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To cite this article: Ahmad M. Qablan & Theodora DeBaz (2015) Facilitating elementary science teachers’ implementation of inquiry-based science teaching, Teacher Development, 19:1, 3-21, DOI: 10.1080/13664530.2014.959552

To link to this article: http://dx.doi.org/10.1080/13664530.2014.959552

Published online: 17 Oct 2014.

Article views: 375

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Facilitating elementary science teachers’ implementation of inquiry-based science teaching

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(Received 20 June 2012; final version received 9 June 2013)

Preservice science teachers generally feel that the implementation of inquiry-based science teaching is very difficult to manage. This research project aimed at facilitating the implementation of inquiry-based science teaching through the use of several classroom strategies. The evaluation of 15 classroom strategies from 80 preservice elementary science teachers was reported. Results indicated that those classroom strategies were useful for promoting preservice science teachers’ understanding and reinforcing their skills for teaching science through inquiry. In addition, findings indicated that preservice science teachers gained more sophisticated understanding of the role of these classroom strategies and their potential implications for facilitating inquiry science teaching and learning. The study provided several suggestions to facilitate the implementation of inquiry science teaching in school science classrooms.

Keywords: preservice science teachers; inquiry; classroom strategies; facilitate; implementation

The most visible psychological impact on science curriculum since 1980 has been the constructivist view of learning (SO 2002). According to Tobin (1993), ‘constructivism represents a paradigm change in science education’ (ix). Constructivism is a theory that sees learning as a dynamic and social process in which learners actively construct meaning based on their prior knowledge and understandings and the social setting that surrounds them (Driver et al. 1994). It describes how people learn and it maintains that scientific knowledge is constructed as teachers and students interact with and build on their own understanding and actions throughout the learning experiences in classrooms (Ullrich 1999). Constructivism also suggests that teachers choose and design their teaching activities to respond to their students’ diverse prior knowledge and understanding (Ullrich 1999). In other words, teachers consider their students’ diverse background and experiences to help them build on their pre-existing schemata (Bullough 1994). In this way, Bullough emphasized that student’s prior knowledge and understanding about science act as filters through which teachers take action regarding designing their classroom teaching activities.

An emphasis on constructivism and inquiry-oriented science teaching has been largely advocated by science educators (Abd-El-Khalick et al. 2004; National Research Council 2000; Slavin 1994; Stofflett and Stoddart 1994). The constructivist and inquiry-based science teaching stimulates students’ conceptual understanding by
building on prior knowledge, and encourages them to actively engage with the subject matter and apply their learning in real-life situations.

Despite the lack of agreement between science educators on the meaning of inquiry in science education, most of them define inquiry as ‘doing what scientists do in the classroom’ (Howes, Lim, and Campos 2008), which is similar to the National Science Education Standards definition (National Research Council 1996), where they describe inquiry as:

A multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations, and predictions; and communicating the results. (NSES, 23)

The benefits of inquiry science teaching are well documented in the literature. It is an effective mode of learning to improve students’ content knowledge (Lord and Orkwiszewski 2006), advance their scientific process skills (Deters 2005; Hofstein, Shore, and Kipnis 2004), nurture their attitudes toward school science (Lord and Orkwiszewski 2006), stimulate their motivation to learn science (Tuan, Chin, Tsai, and Cheng 2005), foster their understanding of the nature of science (Backus 2005), and communication skills (Deters 2005).

However, enacting inquiry in science classrooms rests at the shoulders of teachers and especially preservice elementary science teachers (Bullough and Baughman 1997; Czerniak, Lumpe, and Haney 1999; Pajares 1997), who begin the preparation process of students for a scientific and technological world. Many researchers suggest that teachers hold images of teaching from their experiences as students and that they tend to teach the way they were taught when they were students (Calderhead and Robson 1991; National Research Council 1996). More research indicates that there is a strong likelihood that the way teachers will teach science depends on their undergraduate preparation (Appleton 1997; Loucks-Horsley 1998). Evidently, traditional science teaching experiences impact the way in which science is taught, where teachers learn science through the traditional methods in a period called an apprenticeship of observation (Stuart and Thurlow 2000). As a result, they develop their own teaching beliefs based on their in-class experiences at school, beliefs which are strongly tied to their attitudes about teaching science (Gibson 2001).

However, preservice science teachers face a number of challenges in learning how to teach science effectively (Appleton 2006; Davis, Petish, and Smitley 2006). These challenges include developing their professional knowledge about science content, scientific practices and discourses, and the nature of science (National Research Council 2007) as well as their knowledge about learners’ strengths, needs and ways of knowing. At the same time, preservice teachers need to develop a repertoire of instructional strategies and approaches (Feiman-Nemser 2001) that can foster productive learning communities as well as professional visions and dispositions for effective teaching (Hammerness, Darling-Hammond, and Bransford 2005).

These challenges in learning to teach, according to Mikeska, Anderson, and Schwarz (2009), can also be framed as problems of practice. Science teachers need to learn how to address problems of practice, such as engaging students in science, linking their instruction, assessment and learning together, and developing
productive learning communities to enhance their knowledge, and teaching practices. They want to engage their own students in interesting and real-world science activities and teach science in a manner that is more entertaining, exciting and relevant than it frequently was for them as former students.

Facilitating inquiry science teaching in classrooms can be achieved during the 5E stages of the learning cycle through using several classroom strategies that encourage students to learn to ask investigable questions on a determined topic (engagement), design experiments to find answers for their questions (exploration), collect data and use evidence to formulate knowledge claims and explanations of the science phenomenon (explanation), expand or apply their own learning on different contexts (elaboration) and evaluate their own learning (evaluation) (Bybee et al. 2006).

However, during each stage of the learning cycle, teachers can utilize several strategies to guide their students’ learning to examine their prior knowledge and conceptions. Once ideas are revealed, students have an opportunity to explore their ideas, arguing about and testing them in the process. When students see that their existing ideas do not fully match their findings, a disequilibrium in the cognitive state results, which opens the door to the construction of new scientific ideas. When students reach the stage where they develop the formal scientific understandings and patterns of reasoning that help them make sense of phenomena being studied, they are encouraged to extend their learning and apply their ideas to a new situation or context (Keeley 2008).

Throughout the various stages of the learning cycle, teachers design and monitor instruction so that students become increasingly conscious of their own and others’ ideas. They gain confidence in their ability to learn, apply concepts to new situations and construct evidence-based argument (Lawson 2000). Teachers orchestrate student learning in different ways at different stages, encouraging a classroom climate where ideas are openly generated and sufficient time is allowed for sense making and construction of new knowledge. All the while they are facilitating students’ construction of new ideas and are formatively assessing by monitoring students’ changing conceptions and adapting their teaching and assessment strategies to match their students’ needs.

**Classroom strategies**

In this study, 15 classroom strategies were chosen among the 75 strategies introduced by Keeley (2008) to facilitate preservice elementary science teachers’ implementation of inquiry science teaching during the 5E stages of the learning cycle (Bybee et al. 2006). According to Keeley (2008), these simple classroom strategies allow teachers to skillfully deal with all significant aspects of classroom instruction (i.e. teaching, assessment and management), help science teachers teach, assess and manage their classrooms during inquiry investigations, and encourage them to facilitate students’ activities in each stage of the learning cycle. Thus, these strategies are seen to facilitate the enactment of inquiry science teaching in the science classroom by enabling teachers to engage their students in the science topic, help them pose investigable questions and suggest tentative answers and formulate hypotheses, and explore the scientific phenomenon being studied. They also help lead and facilitate students’ discussion during the explanation stage of the learning cycle and explore possible applications of the new knowledge in life (elaboration stage) and finally
evaluate their learning and understanding of the newly learned science concepts (Schwarz 2009). Table 1 offers possible uses of each strategy in each stage of the 5E learning cycle.

The following passages describe each classroom strategy and possible procedures to apply it in the classroom:

1. Frayer Model: This technique helps learners graphically organize their prior knowledge about a concept being studied. It is designed into four quarters to let learners operationally define, characterize, and provide examples and non-examples (Buehl 2001) of the concept under investigation.

2. I Think-We Think: In this technique, students use a two-column sheet of paper to record their own individual ideas (I Think), prior to group discussion, and ideas their group or class has that surface through group discussion (We Think) (Goldberg, Bendall, Heller, and Poel 2006).

3. I Used To Think... But Now I Know: This technique asks students to compare verbally or in writing their ideas at the beginning of a lesson or instructional sequence to the ideas they have after completing the lesson(s).

4. Point Of Most Significance: In this quick technique, students are asked to identify the most significant learning or idea they gained from a lesson.

5. Verbal Fluency: This technique is used for partner discussion or reflection. Partners take turns in timed rounds, talking ‘off the top of their heads’ about an assigned topic or prompt. While one person talks, the other listens until time elapses and partners switch roles (Lipton and Wellman 1998).

6. Think-Pair-Share: This technique combines thinking with communication. The teacher poses a question and gives individual students time to think about the question. Students then pair up with a partner to discuss their ideas. After pairs discuss, students share their ideas in a small group or whole-class discussion.

7. Traffic Light Cups: This technique is used during group work and student investigations to signal to the teacher when groups need help or feedback. Red, yellow and green stackable party cups placed in the center of a group’s table or workstation represent whether the group is able to proceed without need for teacher intervention or whether they need assistance.

8. Raise Hand For Silence: This technique is used to grab students’ attention during the classroom discussion. When teacher raise her/his hand, students stop the discussion and give the teacher their attention.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Engagement</th>
<th>Exploration</th>
<th>Explanation</th>
<th>Elaboration</th>
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<td>Session</td>
<td>Session</td>
<td>Sort, Fold and Pass, Exit Ticket</td>
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Classroom Management Strategies (Traffic Light Cups, Raise Hand For Silence, Numbered Heads)
Numbered Heads: This technique is used to ensure giving all students participation during the lesson. The teacher asks students in each group to assign a number for each member in the group. When a teacher wants to choose a student to answer a question, he/she can call a random number and let the student answer.

Round Robin: This technique allows students to share their ideas and observations with their peers in the group in an organized way. When the teacher asks students to respond to an inquiry question, each student in the group is given a certain time to share his or her thought with the group.

Gallery Walk: This technique allows students see others’ work. In this technique, each group of students is asked to write their investigation in a poster and hang it on a board or a wall to share it with other groups in the classroom. The teacher asks the students to walk around the classroom and read others’ posters.

Poster Session: This technique is another form of Gallery Walk in the sense that each group of students prepares a poster and hangs it on a wall. For each poster, two group members explain their poster to other groups and answer their queries.

Card Sort: In this technique, each group of students is provided with cards that have relevant information and concepts and is asked to arrange these cards in a certain way according to their previous knowledge and understanding. Students hold a conversation to explain the rationale behind their card arrangement.

Fold and Pass: In this technique, students are asked to write their answer to the teacher’s question on a paper, then fold it and pass it to the adjacent group. Once the other group has received the paper, the students read it and indicate if they have any questions or comments on it.

Exit Ticket: This technique is used to assess students’ learning at the end of the class. Students are asked to answer certain questions written on a card and give it to the teacher before they leave the class.

Purpose of the study

The main purpose of this study was to examine how these various classroom strategies contribute to facilitating the implementation of inquiry science teaching and learning in a preservice elementary science methods course. Specifically, the following research questions guided the overall conduct of this study:

(1) How do preservice elementary science teachers evaluate their experience of using these classroom strategies in teaching science through inquiry?

(2) How does each of these strategies facilitate the implementation of inquiry-based science teaching?

To answer these questions, a qualitative research approach was chosen to guide the overall conduct of this study. This type of research strategy suits the nature of the research problem that demands, as Taylor and Bogdan (1998) stated, an understanding of a social phenomenon from the actor’s own perspective and examining how the world is experienced. Thus, based on this assumption, the researcher relied
solely on the qualitative approach, where informal participants’ interviews, open-ended questionnaires, students’ lesson plans and field notes from the methods course represented the main source of data.

Context of the study

This study was conducted in a science methods course offered to preservice elementary science teachers at the college of education at the Hashemite University in Jordan. At this university, Teaching Science in the Elementary School is the second core course in the elementary preservice science teachers’ preparation program. Based on prior evaluations of the methods course, teacher candidates were entering the classroom with some knowledge about how to implement inquiry in the science classroom using the 5E stages of the learning cycle, as they had been taught their previous pure science courses (Chemistry and Biology) utilizing the five stages of the learning cycle, by the authors of this study. However, they had no previous knowledge about the 15 classroom teaching strategies that this course offers and how to implement them in each stage of the learning cycle.

Participants

In the first semester of the academic year 2010–11, two sections, each of 40 students, were taught the course by one author of this study. At the beginning of the course, the instructors introduced the philosophy of inquiry teaching to students and trained them in how to design an inquiry lesson plan using the 5E learning cycle model. In the second half of the course, students were given an opportunity to prepare a lesson plan using the teaching strategies they had learned in the course and teach their classmates a science lesson designed according to the five stages of inquiry.

Procedures, data sources and collection

This study was an interpretive analysis of learning for the 80 participants described above, relying on qualitative data. The author, who was the course instructor, acted as a participant observer in the class. The elementary sources of data included informal participants’ interviews, open-ended questionnaires, students’ lesson plans and field notes from the methods course.

Questionnaires

An open-ended questionnaire was given to preservice science teachers at the completion of the course. The questionnaire included questions such as: what does inquiry science teaching mean to you, how do you evaluate your competency in teaching science after you took this course? What do you think about the classroom strategies you learned in this course? How did these classroom strategies help you teach science through inquiry? How did these strategies help you teach science through inquiry? Which classroom strategies did you find most helpful for you and which ones did you find not applicable? Do you believe there are any barriers that will prevent you from implementing inquiry in science teaching, and how will learning about inquiry and the classroom strategies impact your future teaching practice?
Informal participant interviews
Preservice science teachers were invited to reflect on their experience during the course. Overall, 30 informal interviews were conducted. The interview questions included: describe the ways in which formative assessment in the methods course has influenced your understanding of and ability to develop formative assessment for elementary classrooms, what role do these classroom strategies have in inquiry learning, and what questions or concerns do you have about using inquiry science teaching overall that have not been addressed in the course so far?

Field notes
The course instructor was periodically observing the participants of this course. Field notes included actions taken by the preservice science teachers, dialog that occurred among them and perceived levels of engagement by preservice science teachers. These notes were taken by the researcher during class sessions.

Science lesson plan
One assignment in this course was to have students prepare an inquiry science lesson plan and utilize some of the 15 classroom strategies offered in the course. In addition, each student was asked to micro-teach his/her lesson to the class. After the student finished teaching the lesson, a whole-class discussion session was organized to offer relevant feedback for the presenter. At the end, each student had to submit his/her lesson plan to the instructor for evaluation. The importance of this micro-teaching activity for preservice science teachers is to simulate the actual classroom teaching at schools prior to their actual practicum year.

Data analysis
Data collection and data analysis occurred throughout the period of the study. All collected data were analyzed in two major stages: open coding and focused coding (Emerson, Fretz, and Shaw 1995).

In open coding, each data source was read line by line to identify and formulate all ideas, themes or issues suggested by the participants, no matter how varied and disparate. During this stage, initial memos reflecting a variety of ideas to begin the preliminary analysis of data were added to the data source. After arranging all data and coding them, the data were reviewed again and meaningful notes were attached to define the core ideas that emerged from this analysis. In the focused coding, data were subjected to fine-grained, line-by-line analysis on the basis of the core ideas that were identified as of particular interest from the open-coding analysis. In this stage, all coded data were combined and reflective memos were added (Bogdan and Biklen 1998). In reviewing the various data sources, patterns or core ideas emerged from the data were identified (Glesne 1999) and organized into broader themes. Prior to that, themes were carefully cross-checked to link related data from different interviewees and other data sources. Finally themes were grouped and marked with accompanying interpretive notes.

For the purpose of this article, since the language of all the collected data was Arabic, all excerpts and quotes used in the results section were translated into
English (Sperber, Devellis, and Boehlecke 1994) by two bilingual faculty members from the Faculty of Educational Sciences at the Hashemite University. Furthermore, to confirm that the translation process was accurate and reflected the meaning that the participants intended, each respective participant was given a draft of the translation, and their feedback was considered in correcting any comments from the participants.

Findings

Inquiry-based science teaching demands a set of teaching practices that are quite different from typical didactic science instruction. Students need to play the role of scientists in researching scientific phenomena (Sandoval, Daniszewski, Spillane, and Reiser 1999). Thus, planning inquiry science lessons requires teachers to think deeply about each step or move that they need to take in order to facilitate their students’ learning of science. While the 5E learning cycle model sets the major five stages of any inquiry journey, preservice teachers find themselves lost in how to design the instructional practices that need to take place in each stage. In this study, preservice teachers found the utilization of several classroom strategies to be beneficial to them as they helped them design the detailed practices of each stage of the learning cycle. The following passages highlight the successful experiences of those teachers in facilitating their students’ inquiry science learning.

The enactment of inquiry in the science classroom

To discern the extent to which these classroom strategies facilitate the enactment of inquiry in teaching science, an analysis of the participants’ responses in the open-ended questionnaire, their classroom practice teaching and their prepared lesson plans was conducted. The results of this analysis show that participants were more informed and skillful about how to design an inquiry lesson plan and functionally utilize these strategies to facilitate the science discussions during each stage of the learning cycle.

I’d never known these strategies before, they are wonderful, I was afraid to teach... but these strategies helped me plan for my inquiry science teaching in an attractive way. (Reem)

I knew how to teach inquiry science through learning cycle model, but actually I was not confident about how to guide and facilitate my students’ discussions during each stage. (Aseel)

I love these strategies, they are so easy to use, they help me design my science learning, and teach science through inquiry. (Mohammad)

Although this is the first time to see myself as a science teacher, I felt so empowered to guide my classmates in an inquiry journey. (Hajem)

The use of these strategies gave me confidence to address the five stages of the learning cycle in my lesson plan and organize my overall classroom teaching. (Lena)

These strategies offered me a variety of ways to enact inquiry in my science classroom. (Ahlam)

Participants’ lesson plans showed that they used these strategies in designing their lesson plans to facilitate their science teaching (Appendix 1).
In addition, most participants indicated that these strategies helped them promote their students’ thinking during the engagement stage of the inquiry learning cycle. As some indicated, these strategies helped stimulate their students’ interest in the content of the lesson and participants felt themselves to be excellent motivators for their students.

Throughout my teaching experience in this course, I found these strategies very helpful for me. Through the use of these strategies, I was able to stimulate my students’ thinking and interests in the lesson that I taught. (Khaled)

These strategies encouraged my students to analyze and look critically to their surrounding environment especially that related to science. (Tareq)

Furthermore, most participants felt that the use of these strategies helped them gather important information about their students’ diverse backgrounds that can affect their readiness to learn science. Revealing such information was an important step for them to determine supports and provisions that may be necessary to help their students succeed in their science classrooms.

One interesting thing about using these strategies is they gave me an idea about my students’ interpretations and explanations of the scientific phenomena that I wanted to teach. (Wa’ed)

I was really surprised about the diverse thinking that my students had about the scientific phenomenon that I wanted to teach. I never thought that I would be able to get to know their diverse interpretations of that phenomenon without the help of these strategies. (Summaya)

Recalling and connecting students’ prior knowledge was another important thing that participants in this study found throughout the use of these classroom strategies while preparing for the engagement stage of the learning cycle. Participants were able to elicit their students’ prior knowledge and ideas about the topic being studied. In addition, they were able to let students discuss and share their ideas in a nonjudgmental way.

These strategies are very suitable to explore students’ prior ideas and discuss them in a safe environment. (Lubna)

Through the use of these strategies, I was able to challenge my students’ ideas and allow them to consider other interpretations of the scientific phenomena being studied. (Ahlam)

I actually made a great use of the ‘Frayer Model’ in teaching my science lesson. I was really able to get to know the previous thinking of my students before the start of the exploration stage of my inquiry science lesson. (Wafa’a)

Involving direct experience with physical objects or processes, reading text or uncovering ideas in discussion with peers was also another opportunity that these classroom strategies offered to participants. These activities are crucially important while planning for the exploration stage in the learning cycle. Many participants mentioned that these strategies allowed them to make predictions that initiate their scientific inquiry, and justify and test out their ideas.

These strategies helped me pose questions, propose a solution, and test out my ideas. (Reem)
I never allowed to predict a solution for a scientific problem, throughout the use of these strategies, I was given an opportunity to predict and design an experiment to test out my prediction. (Aseel)

The classroom climate that these strategies provided was another interesting observation that most participants addressed in their responses and practice teaching. According to them, they were able to share their ideas with their classmates without the fear of being judged or corrected or embarrassed in front of their instructor or other students.

I actually was very hesitant to share my ideas and thinking with other students in the class. However, these strategies encouraged me to participate in the productive dialogue with my colleagues and decide on the best explanation that is supported with more evidences. (Tareq)

The use of ‘think-pair-share’ was especially excellent for me. It encouraged me to share my knowledge with other students in the group. I used to keep myself silent but now, I became really a big fan of using these strategies because I really learned a lot from sharing my ideas with other students. (Summaya)

I felt that when I gave my practice science lesson. I noticed that my students liked that so much. I was one of them, I never seen them fully engaged like that … they were really engaged. (Hajem)

Developing scientific concepts during the explanation stage of the learning cycle was also facilitated throughout the use of these classroom strategies. According to participants, these strategies helped them determine the extent to which they grasped the concept, recognized its relationships with other scientific concepts and used appropriate terminology.

These strategies allowed us to negotiate our understanding and weigh our evidences and arrive at a suitable and logical scientific terminology of the phenomena we studied. (Tareq)

These strategies gave me an opportunity to build my concepts through discussing my understanding with my teacher and other colleagues. (Ola)

Transferring scientific concepts to new situations, which is the elaboration stage in the learning cycle, was also offered by these strategies. Through using the assessment strategies that participants learned, they were able to assess their understanding and use their newly formed or modified ideas in a new situation or novel context.

The use of these strategies pushed me to transfer my learning to new contexts and environments. (Ahlam)

These strategies offered me a great opportunity to explore the various applications of my learning. (Lena)

The same comment was also noticed during their practice teaching. Most participants commented that the classroom strategies were very useful in assessing learners’ understanding.

I used several assessment strategies to assess my students’ knowledge and understanding during my practice teaching. I was actually lost on how to conduct diagnostic, formative and summative assessment in my teaching. But with the use of these strategies, I was really organized and prepared to conduct all these types of assessment. (Lena)
Furthermore, the use of assessment strategies during the evaluation stage of the learning cycle was very beneficial to participants as these strategies encouraged them to reflect and self-assess their learning. Self-assessment and reflections provided valuable feedback to participants and informed them how their learning had changed over time.

The assessment strategies I learned offered me a great opportunity to track my understanding and things that have changed over the learning experience that I have gone through. (Reem)

I have learned so many assessment strategies in this course that helped me think about my thinking and learning. They were really helpful. I loved them because they forced me to appreciate my learning. (Tareq)

**The role of strategies in facilitating inquiry science teaching**

To discern how each of these strategies facilitated the implementation of inquiry-based science teaching, several responses were collected from the open-ended questionnaire. A tally analysis of participants’ responses on one open-ended question (Which classroom strategies did you find most helpful for you to teach science through inquiry and which ones did you find not applicable?) indicated that all participants found these classroom strategies useful and of great value for them as they helped them manage, teach and evaluate their students’ learning. Figure 1 shows the participants’ responses on the various classroom strategies offered in this course.

![Figure 1](image-url)  
**Figure 1.** Participants’ responses on the various classroom strategies.
Figure 1 shows that ‘Think-Pair-Share’, ‘Fold and Pass’, ‘Verbal Fluency’ and ‘I Used to Think... But Now I Know’ classroom strategies were the most favored strategies for those participants. The comments of those teachers indicate that ‘Think-Pair-Share’ technique helped promote their thinking, encourage them to share their ideas with their peers, and enhance and organize their participation in the classroom, as this technique begins by providing students with an opportunity to activate their own thinking. In addition, it allows them to share their ideas and modify them as a result of interaction with their peers. Participants also mentioned that when they were asked to share their ideas with other groups in the classroom, they felt more willing to respond as they had a chance to discuss their ideas with other students in their group. In addition, many participants indicated that this technique enhanced their verbal communication skills as they discussed their ideas with their peers, which is a critical feature of successful inquiry science teaching.

With respect to the second-favored classroom technique, ‘Fold & Pass’, teachers’ comments showed that this technique offered them an opportunity to know others’ ideas and explanations of the scientific phenomenon under investigation. As they mentioned, ‘Fold & Pass’ technique provides them with an opportunity to think about what they know and come to a consensus of thinking with their peers. After they have passed their thoughts to a new group of students, the new group must examine the thinking of their peers and decide whether they agree with their thinking. Both groups then get together to give feedback to each other. This technique helps students receive constructive (formative) feedback from each other in a safe environment.

For the ‘Verbal Fluency’ technique, participants indicated that this technique helped activate their thinking as the act of talking nonstop for a specified interval stimulates them to construct meaning through language while digging deeper into their existing knowledge base. In addition, some participants mentioned that this technique encourages active listening to other colleagues, which stimulates additional thinking about the topic. Furthermore, this technique, as one of the participants mentioned, forces each group member to participate in the discussion by expressing his or her explanation and ideas to the other members in the group. This technique also helped students know the nature of the activities and conversation that should dominate their explanation stage in the learning cycle.

Regarding the ‘I Used to Think... But Now I Know’ technique, participants commented that this self-assessment technique helped them recognize if and how their thinking had changed at the end of the lesson. According to them, this technique prompted them to recall their ideas at the beginning of the instruction and consider how they had changed. In addition, the technique provided them with an opportunity to self-assess and reflect on their current knowledge and how it may have changed or evolved from their previously held ideas. In addition, this technique offered student teachers an opportunity to monitor their classmates’ progress and understanding of the scientific concepts being studied.

On the other hand, both the ‘Poster Session’ and ‘Gallery Walk’ classroom strategies received the least interest from these participants as these two strategies require more time to prepare and apply inside the classroom. Another concern about using these two strategies in the classroom was addressed by some participants because they create noise in the classroom.

I don’t think that these two strategies are very applicable in our classroom; they need more time and effort to manage the classroom. (Tareq)
Discussion and implications for pre-service teacher education

Successful enactment of inquiry science teaching means teachers know how to prepare for an inquiry lesson, guide students to get engaged in the subject, predict and formulate hypotheses, explore scientific phenomenon, interpret results, extend and transfer the newly learned knowledge to different contexts and situations, and evaluate their learning (Schwarz 2009). Inquiry learning encompasses also learning how to elicit, recognize, describe and use students’ knowledge to inform instructional practices and facilitate students’ conceptual development (Otero 2006). In fact, teachers need to be planners as well as diagnosticians who can take into account variables and teach in a reciprocal relationship (Darling-Hammond 2000). To enact inquiry science teaching in classrooms, science teachers need to be provided with diverse classroom strategies that help them enhance their lesson-planning skills, guide students through their scientific projects, increase their knowledge about assessment and develop their classroom management skills. Therefore it is important that teacher education courses focus more on enabling student teachers to develop greater cognitive complexity in their thinking about using inquiry in science teaching and assessment through active, frequent and systematic engagement in their professional preparation (Maclellan 2004).

The first research question concerned the evaluation of various classroom strategies used in teaching a methods course to help foster preservice science teachers’ science teaching skills. Results indicate that these classroom strategies were useful for promoting preservice science teachers’ understanding and the contextualized approach helpful for reinforcing preservice science teachers’ skills for linking inquiry science instruction, assessment and learning. The inquiry-based classroom teaching experience provided preservice science teachers with a productive opportunity to practice their developing instructional knowledge and skills and utilize these classroom strategies in their inquiry instructional lesson plans. While all preservice science teachers favored the use of the 15 classroom strategies, they tended to use those strategies that encourage learners to share their ideas and previous knowledge about the scientific phenomenon being studied (i.e. Think-Pair-Share, Fold and Pass, and Verbal Fluency). According to them, those strategies offered preservice science teachers significant help to plan their science teaching and be able to manage their students’ work inside the classroom. Participants addressed the need for those strategies to help them link their assessment, instruction and learning practices inside the science classroom. Thus, the suggestion to include those and similar classroom strategies in preservice science teachers’ methods courses would greatly support preservice science teachers in teaching science effectively. Furthermore, enacting the use of these strategies in the university classroom would further support preservice science teachers’ understanding of the dynamic nature of teaching. Moreover, discussing the merit of utilizing those strategies with preservice science teachers in the methods course may also serve to mitigate their inclination to merely copy and repeat the strategies modeled by the instructor during contextualized instruction.

The second research question in this research focused on the extent to which introducing the 15 classroom strategies in preservice science teachers’ methods course facilitate the enactment of inquiry in the science classroom. The goal was to prepare preservice science teachers who are able to plan instructional lessons based on the 5E inquiry model, diagnostically assess students’ prior knowledge and backgrounds, begin instructional planning by matching assessment outcomes to learning
goals, guide students through the five stages of the inquiry model and change instructional strategies as needed (Graham 2005). Overall, findings indicated that preservice science teachers gained a more sophisticated understanding of the role of these classroom strategies and their potential implications for facilitating inquiry science teaching and learning. After explicit instruction, preservice science teachers showed intentionality in their conceptions of inquiry through their lesson plans and responses in the open-ended questionnaires, where they reflected on the importance of utilizing these classroom strategies as part of daily instruction. As well, they exhibited the ability to incorporate those strategies into their instructional lesson plans, implement planned assessments, describe students’ conceptions prior to instruction, encourage students to predict and design experiments, test out their predictions and weigh their explanations using relevant evidence through classroom negotiation and discussion. This result suggests that the use of these strategies offered preservice science teachers practical tools to guide their students in inquiry science learning and foster their beliefs and understanding on how to use inquiry in science teaching. Additionally, these strategies help resolve preservice science teachers’ contradictory beliefs about the roles of teachers and learners that might exist (Crawford 2007) and shift their teaching beliefs from teacher centered to student centered (Abell, Bryan, and Anderson 1998; Appleton and Kindt 2002; Roehrig and Luft 2006). In the case of this study, the preservice science teachers articulated the importance of eliciting student understanding, were able to enhance or revise instruction to support students’ needs and proved able to provide students with substantive help that would have engaged students in active participation in their own learning.

This research extends on previous studies by providing preservice science teachers with real-life-based teaching experiences. The hope of providing the preservice science teachers with real teaching experience was to get around logistical and institutional challenges that preservice science teachers experience, offer them appropriate field placements and assist them in how to enact inquiry in science teaching (Abell 2006; Luehmann 2007). In essence, this experience allowed preservice science teachers to experience reform-minded practice in a social setting, thereby creating opportunities for increased learning (Abell 2006). Furthermore, the teaching experience offered to preservice science teachers in this course helped them realize that inquiry science teaching does require time through the use of those classroom strategies. This suggests that extended real teaching experiences in which preservice science teachers engage in inquiry science planning and teaching would support teacher educators’ efforts to promote effective inquiry science teaching practices (see Ohana 2004; Zembal-Saul, Blumenfeld, and Krajcik 2000).

While field-based practicum experiences can be a powerful approach to helping prospective teachers develop practical procedures and a sense of realism with regard to planning and teaching, these experiences alone are insufficient for improving their practice (Luehmann 2007). In light of this study, we suggest expanding the use of these classroom strategies in undergraduate methods courses to facilitate the enactment of inquiry in science teaching. By bringing these classroom strategies into the methods courses and train preservice science teachers in how to use them in science teaching prior to their field-based experiences, they can explore the complexity of teaching science through inquiry in a controlled, nonthreatening environment. Indeed, training preservice science teachers in how to use these strategies in teaching science through inquiry gives them an opportunity to reflect on one another’s
teaching, by critically comparing practices with evidence of student learning, in order to develop new understandings and improve practice (Abell, Bryan, and Anderson 1998). According to Abell and Bryan (1997), Bryan and Abell (1999) and Zembal-Saul et al. (2000), case-based pedagogy followed by discussion within a community of learners has potential for the greatest impact on prospective teachers’ practice and beliefs about science teaching. Furthermore, engaging preservice science teachers in regular discussions of exemplary teaching will enhance their capacity to learn from their own and one another’s experiences (Abell and Bryan 1997; Abell, Bryan, and Anderson 1998; Shulman and Shulman 2004).

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References


Appendix 1. Sample Lesson Plan

Science Lesson Plan

Scientific Idea: Comparing the three states of matter

Learning Objectives:
Students will be able to conclude the followings:

Prior Knowledge:
Knowing the three states of matter; solid, liquid, gaseous.

1. Some common physical and chemical characteristics of the three states of matter.

Engagement Stage
- Students will be divided into 6 groups of 5–6 students each. Each group will give each of its members a number 1–5/6.
- Each group gets cards that have names of different substances.

Cards Sort and Think _ Pair _ Share Strategy
- Each student individually in his science journal writes down the classification of the pictures given to his group.
- Students share and correct their answers in their groups.
- The group collectively agree on the correct answer and write down their answer on an A4 paper.

Fold and Pass Strategy
- Each group passes their paper to the group next to them. Papers are continually passed around the room until a signal is given. (anonymous papers)
- The groups read the paper in their hands and check their answer.

Hands-Up strategy
- The teacher asks one member from each group to raise their hands if they have incomplete match.
- Raise hands if they have any disagreement.
- The teacher listens to the type of errors in the groups’ answers.
- The teacher addresses and clarifies any misconception.

Exploring Question:
The teacher asks the question ‘how can we compare these substances that you have against the following two criteria:

- The physical state of the material in room temperature.
- Whether the material takes the shape of the container or not’.

Exploration and Explanation Stages
The teacher asks students to carry out the next activity to answer the previous question.

Activity:
- Each group starts investigating the physical state of each material that they have. The students investigate whether the materials they have change their shapes according to shape of the container when put inside it or not.
- Each group writes down their answer on a piece of paper.
- Using Fold and Pass strategy, each group passes their paper to the group next to them.
- The groups read the paper in their hands and check their answer.

(Continued)
Appendix 1. (Continued)

Explanation
- Using Numbered Heads Strategy, the teacher collects the group responses. Ensuring they provide evidence on their findings.
- The teacher facilitates students’ discussion and argumentation through probing several questions such as:
  - Why don’t solid materials take the shape of the container? Why do fluid and gas take? What does the chemical structure of each material look like?
  - The teacher provides students with a basket full with balls to help them imagine the structure of each material.
  - For solid substance: All balls are glued together and not allowed to move [this is why solid substances don’t take the shape of the container].
  - For liquid substance: balls are not glued and are flexible to move [this is why liquids take the shape of the container].
  - For gaseous substances: balls are away from each other and can be easily moved around.

Elaborations Stage
Physical Characteristics Substances:
- The teacher guides the students to examine how a solid substance can be transformed into another state through the use of temperature.
- The teacher helps students explore the use of several materials in live such as iron, water, oil, sand...etc.

Evaluation Stage
Formative/ Diagnostic Assessment:
- Eliciting students’ prior knowledge and addressing misconceptions.
- Observing the group work and assessing their explanations.

Summative Assessment:
- Individual Exit Ticket: the teacher asks the students to answer the following questions and hand in their answers on their way out:

What is the effect of temperature in transforming the physical state of iron, ice, water? Compare between the following three substances; cool, oil, sand in terms of their physical properties and whether they change their shape when put in a container or not.