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Education Method

Searching to Effectively Teach the 5E Learning Cycle: Teaching Future Science Educators

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Abstract

Roger Bybee's inquiry-based 5E Learning Cycle (5E), where students engage in scientific practices, is considered best practice for elementary science classrooms. Each E stands for a different portion of the lesson and includes engage, explore, explain, elaborate, and evaluate. Research of 5E mastery was conducted during a capstone methods course one semester prior to student teaching. The researcher, a teacher educator, examined her own instructional practices to improve teacher candidates' mastery of the strategy. A pre-/posttest with classroom scenarios measured mastery of 5E, and the instructor used specific interventions to teach 5E concepts. Teacher candidate participants' posttests indicated improvement, but they need more practice with the strategy. A plan of action for future interventions and future research is shared.

Keywords: STEM education, Evidence-based practice, Inquiry Based Teaching, Teacher Education

1. Introduction

1.1 Science education

Teaching science in elementary settings has moved from teaching about science to teaching students to be scientists. One strategy that promotes development of science practices is inquiry-based teaching. When teachers use inquiry strategies, students practice applying scientific knowledge in context such as making predictions, testing hypotheses, and dealing with inconclusive data (Sullivan-Watts et al., 2013). Lakin and Wallace (2015) suggest that a more obvious name for inquiry teaching in science would be scientific practices. Students construct their own understanding through hands-on experiences and discussions with peers. This authentic process reflects how scientific knowledge is constructed over time through discourse between scientists (National Academy of Sciences, 2012; National Science Teachers Association, 2018). Inquiry teaching also promotes scientific skills such as critical thinking, problem solving, argumentation, and when centered in problem-based learning, can improve metacognition (Mukagihana et al., 2022). Teaching science where students engage in hands-on experimentation, develop models, and construct understanding of concepts promotes college and career readiness as students are applying content specific practices. Teacher preparation providers are tasked with equipping teacher candidates with knowledge of how to provide rich learning environments that engage students in discipline specific practices (Council for the Accreditation of Educator Preparation, 2013), and for science this should include inquiry-based teaching strategies (Mukagihana et al., 2022). Additionally, state standards based on the Next Generation Science Standards include crosscutting concepts that help students understand broad concepts across disciplines (National Academy of Sciences, 2012). This can potentially increase students' ability to transfer learning across different science sub-content areas because they have a deeper understanding of science content than they would if the teacher focused on teaching a large variety of topics (Mukagihana et al., 2022). In other words, it discourages treating science as just facts to recall and encourages treating science as an area that has related concepts and ways of thinking (Jin & Liu, 2022; National Science Teachers Association, 2018).

One well-established model for inquiry-based teaching is the 5E Learning Cycle (5E). Proposed in the

late 1990s by Richard Bybee (2014) and a team of colleagues, it has five components that are used as a framework for lesson planning. The components include:

1) Engage- a high-interest, highly motivating hook that gets students involved in the content.

2) Explore- when students interact with content, often in a hands-on way that allows for experimentation with and construction of their own understanding of content.

3) Explain- when students work with each other and the teacher to articulate understanding of content. While this is similar to guided practice in a gradual release lesson because immediate feedback helps students to correct misconceptions, refine ideas, and generally check that they are on track, it is not the same. In the explain phase of learning, the goal is that the students articulate their understanding rather than replicating a teacher-driven explanation.

4) Elaborate- when students add details to their understanding. It could be that they enrich or extend their understanding into other concepts, or they refine or develop a deeper understanding of current content. Frequently, this is where students are asked to apply their understanding.

- Evaluation- the teacher assesses throughout all steps of the lesson. Measures of student comprehension could be done through checklists, products, projects, discussion, etc. during 5E and/or also as a summative assessment. Evaluation can be integrated throughout 5E rather than a distinct step.

While the components have numbers here, they are not necessarily linear. Yes, Engage typically is done first, but teaching may cycle back-and-forth between two or three components as needed. For example, the teacher may engage the students with the new content, and then give them some chance to explore it. Next, the students may work on their explanation, but then be given more time to explore the content so that they can further develop their explanation before applying it during the elaboration. All the while, the teacher is circulating gathering information to evaluate student mastery.

Teacher candidates tend to teach in ways that they have experienced. Some may have negative views of teaching science based on their experience as a student. College coursework can help teacher candidates overcome hesitancies and negative perceptions about teaching science. Methods courses and student teaching experiences help shape what teacher candidates will do in their future classrooms (Sullivan-Watts et al., 2013). Some teacher candidates enter the science methods course with an inflated confidence in their ability to teach science, as they may intuitively understand that children need hands-on lessons. At the end of the semester, they typically are better able to gauge their ability to teach science because they have a better understanding of the context of the classroom (Hechter, 2011). However, even experienced teachers tend to overestimate how much inquiry-based teaching they are using (Lakin and Wallace, 2015). Teaching science well takes teachers who can allow students to figure things out rather than just telling them the answer, teachers who can question to help guide students to ideas, teachers who can implement science demonstrations, experiences (i.e., times when children are figuring out the answer, but the adult already knows what is going to happen), and genuine experiments that allow students to make connections and interpret, teachers who can support and provide appropriate scaffolding for inductive and deductive reasoning, among other things. In other words, effectively teaching science means that teachers need to shift their classroom from direct instruction to being a constructor of student experiences that the teacher orchestrates and supports.

1.2 Purpose of the Research

The researcher sought to examine her own instructional practices as a science methods instructor, specifically teacher candidates' mastery of 5E. The researcher questioned which teaching strategies were most likely to produce comprehension and adoption of 5E by teacher candidates. Additionally, she wondered which learning interventions related to 5E were most impactful for teacher candidates. These questions provided the framework for the research.

While 5E can be used in any content area, it is frequently used in science. To keep things simple, as this was the initial implementation of the research, the measures and the main teaching interventions were framed in terms of science teaching in elementary schools.

2. Method

2.1 Definitions

For the purpose of this research and clarity of the discussion about the research, these terms will be used:

- Instructor- the researcher who was teaching the college-level senior methods course.
- Teacher Candidate- the college students who are earning a college degree and certification in elementary education or in elementary education and special education. These are the participants of the research study.
- Student- children of elementary age, or teacher candidates pretending to be children of elementary age.
- Intervention- the methods and strategies used to teach the teacher candidates about 5E.

2.2 Setting

The researcher was granted approval from the Institutional Review Board at the University to conduct research with a convenience sample of students in her senior-level science and social studies methods course. The course is part of a university-based teacher preparation program leading to a bachelor's degree and certification in elementary education for grades 1-5.

Teacher candidates come to the senior methods course with a firm understanding of the gradual release model of teaching and show some level of fluency in being able to plan and implement graduate release lessons. The teacher candidates have had a basic lesson plan writing course and a junior-level methods course that emphasize direct instruction with gradual release as the lesson model. The teacher candidates tend to use the informal "I do, we do, you do" to describe the parts of the lesson. Many candidates come to the senior-level course using the term whole group instruction to mean direct instruction. At this particular university, the course discussed in this paper is usually the first introduction to the 5E Lesson.

2.3 Demographics

The semester research data was collected during a time of program transition for the teacher preparation program at her university. The instructor's section of the course was used as a pilot for a two-semester residency program. Students in her section voluntarily agreed to complete the first student teaching residency semester in which they were in student teaching placements for the entire semester (i.e., they completed more than 200 hours with a mentor teacher). Their peers who did not volunteer continued with the traditional methods courses that included only about 40 hours of teaching in classrooms, with those hours being divided between two to three student teachers who were grouped into the same hosting teacher's classroom. This means that the participants in the research were working towards a variety of certification that included elementary education majors and special education elementary majors, but also included a few early childhood majors working in lower elementary classrooms. The participant teacher candidates were placed individually in classrooms in two local school districts. The placements varied and, due to local district practices, some were in self-contained classrooms, but many were in classrooms where students switched between teachers for different content. The participants were expected to be in their placement classrooms Monday, Wednesday, and Friday for at least half of the day and then on campus for class on Tuesday and Thursday of each week. To be able to teach their required science lessons for the course, many participants had to step into another classroom or to stay in the afternoon in their mentor teachers' classrooms. There were thirteen students enrolled at the beginning of the semester, but one student withdrew during the semester. Her pretest results were removed from the data set.

Of the twelve students who finished the pilot residency semester, all gave consent to use their data in the research. The volunteers for the pilot residency program consisted of three students earning early childhood certification, seven students completing elementary certification, and two students completing dual certification in elementary and special education. All participants were female. All participants who completed a posttest were under the age of 30.

2.4 Data Sources

The first hurdle in conducting the research was in how to measure the participants' comprehension of 5E. In previous semesters, to measure teacher candidate's ability to recognize the phases of 5E, the researcher gave a midterm exam that included two classroom scenarios. These scenarios give narratives of two classroom lessons that explain what teachers did to teach the water cycle. One scenario is a direct teaching lesson with gradual release and the other is a 5E lesson. The instructions to the students were to break the scenarios into sections that correspond to parts of a lesson, label those parts, and then explain why that label was used. It was decided to use this exam question to measure participant's knowledge of 5E. The teaching scenarios assessment was given at the beginning of the semester as a pre-test.

For a post-test at the end of the semester, participants were again given two classroom scenarios about teaching science. Both scenarios related to teaching the same science concept, but instead of being about the water cycle, they were about teaching food webs. Again, one scenario was a gradual release lesson, and one was a 5E lesson. The instructions for the post-assessment were the same as those for the pretest.

Additionally, participants were asked to list what classroom activities during the semester were most impactful. The question was not specifically tied to the concept of the 5E but was a general question.

2.5 Interventions

Several different interventions were used to teach about 5E. The instructor attempted to scaffold comprehension by beginning with the gradual release lesson model with which teacher candidates typically were already familiar with due to that being the focus of a lesson planning class taken in a prior semester.

The instructor modeled teaching elementary science lessons. Participants had to imagine they were elementary students. The instructor acted as the teacher and taught about using a balance scale with a traditional direct instruction lesson. After that lesson the instructor displayed a state science standard that related to the lesson, and participants helped write a brief lesson plan for the lesson they had just experienced.

Next, the instructor asked the participants to again imagine that they were elementary students, but this time they were learning about pendulums. The topic of pendulums was picked not because it is an elementary school science topic, but specifically because teacher candidates usually do not know what part of a pendulum determines the frequency. The instructor wanted a science concept in which the participants could participate in the lesson to have a similar experience to PreK-12 science students. That is, they genuinely have to explore and explain what they have learned rather than to pretend they do not know something they already know.

The instructor modeled a 5E lesson by showing a brief video clip to engage (Engage). Then drawing a diagram of a pendulum and having the participants identify the parts (e.g., amplitude, weight/bob, etc.) and she modeled how to make a pendulum and measure the frequency of the swing. The participants, in groups, were given a sheet for recording data and materials to make pendulums. The instructor, and the data sheet reminded participants about the importance of only varying one characteristic of the pendulum at a time while keeping others constant. Then the groups worked to figure out that the length of the pendulum is the only characteristic that will change the frequency. Each group worked until they discovered this (Explore). When the groups all discovered how pendulums work, the instructor conducted a class discussion about their findings, and she confirmed their understanding (Explanation). Lastly, the instructor introduced the idea that the development of a pendulum clock was important in history, because it led to the innovation in clocks that gears could be used and that was the birth of modern navigation (Expansion). During the lesson the instructor walked around listening to group conversations and questioning individual students (Evaluation). At the end of the lesson, the instructor introduced each part of 5E, and the teacher candidates identified the learning tasks to write the 5E lesson plan for the lesson they had just experienced.

As an intervention, the instructor also used the analogy that the lesson plan is like a house blueprint,

and that the rooms in the house are like the parts of the lesson plan. She extended the analogy by explaining that different blueprints are needed for different house styles. Different styles of housing, such as a ranch or Craftsman home, will have the same or similar rooms, but they will look different or be in a different order on the blueprint. Similarly, a gradual release lesson and a 5E lesson will have similar parts, with a section that grabs students' attention and activates prior knowledge, a section that provides students with immediate feedback about their understanding, a section that provides closure to the lesson, etc. but those sections happen in a different order depending on what lesson format is used. The instructor also stressed the major differences between the gradual release lesson and a 5E lesson. That is, in a gradual release lesson it is teacher-directed, but can still have hands-on portions where students explore content after they have been explicitly introduced to the concept. However, in a 5E lesson, it is more student-centered, and students are allowed to explore concepts and then receive clarification from the teacher about their understanding. The instructor guided the participants to recognize 5E as not only inquiry-based teaching, but as a constructivist strategy (Mukagihana et al., 2022; Rodriquez et al., 2019).

Additional interventions included readings and discussions. The textbook included a section with information about 5E. The instructor continually emphasized throughout the semester the difference between learning about science and learning to be scientists.

The instructor had control over the interventions that took place within the on-campus course hours. While there were readings required, the instructor cannot guarantee that participants actually read assigned textbook readings in their entirety. Participants were encouraged to use the 5E lesson plan but were not required to implement it in their clinical practice classrooms.

3. Result

On the pre-test, participants scored on average 31% on the lesson plan scenarios. Several teacher candidates did not answer specific lesson parts on their scenarios, but instead wrote comments in the margin such as "I think this might be an inquiry lesson" or "Inquiry??" It could be predicted that participants should have had baseline mastery of at least 50% on the pre-test considering they already had high familiarity with direct teaching lessons. However, many teacher candidates mislabeled sections of the scenarios using student grouping patterns instead of teaching practices. A common mislabel was the term *whole group* rather than *direct instruction*. This was consistent with answers the instructor had seen during previous semesters.

The post-test scores were only slightly better, with the average being 33%. The participants tended to label all of the lesson parts using gradual release lesson labels and still sometimes labeled teaching strategies using grouping strategy terms. While the instructor has not formally tried to research use of the classroom scenarios in prior semesters, she has used the pre-test classroom scenarios as part of a midterm exam in many previous semesters. Typically, the midterm exams show that most teacher candidates can recognize the different lesson plan formats. In a class of twenty students, there will typically be two who do not recognize the 5E lessons, and all others will label them correctly. However, there were some major differences in how the exam was measured between the traditional semesters and the research semester that most likely impacted the results. In a traditional semester, the time between the 5E model lesson and the mid-term exam is only a few weeks. In the research semester, the model lesson occurred at relatively the same time as it did in the traditional semester, but the post-assessment occurred about ten weeks after the model lesson. The instructor during the traditional semester allowed teacher candidates to use their textbooks as a resource during the exam and the teacher candidates complete the exam at home over a period of days so that they have time to think about their answers. None of this occurred during the research semester due to time constraints related to it also being a pilot semester for the two-semester residency. During the pilot semester, participants completed the post-assessment on the last day of class on campus. There were several questionnaires and other paperwork also being completed at the same time. None of the participants had their textbook because they had all returned them to the on-campus textbook rental office, and they were all exhausted due to the demands of the semester. All of these factors most likely impacted the results of the post-assessment.

Several participants, when discussing what on-campus instruction was the most impactful to them,

mentioned the modeled science lessons with the gradual release lesson and the 5E lesson. Verbally, several of the teacher candidates mentioned that they wanted to teach using more inquiry-based teaching methods, but they believed they did not have time during the school day. They commented that their mentor teachers in their clinical practice classrooms spent minimal time on science because there was so much emphasis placed on English Language Arts and Math, and that science was primarily taught at the end of the day, and only if there was time. This fits as the extent that inquiry teaching is used is related to the instructional time available to teach science (Kolbe et al., 2020; Rodriguez et al., 20109; Sengul, 2021). Additionally, the availability of science resources, a science curriculum that uses inquiry strategies, and the training of the mentor teacher in using inquiry-based teaching methods influences what teacher candidates experience in their assigned classroom (Sullivan-Watts et al., 2013), so it is likely that a lack of quality science instruction across all candidates impacted their mastery of 5E.

4. Discussion

The results lead to the main conclusion that further research needs to be done, and the research process needs to be refined and updated. The sample in this research was small. The research needs to be done with more teacher candidates. Additionally, it takes time for any sort of student, including teacher candidates, to fully comprehend a new concept and then adopt it as their own to the point of fluency with the concept. This holds true with 5E. The teacher candidates may be able to recognize 5E but might not be fluent enough with it after one semester, or really less than one semester, of exposure to be able to reproduce it on their own. They may still need the support of their textbook to help clarify for themselves that they are labeling the sections of the 5E lesson correctly. Strong comprehension of inquiry teaching is required for teachers to be able to recognize it (Lakin and Wallace, 2015).

It was also likely that during that pilot semester the 5E model was not reinforced during clinical practice. Many, if not all, of the teacher candidates were unable to practice 5E in their placement classrooms if their classroom mentor teacher did not use the model. Teacher candidates may want to experiment with different teaching strategies in the classroom, but they usually end up teaching in similar ways to their mentor teacher (Sullivan-Watts et al., 2013; Tannebaum, 2016).

Additionally, data collection methods need to be streamlined. While it is fairly easy to score assessments for a sample size of 12, there are better ways to efficiently collect data from a larger sample and there is other data that needs to be collected. It is fairly common for research on preservice teachers in teaching science to include efficacy as a measurement, due to the fact that their confidence in their understanding of science and ability to teach it informs teacher candidates' pedagogical decision-making process (Hudson, et al., 2012). Efficacy was not measured in this study but should be added in future semesters. Furthermore, it is one thing to recognize the 5E, but it is a more complex task to plan and implement a 5E lesson. Another factor worth measuring would be whether the teacher candidates believe they are using inquiry. It is likely similar to findings with experienced teachers, that teacher candidates believe they are using inquiry when in fact they are not (Lakin and Wallace, 2015).

Due to the fact that there was little opportunity for teacher candidates to consistently participate in 5E lessons with their mentor teachers, the instructor came to several conclusions about planned intervention strategies to help teacher candidates master 5E. First, the instructor realized that a majority, if not all, of the interventions to teach it need to happen within the context of the on-campus college course instruction. At the time, she could not consistently rely on mentor teachers to model actual classrooms use of inquiry teaching. However, recent shifts in statewide use of high-quality instructional materials mean that more districts are investing in science curriculum that uses inquiry teaching strategies. This means that more classroom teachers are likely either teaching science using inquiry methods, or at least teaching science with an approach that is inquiry-like (i.e., they have the inquiry lesson plan but implement it more like a direct instruction lesson). This is promising for whether teacher candidates are likely to encounter inquiry teaching in science lessons, but there are still barriers.

Locally, many schools use "swap" teachers so that even in elementary school students move between teachers for each subject and each teacher has one, or maybe two content area preparations for lesson planning. For teacher candidates who are residents, this could mean that they are placed with a teacher who does not teach science at all. Additionally, some of the districts local to the university do not teach

science or social studies until third grade. Therefore, teacher candidates in residency may teach science a lot, or may not experience teaching science at all.

In the most recent semesters of teaching the course, it is no longer tied to residency semesters. Instead, it is a junior methods course that is taught the semester prior to the two-semester teaching residency. For school experience, the teacher candidates are placed in their requested district (i.e., usually they request the district in which they reside) and then complete their hours on their own around their scheduled college coursework. Some are able to observe and participate in science teaching, but their science teaching experiences still vary depending on the individual school and hosting classroom teacher.

5. Conclusion

The instructor has kept a number of the same interventions used in this research in more recent semesters. The model 5E lesson with the pendulums was cited by teacher candidates as being impactful of their learning, so it was kept. There is the expectation that courses have textbooks and use them, so the instructor has a "time-with-the-text" that is done in class. The teacher candidates skim the text chapters and there is class discussion. This allows the instructor to highlight, discuss, add-to, question, etc. about topics in the text. It generally takes the first few minutes of class and serves as a launching point for the lesson for the day. Currently the instructor has a portion of the lesson topics for the semester calendar as the phases of the 5-E Learning Cycle. The instructor also spends a portion of the semester building the case for children's need for discussion and to work in groups to support their learning.

The instructor has continued to look for examples of 5E lesson videos. There is a video that was used in the semester following the research semester that labels the sections of 5E, and another video was found that has an overview of 5E Learning. The instructor currently has teacher candidates watch these two overviews and then contrast them to a couple of videos showing direct instruction. Teacher candidates are asked to look for differences such as student-role versus teacher-role.

Based on the result of this research, the instructor decided to require teacher candidates to actually write a 5E lesson and complete microteaching of peers in the college classroom (Sengul, 2021) that can function like a simulation of the learning environment found in a science classroom (Mukagihana et al., 2022). The hope is that in their clinical practice placements the teacher candidates gain an understanding of how to manage and motivate children, as well as an understanding of what children are capable of at different developmental levels. The responsibility for teacher candidates being able to plan and implement content-specific teaching practices, such as 5E, is shifted to the college campus and is controlled by the instructor.

These findings are all based on a small participant sample of teacher. Additionally, based on the findings, the instructor has shifted several interventions since the data was collected. Many districts have adopted curriculum that teachers are required to use. The curriculum has pre-written lesson plans and the teacher candidates in the program are now taught both to write their own lessons plans, but also how to annotate existing lesson plans to use with specific groups of students. Updated research is needed to compare which new interventions are most effective and should be kept or discarded, as well as to address the differences between asking a teacher candidate to write their own 5E lesson versus annotating and implementing a lesson from a curriculum that utilizes 5E.

Lastly, it would be beneficial to determine teacher candidates' adoption of 5E at the end of the junior level science methods course and then again at the end of the program (i.e., after they have completed the two-semester residency). It is suspected that whether teacher candidates are placed in a classroom that teachers science will have an impact on their mastery of 5E teaching.

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