RPL in Teacher Education: A Science Teacher Education Example from the USA

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DOI: https://doi.org/10.54337/ecrpl25-10927

Abstract

For effective preparation to teach science, practice-based learning experiences are of paramount importance. However, practice alone is not sufficient for developing effective teaching attributes. Reflection on the practice is equally important to develop the desired attributes. Effective teaching requires far more than learning a few specific skills or techniques. A reflective mindset involving evaluation of the practice is essential for understanding and improving on various elements of effective teaching. Thus, learning experiences in teacher education must "marry" practice to reflection in order to produce competent teachers. In the context of science teaching, the fundamental question becomes, what are the key elements of effective science teaching and how can they best be taught to pre-service teachers (PSTs)? The author has attemped to address these questions by "marrying" practice and reflection in secondary science teacher preparation across three universities over 26 years in the USA. This "marrying" was done at three levels: Specific assignment-based, full course-based, and an entire program-based reflection on practice. This paper focuses only on the results of a course-based reflection on practice in one science teacher education program. The research question being explored and addressed is: To what extent do the reflective, practice-based course level experiences lead to a shift in PSTs' mindset regarding key elements of effective science instruction?

Qualitative analysis of PSTs' responses to an open-ended question, given as a pre- and post-course assessment, was conducted. The results indicate that the 5E Model of the Learning Cycle Approach to science instruction enabled pre-service teachers to shift their mindset regarding key elements of effective science instruction.

Keywords
Science Teacher Education, 5E Model, Learning Cycle, Secondary Science Education, Science Instructional Practices

The Challenge or Problem

The primary purpose of a pre-service science teacher education program is to prepare teachers for effective science instruction. One might ask, though, what does effective science instruction mean or look like? During the final decades of the 20th century, national documents in the USA, such as *Science for All Americans* (American Association for the Advancement of Science, 1990), *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science, 1993), and the *National Science Education Standards* (National Research Council, 1996), provided guidance about elements of effective science instruction. More recently, during the opening decades of the 21st century, *A Framework for K-12 Science Education* (National Research Council, 2012) introduced the idea of a 3-Dimensional science instruction, premised on the recognition of the following THREE dimensions of science to serve as key elements of effective science instruction: Disciplinary Core Ideas; Crosscutting Concepts; and Scientific and Engineering Practices. Usually, pre-service teachers (PSTs) develop the knowledge of disciplinary core ideas through the disciplinary content courses, such as courses in biology, chemistry, etc. However, learning to teach those disciplinary core ideas in a manner so as to weave the crosscutting concepts and engage students in the scientific and engineering practices (the other two dimensions of the 3-Dimensional approach), is expected to be accomplished in the so called 'teaching methods' courses. These courses are sometime 'stand-alone' and sometime coupled with field experiences (practice-based learning) in school classrooms. The ability to implement 3-Dimensional science instruction effectively, may be termed "pedagogical capital". Enabling PSTs to develop the "pedagogical capital" for such instruction poses a major challenge in those teacher education programs that include only ONE science 'teaching methods' course within which most, if not all, pedagogical preparation must occur.

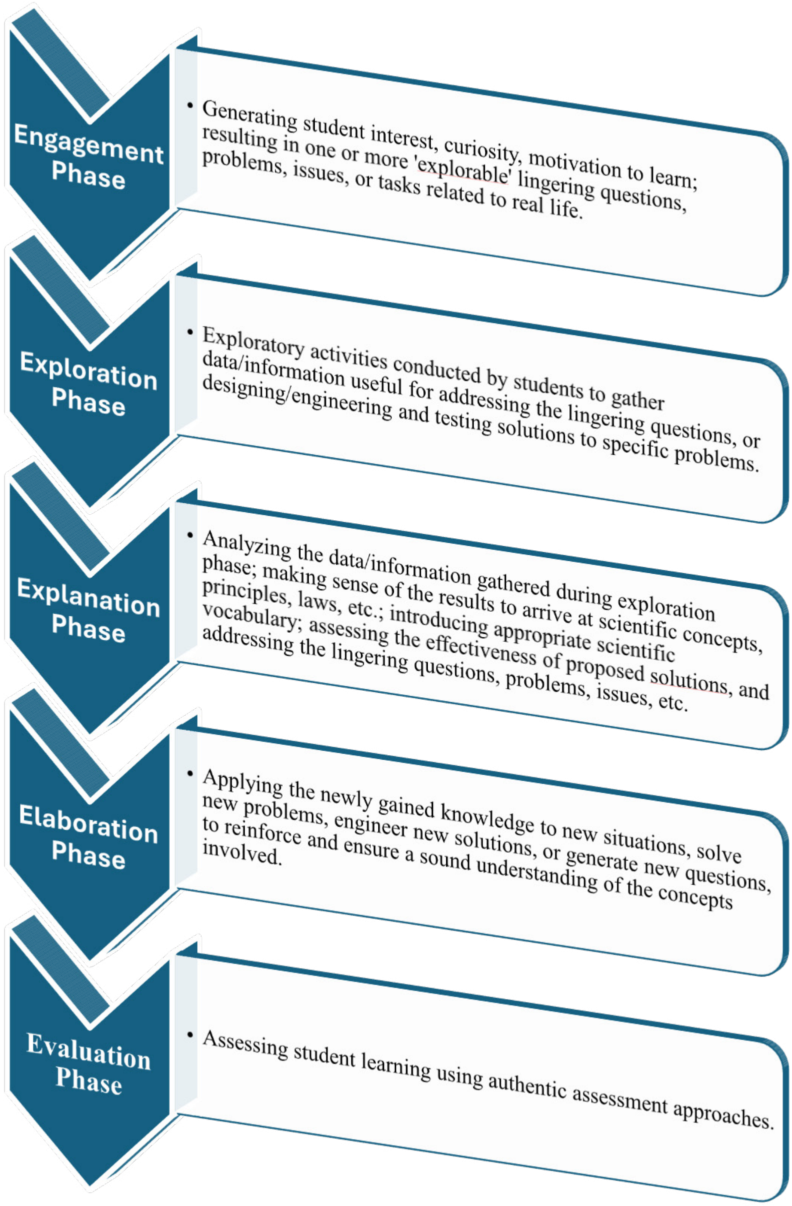
A Response to the Challenge

The author worked in just such a program for 13 years, during which he taught the lone 'methods' course for middle and secondary PSTs. Realizing the challenge identified above, he designed his 'methods' course around the 5E Model of the Learning Cycle Approach (Bybee et al, 2006), in such a way that the students experienced the 5E Model throughout the course activities all semester long. The premise behind this course design was that by the end of the course, the PSTs would have first-hand experience of the potential of the 5E Model in delivering "effective" science instruction and would have developed a sound understanding of the elements of the 5E Model. Thus, they will become equipped with an initial "pedagogical capital" for immediate use in their own classrooms to implement 3-Dimensional science instruction. Similar attempts to use the 5E Model and the Learning Cycle Approach in science teaching methods courses have been made and reported in recent years (Bradbury, 2017; Hick, 2017). These reports focus on student ability to write a Learning Cycle based Lesson Plan and to reflect on the teaching episodes. However, the mindset of students regarding the elements of effective science instruction, a mindset that they would carry with them into the profession and their classrooms, was not explicitly examined. Thus, the existing literature documents PSTs' "skill" development in writing Learning Cycle based lesson plans and reflecting on their implementation during the "methods" course. It does not, however, provide any documentation of the impact of this skill development on their dispositions and mindset regarding effective science instruction. Herein, lies the research gap being addressed by the study reported here.

Table 1: Alignment between the phases of the Learning Cycle and Scientific & Engineering Practices

Phases of the 5E Model of the Learning Cycle (A pedagogical approach for effective science instruction)	Essential Scientific & Engineering Practices (One of the THREE Dimensions presented in *A Framework for K-12 Science Education*, 2012)
ENGAGEMENT	Asking Questions Defining Problems
EXPLORATION	Developing & Using Models Devising Testable Hypotheses Planning & Carrying out Investigations Collecting, Analyzing and Interpreting Data Using Mathematics & Computational Thinking
EXPLANATION	Analyzing and Interpreting Data Constructing Explanations and Critiquing Arguments based on Evidence Designing Solutions Communicating and Interpreting Scientific Information
ELABORATION	Applying and Using STEM Knowledge
EVALUATION	Applying and Using STEM Knowledge

Figure 1: The 5E Model of the Learning Cycle



Considering the importance of ”practice” in teacher preparation and making this practice authentic, the author implemented two levels of practice within this course: having PSTs practice the phases of the 5E model within the ’methods’ course where the audience was their course peers; and developing and teaching a 5E model-based science lesson in a local school classroom. Each of these levels of practice were followed by reflective analyses of the teaching episodes by the presenters as well as the course peers who were the audience (in case of presentations within the ’methods’ class) and observers (in case of lessons taught in the school classrooms). These reflective analyses were both verbal during ’methods’ class sessions and written after each teaching ’practice’ episode. The ’methods’ course was offered each Fall (Autumn) and Spring semester for a 15-week duration.

The impact of practice-based learning experiences coupled with reflection in this ‘methods’ course designed around the 5E Model, on shifts in PSTs mindset regarding effective science instruction, was examined via a free-response essay. PSTs were asked to respond to the question, *“How should science be taught?”* in this essay, given as a pre- and post-test. The pre-test was given on the first day of class prior to commencing any learning activities. The post-test was given on the last day of class. This pre- and post-test essay represents a ”meta-reflection” expressing the PSTs mindset at the beginning and end of the course. The comparison of the pre-test essay response to the post-test essay response demonstrates the cumulative impact of multiple teaching practice episodes followed by reflection on those episodes throughout the ’methods’ course.

The research question being explored and addressed in this study is: To what extent do the reflective, practice-based course level experiences lead to a shift in PSTs’ mindset regarding key elements of effective science instruction?

Theoretical Foundation

The theoretical foundation of reflective practice employed in this ’methods’ course is based on Lisle’s (2006) conception of reflective practice, which characterizes reflective practice in education as ”learning-in-practice”. PSTs in this ’methods’ course were indeed learning in practice since throughout the course they were engaged multiple times in the practice of teaching using the 5E Model and then reflecting in a systematic way on how that practice represented elements of effective science instruction and in what ways could their practice be improved to better incorporate those elements. This reflective approach was very similar to the one designed by Belvis et al (2013) for a mathematics teacher education program in which teachers reflected on their own educational practices and then shared among colleagues and in small groups.

A review of 120 publications, representing an international body of literature, conducted by Jensen, Georgsen, and Dau (2023) concluded that the concepts of reflection, practice, and theory are interconnected and the combined experience of all three is essential for developing deep meaningful learning that impacts the professional lives of people. In the case of science teacher education example reported here, the theory was the 5E Model of Learning Cycle, the practice was designing and implementing 5E-based lessons in school classrooms, and then structured reflection on each teaching episode of these lessons. The combined experience of these three —reflection, practice, and theory—in this teaching methods course was expected to impact the mindset of the PSTs toward implementing effective science instruction congruent with the 3-Dimensional Framework described earlier. This impact was investigated using the ”meta-reflection” approach via the pre- and post- essays.

Reflective practice has the capacity to transform instruction (Parsons and Stephenson, 2005). In the case of pre-service teacher education, the first step in the transformation of instruction is a change of mindset. Specific to science instruction, most PSTs' recent experience of science instruction comes from their college science classes. For the most part, these classes use didactic, lecture style method of content delivery, coupled with ”cook-book” recipe style laboratory exercises. For learning about elements of effective school science instruction, PSTs need to experience, practice, and reflect upon specific pedagogical approaches, such as the 5E Model. Learning and experiencing such approaches can be expected to develop the ”pedagogical capital” PSTs need in order to deliver effective science instruction and accomplish the current goals 3-Dimensional learning in science. With this expectation, the impact of such practice-based reflective learning experiences on PSTs mindset (toward transformation of instruction) must then be assessed. That assessment was performed via the pre- and post- meta-reflective essay in this ’methods’ course.

Methodology

Data regarding change in PSTs' mindset were collected through this pre- and post- essay each semester from Fall (Autumn) 2007 through Spring 2013. Data from only those PSTs who wrote both the pre- and post- essay were included in the analysis, since it is essential to have both the pre- and post- essay from a PST in order to examine any change in their mindset. Collectively between Fall 2007 and Spring 2013, a total of 85 PSTs submitted both pre- and post- essays. Thus, the results presented below show the impact of the reflective, practice-based learning experiences in this methods course on 85 PSTs.

The essays were analyzed first by using qualitative comparison of the narrative in pre- and post- essays for themes that indicate student ideas regarding ways of teaching science effectively. Ideas that showed connection to or alluded to specific components of *Scientific and Engineering Practices* of the 3-Dimensional framework, or comments that referred more generally to inquiry-oriented, hands-on type instruction, were coded broadly as 'elements of effective science instruction'. Next, a quantitative approach was taken to record the number of times such ideas or comments appeared in a PST's pre- and post-essay. The number of times these ideas appeared in the pre-essay was compared with the number of times similar ideas appeared in that PST's post-essay. This comparison provided a measure of the degree to which PSTs mindset was impacted by the reflective, practice-based learning experiences in this science teaching methods course.

Results of the Response (Findings)

In general, the results of these analyses indicate shifts in PSTs' understanding of the elements of effective science instruction from didactic, information-imparting features, to more interactive, hands-on/minds-on, features. The following are some specific instances demonstrating change in the mindset of PSTs between the pre- and post- essay.

1. 5 E's were mentioned much more frequently in the post- essays, but never in the pre- essays.

2. PSTs are more focused on the content (disciplinary core ideas) in the pre- essays. They have ideas on ways to structure and organize the content they would teach, but not on methods to do that. The post- essays show greater focus on demonstrations, labs, and interactions among the students, as methods of learning.

3. Most PSTs indicated only brief familiarity with the concept of hands-on learning in the pre- essays but provided much more detailed account of how to implement hands-on/minds-on learning, in the post- essay.

4. In many of the post- essays, the PSTs wrote about wanting to help students take responsibility for their own learning and they want the students to discover their own answers without being told through a lecture.

5. Most PSTs discussed how hands-on experiences are more important and lasting than lectures and memorization, in their post- essays but not in the pre- essays.

6. There was a significant focus on questioning things and letting questions guide the class lessons, in the post- essays compared to pre- essays.

7. The pre- essays of some PSTs are more focused on content and teaching it in understandable and simple ways. The post- essays of these PSTs focused more on student engagement and how to get them to discover things for themselves.

8. Many of the pre- essays mentioned engaging students or having experimentation. But, they didn't describe concrete methods on how to engage students. Elaboration of the methods to do so showed up in the post- essays.

9. In the pre- essays, many PSTs wrote about teaching enthusiastically, but not how to do this. In the post- essays, they didn't say this directly, yet their descriptions included ideas, which, if implemented, would result in an enthusiastic teaching environment.

10. Most PSTs used the term 'inquiry' in the post- essay, but not in the pre- essay. Instead, the pre- essay refers to the concept as "hands-on".

11. The idea of not just memorizing and regurgitating the material comes up a lot. Instead, PSTs mention connecting science to the real world, so students can apply their knowledge.

12. To truly understand information, you need to be involved in it, not just merely memorize facts. Many PSTs mention the 5 E's as a good way to help students understand and get involved in science, in their post- essays.

13. Many PSTs mention interactive activities to get students interested, in their post- essays but not in their pre- essays.

14. Some PSTs mentioned vocabulary terms or particular content in the pre- essay but it wasn't mentioned at all in the post- essay. Rather, the post- essays included a greater focus on how to get the students actually doing science.

Samples of student statements in the pre- and post- essays, shown in Table 2, demonstrate the change in their mindset about elements of effective science instruction and corroborate some of the summary findings listed above. The *highlighted* statements in the post- essay column represent direct connection to parts of the *Scientific and Engineering Practices* dimension, which characterize effective science instruction.

Table 2: Sample statements demonstrating mindset shift from pre- to post-essay

Student	Pre- Essay	Post- Essay
1	*The best way to teach science is to let the kids experience it first-hand, and get to do experiments. Should also be relatable to their lives.*	*Science should be taught the way it is performed, by asking questions and designing a way to answer it. It must be relatable to their lives. Hands-on is good but it will only work if it is also minds-on.*
2	*To engage students in science you must be enthusiastic Hands-on experiments are important but you need some lecture or reading to be able to understand what is happening.*	*To teach science you need to make it relevant to the students' lives. Then students should be able to explore and ask questions. She then walks through the rest of the 5 E's which encourages student involvement.*
3	*Science should be taught using experiments and labs since that is how real science is done. Students learn better when they actively participate, and small group work can help with this.*	*Students should be doing science not just hearing about it. Activities should be hands-on and minds-on. There should be situations where students can ask questions and discover their own answers rather than just following a procedure.*
4	*Science should be taught by asking questions and letting them investigate through hands-on activities. But some background information should be given first.*	*Science should be taught by letting the students do experiments and the teacher should only give information after the students have had a chance to look at it themselves. Discussion is important and will interest and motivate students. Also, it should be connected to things students interact with in their lives.*
5	*Science should be taught as something that everyone is capable of, and we should use everyday examples to encourage students. This will help them make connections between the content and their lives.*	*Science should be taught through scientific inquiry. This allows students to ask questions, discuss, experiment, analyze/collect data, make predictions etc. The 5 E's help students learn through hands-on and minds-on. The teacher should be a guide rather than the ultimate giver of info. Also, we need to connect things to students lives.*

Significance of the Results

It is important to point out that this work was conducted in the context of the *National Science Education Standards* (National Research Council, 1996), prior to the publication and widespread impact of the *Framework* (National Research Council, 2012). The Framework ushered a new 3-Dimensional approach to the teaching and learning of science, which has become widely accepted and being implemented across the USA. Thus, it is appropriate to raise the question whether or not the results of the work presented here are still relevant for the post-*Framework* era of science education.

When the results presented above are examined carefully, it becomes obvious that the PSTs were impacted positively regarding the importance of elements of science instruction that feature within the *Scientific and Engineering Practices* dimension of the *Framework*. These include ideas such as students being given the opportunity to ask questions, make predictions, collect and analyze data, etc. Thus, it can be argued that the 5E model of the Learning Cycle does hold promise for helping pre-service teachers realize the importance of incorporating the *Scientific and Engineering Practices* in their science instruction. Indeed, specific '*Practices*' map well onto specific phases of the 5E model (Dass, 2015). This makes the 5E model a useful tool for equipping pre-service teachers with an initial "pedagogical capital" for implementing 3-Dimensional science instruction, envisioned in the *Framework*. It is, therefore, useful to have pre-service teachers experience the 5E model of the Learning Cycle, as thoroughly as possible, during their science teaching methods courses. It is even more important to couple the 5E model with reflective, practice-based learning experiences during these courses in order to effect a mindset shift toward effective science instruction.

Conclusions

The purpose behind using the 5E Model and a reflective, practice-based approach in this 'methods' course was twofold.

- To develop a mindset about effective science instruction in PSTs.
- To provide the "pedagogical capital" to PSTs to implement effective science instruction in their own classrooms.

The comparison and analyses of their pre- and post- meta-reflective essays, indicate that both goals have been met to a significant extent. These results also support the idea posited by Parsons and Stephenson (2005) that reflective practice has the capacity to transform instruction. However, what was assessed in this 'methods' course was only the first step of the transformatiom of instruction, namely the transformation of mindset. To what extent did this transformation of mindset result in actual transformation of instruction in these PSTs classrooms after they graduated from the program has not been examined. This is a limitation of the work being reported here and warrants further investigation.

Finally, it is resonable to claim that multiple episodes of teaching practice, each followed by systematic reflection, can have a cumulative effect of transformation of the mindset toward effective instructional practices and this transformation of the mindset can be assessed via a meta-reflective essay.

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