction.”). | The student mentions the control-of-variables rule and may even cite it correctly. However, there is no clear evidence that s/he understands the rule and applies it correctly (“I will tell him that I controlled variables. And I wanted to see if the electric field strength affects the magnetic attraction. In the second experiment, I wanted to see how the electric current affects the electromagnetic field.”). |
| 5 | The student’s goal is to find out which feature makes a difference, referring to one variable at a time (“I would tell him that the goal of the task is to find the feature we want to test. to see whether this feature makes the main difference.”). | The student compares between experiments when only one variable has been changed across experiments, but makes no reference to other variables (“First I took the electric field strength and then I did not take the electric field strength to see whether it makes a difference, but it made a difference.”). |
| 6 | \_\_\_\_\_ | The student compares between experiments when only one variable has been changed across experiments, and makes explicit reference to keeping all other variables constant. Sometimes the student talks explicitly about the name of the strategy (“I took one feature whose effect I wanted to examine, and I left all other features the same. I changed only this variable from one experiment to the next. This process is called control of variables.”). |

Fig. 1. Mean scores (vertical axis) of explicit and implicit MSK teaching of LFTB + LFSB and LFTB groups in the practicum course.