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Pre-Service Teachers' Perceptions of Literacy in STEM Classroom Instruction by Implementation of Project- Based Lessons

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ABSTRACT

This study examines how project-based learning (PBL) supports pre-service STEM teachers (PSTs) in understanding and applying disciplinary literacy in classroom instruction. Conducted in a semester-long PBL course at a mid-sized public university, the research explores PSTs' shifting perceptions of literacy in STEM and the challenges and successes they experience. Using qualitative methods grounded in student voice and case study frameworks, data were collected through focus groups, reflections, and lesson plan analyses. Findings show PSTs initially held narrow views of literacy but developed more nuanced understandings through PBL. Key successes included increased confidence and use of inquiry-based strategies; challenges involved time constraints and students' unfamiliarity with active learning. The study highlights PBL's value in fostering authentic, inquiry-driven STEM instruction.

Keywords: Inquiry, Literacy, Pre-Service Teachers, Problem-Based Learning, STEM

INTRODUCTION

Evolving United States (U.S.) state and national learning standards have prompted close consideration of how to appropriately prepare future secondary teachers for modern science, technology, engineering, and mathematics (STEM) classrooms that support all learners. The most recent standards in STEM have placed increased focus on engaging students in the literacy practices of experts in the field, highlighting inquiry, discovery, and experimentation activities that utilize advanced reading, writing, and communication skills. As such, STEM teacher preparation programs must strike a balance of content and pedagogy coursework that promotes training pre-service teachers' (PSTs') to actively engage students in disciplinary practices. One way to accomplish this balance is to integrate what some researchers term disciplinary literacy (see Moje, 2008; Shanahan & Shanahan, 2008; 2012) into teacher education coursework, which places a targeted focus on studying, communicating, and providing interpretations in the disciplines similar to the way experts engage in disciplinary study.

It is important to emphasize the significance of integrated disciplinary literacy in PST preparations. PSTs in STEM areas are encouraged to engage students in authentic, inquiry-based STEM activities, particularly activities centered in PBL environments. (Lee & Lee, 2025). Indeed, disciplinary literacy considers that for students to be literate in a secondary content area, they must be able to engage in similar practices as disciplinarians, such as those used by scientists, mathematicians, and engineers. In integrating this type of instruction into PST coursework, PSTs learn to consider what authentic disciplinary practices experts in STEM utilize in the field and how those practices might be integrated into their future teaching.

One identified challenge to this type of instruction is that PSTs often view disciplinary literacy as an add-on to instruction or as methods that run counter to the type of instruction they remember from their experiences as high school students (Siebert & Draper, 2008). Preparing STEM PSTs in disciplinary literacy-focused instruction encompasses more than providing them with tools to develop discipline-rich lesson plans, assign homework, and grade quizzes or tests in their future classrooms. While these tasks are important, it is critical to engage these teachers in disciplinary literacy coursework activities that model robust teaching methods to support writing and communication particular to STEM instruction (Moje, 2008; Shanahan & Shanahan, 2008; 2012). Literature suggests multiple benefits of STEM teacher education disciplines (e.g., mathematics, science, technology & engineering) in supporting disciplinary literacy instruction so

preservice teachers learn to teach future students to actively study, write, and communicate disciplinary information and knowledge, instead of simply memorizing information and facts for rote memorization tests (Draper & Siebert, 2010; Moje, 2008).

One of many challenges teacher preparation programs face is convincing STEM preservice teachers that literacy in their subject area is more than traditional reading and writing skills. It is not uncommon to hear preservice teachers profess that reading and writing (or literacy) is the English teacher's domain and should not be a part of what science (or technology & engineering or mathematics) teachers are expected to teach (Hurst & Pearman, 2013; Moje, 2008; Pearson, Moje, & Greenleaf, 2010). However, each content area of STEM has specific ways and means of knowing and communicating understanding. It is important to consider the specific literacy practices necessary for full engagement in a given discipline, not only to apprentice novices but also to enable students to more deeply understand the discipline itself, thus inviting them to engage in the disciplinary discourse and culture (Moje, 2008). Researchers believe this dialogue is important for all professionals, including teachers and the students they teach. Disciplinary literacy continues to impact how preservice teachers make instructional decisions, particularly as they incorporate new tools and design practices into their STEM teaching practices (Kang, Shi, & Zhu, 2025).

Thus, it is critical for STEM programs to engage in activities that help PSTs (a) understand and communicate what it means to be literate in the STEM disciplines, and (b) transfer such knowledge into practice. In this study, the authors considered that a project-based learning (PBL) course for STEM preservice teachers was an ideal place to address these points. Thus, literacy became a focal point of a PBL course for pre-service STEM educators at a mid-size public university to address STEM literacy and the role it plays in middle and high school STEM classrooms. The following two research questions focal to this study included:

RQ1: What are preservice STEM teachers' understandings of disciplinary literacy, and do they change over the course of a semester?

RQ2: What successes and challenges exist in trying to integrate literacy into STEM classroom instruction?

Using the PBL course to address these questions was a natural fit as PBL allows opportunities for students to engage in creative thinking, which is different than traditional classroom instruction. In the section that follows, we provide background literature related to both literacy and PBL to showcase for readers how to support future teachers' understanding of and incorporation of literacy into their regular teaching.

LITERATURE REVIEW

This study originated as a result of an Improving Disciplinary Literacy movement across the host campus community. A collaboration between literacy faculty and STEM education faculty brought about the need for greater attention to literacy in classrooms in ways that were meaningful to the discipline of study. Other research has demonstrated the challenge of getting mathematics teachers vested in searching for ways to implement and promote literacy in classroom instruction (Enderson & Colwell, 2021; Colwell & Enderson, 2016). This campus movement provided an opportunity to continue working in this area and expand from reaching just mathematics preservice teachers to also including science, technology, and engineering preservice teachers. Current research also emphasizes the importance of discussion and collaboration in strengthening PSTs' interdisciplinary STEM teaching skills (Tu et al., 2025).

Draper and Siebert (2010) have a strong history of working together as literacy and content experts, where they define a reimagined approach to literacy: Literacy is the ability to negotiate (e.g., read, view, listen, taste, smell, critique) and create (e.g., write, produce, sing, act, speak) texts in discipline-appropriate ways or in ways that other members of a discipline (e.g., mathematicians, historians, artists) would recognize as “correct” or “viable” (p. 30).

This perspective has promoted a disciplinary writing movement for various fields of study, and in this study. We believed that this perspective would provide fertile ground to work with PSTs in their own understanding of literacy and how they could promote discipline-specific texts in carrying out classroom instruction. Thus, a specific focus on disciplinary literacy was integrated into a required project-based course all STEM PSTs took.

Project-based learning (PBL) is a type of instructional learning style where students study real-world problems that have multiple ways of being solved and allow for student decision-making and creativity (Lee & Lee, 2025). The PBL instructional model is grounded in constructivist theories of teaching and learning and emphasizes the construction of knowledge through experiences (Lazaro, 2021). Problem-Based Learning, the type of learning that occurs through PBL or PBL lessons, has been defined as “an inquiry process that resolves questions, curiosities, doubts, and uncertainties about complex phenomena in life” (Barell, 2006, p. 3). Within a PBL instructional experience, students are challenged with taking control of their learning as they work through sequences of planned experiences that guide their knowledge acquisition and understanding growth (Spires et al., 2022). Because PBL motivates students to ask questions and seek understanding, PBL helps to give students 21st-century skills necessary for success in their future careers. PBL-based STEM coursework can enhance preservice teachers'

collaborative problem solving and interdisciplinary thinking while also promoting the integration of STEM literacy practices into their instructional strategies (Fitriani et al., 2025). PBL lessons also provide students with new ways to connect to professional and community members while seeing real-world content applicability (Larmer, et al., 2015), which aligns with tenants of disciplinary literacy (Moje, 2008). Larmer et al. (2015) describe a seven-component “gold standard” for project-based instruction and learning, which includes:

1. a challenging problem or question
2. sustained inquiry
3. authenticity
4. student voice and choice
5. reflection
6. critiques and revision
7. a public presentation

The PBL course that was used for this study was designed as a Project-based learning experience for the PSTs. Prior to this PBL course experience, PSTs had little to no experience with project-based learning experiences. With lecture being a popular instructional style (Lambert, 2012), PSTs were accustomed to having knowledge directly stated to them rather than being given learning experiences through which they would self-construct knowledge and gain understanding. Throughout their PBL course experience, PSTs explored the components of a project-based lesson while working through creating their own PBL lesson. Focal points of the PBL course experience included strategies such as creating a strong driving question, focusing on the integration of the topic with a real-world task or problem, and allowing freedom for student creativity and student voice and choice within the parameters of the assigned task.

PSTs spent 10 weeks learning about PBL-style lessons through critiquing instructional videos, engaging in class discussions, exploring real-world connections, and reflecting on instructional delivery strategies. During this time, PSTs also worked on creating their own PBL instructional unit, gaining an understanding of content literacy, exploring inquiry-style teaching strategies, and practicing student engagement strategies. The PSTs began their PBL planning by first unpacking the unit topic standard, then creating learning experiences that aligned with the standard, preparing guided research opportunities for students, and creating a driving question to propel students through a knowledge acquisition journey culminating in content understanding relative to devising a way to solve the posed real-world task or problem. Similar shifts in PST beliefs and competencies have been documented in recent research on integrated STEM education, where structured interventions led to more detailed understandings of STEM literacy and practice (Fitzpatrick & Leavy, 2025).

RESEARCH METHOD

Framework of Study

This STEM literacy study was framed around student voice, which is defined as “hearing what students say and using what they say to make improvements” (Campbell, 2007, p.4). The goal of this study was to make improvements in instruction based on student voice. Student voice work is known to involve meta-cognitive activities such as:

- asking questions about student experiences;
- seeing and understanding the student perspective;
- reflecting on implications for practice;
- hearing or listening to previously inaudible or ignored voices (Seale, 2010).

Such actions provide insight into the nature of students’ learning experiences and provide teachers with valuable sources of information to improve the delivery of course content.

Researchers utilized STEM PSTs’ student voices to explore their perceptions relative to their understanding of disciplinary literacy and their inclusion of disciplinary literacy techniques into PBL lesson implementation experiences. The PST participants shared their experiences and how their experiences help them to form a better understanding of STEM literacy. The use of student voice for this study enabled the PBL course instructor and researchers to have reflective insights from PSTs detailing their thoughts, learning, and experiences.

While student voice was used as a framework for this study, the methods employed throughout the research were qualitative and focused on case study research. Yin (2014) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon (the ‘case’) within its real-life context, especially when the boundaries between phenomenon and context may not be clearly evident” (p. 16). This case study is focused on and bounded by STEM PSTs in a semester-long course who were trying to make sense of literacy with respect to their discipline and how to incorporate literacy into a project-based lesson.

Setting and Participants

This case study (Yin, 2014) focused on PSTs’ perspectives of developing their understandings of and integrating STEM literacy into classroom lessons/instructional units. This study was carried out as a component of a PBL course for STEM PSTs and was the fourth field-based course in their university program of study. One of the researchers was the instructor of this course, while

the second researcher carried out various elements of data collection and analysis. The third researcher supported considerations of disciplinary literacy in STEM-focused PBL. PSTs learned about and experienced the PBL instructional format as they developed and organized a series of lessons around a big idea for middle or high school STEM students. Once their PBL instructional unit was developed, PSTs taught their lesson to middle or high school students over a three-day instructional sequence with support from their university instructor and a practicing classroom teacher. PSTs were grouped in the same field (or closely related field) for the teaching of the lessons with at least one to two partners, where they could support each other in the field teaching experience. Each group was then paired with a practicing teacher to serve as an in-the-field mentor and in whose students the PST would facilitate their lesson. PSTs in the course were given the option to participate in this study or opt out, but all were required to engage in on-campus class discussions as well as complete the multi-day PBL classroom teaching at their assigned school and classroom.

This study consisted of 14 PST participants which included 6 biology, 1 physics, 5 mathematics, and 2 technology and engineering education majors. All study participants were in a teacher preparation program where they would receive a degree in the sciences with a minor in education focused on their specific discipline. Typically, students in this course are near the end of their program of study and are at the junior or senior level status and have had multiple prior teaching experiences in middle and high school science, technology education, and mathematics classrooms.

Data and Data Analysis

Data consisted of small focus group interviews (recorded) where participants shared their perspectives on assignments and lesson plans that incorporated literacy components into instruction. Participants were permitted to share some of their work or lesson plans to support or elaborate on their comments in the interview process. The small focus group discussions were followed by a whole class discussion (recorded) of the successes and challenges faced by STEM PSTs. Since this was designed as a whole class endeavor, students who opted out of the research study were asked to record any information they wanted to share with the class on a note card. These students then gave the notecard to the instructors/researchers who shared the noted point(s) and made references within the discussion so as not to link the comments to a specific student participant. Themes or categories for these successes and challenges were later identified and checked among researchers for validation.

In addition to the interviews, early course discussion board posts related to literacy and its meanings were also used as data points. PSTs were assigned readings on literacy and how material might apply to one's area of science,

technology, engineering, or mathematics. Toward the end of the course, all PSTs were required to complete an individual reflection paper that was collected to triangulate data in identifying successes and challenges in integrating literacy into science, technology, engineering, and mathematics classroom instruction. In all cases, student voice was important in identifying PSTs' perceptions of disciplinary literacy and its roll in PBL STEM instruction.

It should also be noted that while study participants taught and reflected on their experiences incorporating disciplinary literacy into the teaching of their PBL unit to secondary school students, they were not solicited to provide data for this study. Study participants could explain interactions with students, but no middle or high school student work or opinions were part of the data collection or analysis.

RESULTS

Results and Findings of Research Questions

The findings of this study are presented by answering the two driving research questions. After reporting on the research questions, overall findings of the study will be conveyed.

RQ1: What are preservice STEM teachers' understandings of disciplinary literacy, and do they change over the course of a semester?

In one of the initial class sessions, PSTs were to think about and share what they thought disciplinary literacy means. To no surprise, PSTs connected the literacy and content pieces verbatim and described the physical act of reading content in a discipline. Some PSTs went past just reading to also include comprehension and interpretation, and connected the reading to scientific journals or research. One participant even suggested that disciplinary literacy is "equivalent to knowing the many laws, or formulas, or vocabulary of many of the sciences." While this description did speak to the foundations of disciplinary literacy, it was lacking in description of being able to interpret, understand and put into practice these aspects of disciplinary literacy. Some considerations that were missed by PST responses included:

- Are students understanding variable assignments?
- Can students decipher data from a graph or extract meaning from experimental outcomes?
- Can students interpret the scientific texts in a meaningful and age-appropriate way?

Such questions form the basis of this investigation in looking at ways PSTs' understanding of disciplinary literacy might develop over time with education and

exposure. The desire to enhance PSTs' disciplinary literacy understanding was to impact their own students' understandings, where they become fluid in interpreting, making meaning, and sharing information through a variety of mediums.

Following the "meaning-making" discussion of disciplinary literacy, PSTs were assigned a chapter to read from the book, *(Re)Imagining Content-Area Literacy Instruction* (Draper, 2010), focusing on their content area of mathematics, technology education, or science. The chapters provided PSTs with interpretations of literacy specific to their content area and how such definitions might impact their thinking of literacy. One PST, Sandra, addressed the dramatic shift in her understanding of disciplinary literacy by stating:

"Prior to the readings, I viewed [science] content literacy as being about to interpret text. More specifically, being able to read and interpret a scientific journal or research. After the reading, my definition of scientific literacy changed. The heart of scientific literacy, as the chapter mentioned, is allowing people to understand and critically evaluate scientific arguments by educating them in science. This did not seem too far off from how I viewed scientific literacy. However, to see the application throughout the chapter, expanded upon my concept of text and what scientific literacy looks like in the classroom."

Tony, another PST, commented:

"Honestly, this chapter [math] threw me for a loop. I thought it would be about deriving formulas and knowing why things work the way they do. Instead, it focused on critical thinking and problem-solving for students and how teachers can push that agenda."

PSTs began to think about literacy in a more "active" way and to think about how such action might impact their teaching and student learning. Terry, a science PST, stated:

"Students must also learn the skills needed to interpret the other 'languages' of science such as equations, graphs, texts, models."

Along a comparable manner, Jonelle, a mathematics PST, shared that "real-world connections can open students' eyes and help them see the different ways you can solve or set up an equation."

Responses like Terry and Jonelle's provide evidence of PSTs' exposure to ways of interpreting disciplinary literacy and the impact it can potentially have on their STEM instruction. PSTs were starting to think beyond teaching as a set of memorized procedures and rules, often a focus in the sciences, to looking more deeply at the "how's" and the "why's" of what they are doing whether in formulas, laws, or use of technological tools. As PSTs' views of literacy expanded, their

understanding of concepts was enhanced, which would allow them to think about instruction in a more flexible manner. As Tonya shared:

“When presented with the simple quadratic equation, I am no longer being asked to find three points and then graph. I am being asked WHY does this equation work the way it does and HOW are the formulas for finding the vertex and roots derived? A concept that I felt I had “mastered” has become more fluid and meaningful as I become fluent with all of its different aspects.”

This new awakening of literacy was valuable for Tonya, and it promoted instruction that was more conceptually-based to aid students in developing deeper mathematics content understandings.

RQ2: What successes and challenges exist in trying to integrate literacy into STEM classroom instruction?

In the process of preparing lessons for the PBL course and classroom instruction, PSTs had a check-in assignment where they were asked to identify the literacy components of their multi-day series of lesson plans. Lesson plans were checked and approved by the instructor of the PBL course as well as the classroom mentor teacher they were assigned to for this teaching experience. All parties agreed on the series of lessons and how they would be executed prior to the actual teaching of the lessons. Once lessons were taught and feedback provided, researchers wanted to solicit successes and challenges of this PBL literacy focus.

In small focus groups with a follow-up as a whole class interview, successes and challenges were identified and discussed. The small groups provided a safe space for all to talk openly, and the entire classroom discussion allowed perspectives to be shared as a group rather than as an individual.

Identifying success as they relate to the incorporation of STEM literacy took on various responses from participants, but one item rose to the top – use of inquiry-based instructional techniques. This key point was mentioned by many of the PSTs in sharing the importance of active student learning, helping students make connections, studying real-life problems, and really engaging students in the lesson at hand. One PST commented, “I believe utilizing the 5E learning plan and emphasizing inquiry-based learning within your classroom is an excellent way to incorporate literacy into instruction”, and another said, “thoughtful and inquiry-based lesson planning as well as flexibility in presentation and facilitation are key to successful teaching, which will promote and achieve content literate students”. This was a real success for PSTs in having students involved in their own learning. Other categories that were identified as successful included student excitement, teacher support, confidence, and feelings of fulfillment.

As with any successes, there are also challenges. In the whole class interviews, it was shared how valuable the inquiry-based instructional model was but at the

same time, it often was not aligned well with what students were accustomed to. Paul pointed out that “students are so used to being told what to do that they don’t know how to think or act in a PBL lesson steeped with literacy.” This was a real challenge for some PSTs in their lessons, but others indicated that students jumped on board with this “hands-on” style of learning and their excitement overtook the challenge of not knowing how to totally explore concepts. One group described:

“The inquiry-based and PBL lesson plan styles kinda forced content literacy to occur because it put a lot of the learning on the students themselves. You’re [the teacher] not just the giver of knowledge – as the giver of knowledge – like multiple choice – doesn’t mean they [students] are literate.”

This group engaged the class in further discussion about how some students showed excitement over the learning in ways that they had not observed prior to their implementation of the PBL lessons.

Another area of challenge was noted when PSTs recognized why teachers do not always use an inquiry-based type of instruction. As a result of this PBL teaching experience, they determined that the amount of time to carry out this type of instruction is very extensive, and teachers often struggle to cover required standards in allotted instructional time. A second group specifically addressed the importance of carrying out activities that engage students in addressing critical concepts of study and how it can “stick with them” as they advance their studies and understandings of important standards-based concepts. They noted how developing “fun” investigations benefit students over time in ways that traditional instruction does not. The group spokesperson shared:

“One thing we talked about is how much classes build on each other – um, even Algebra 1 [to] Algebra 2, Calc 1 and 2 – start with PreCalc. But even in the sciences – the things you learn in middle school like scientific method or cell, um, function and structure stay with you throughout your higher secondary education and career. So – if you can do an activity that invokes content literacy as fun for students – something they remember um as early as 6, 7 grade – that’s something they will remember throughout high school that they will need.”

This second group professed that the time teachers spend working on activities or problem-based scenarios benefit student learning and should be incorporated on a regular basis.

Confirming Student Voices

Based on small focus groups and whole class interviews, two major categories emerged from the research questions. As the class joined together, these classifications were checked and participants verified to determine if they felt they

provided an accurate interpretation and representation of their voices. The two categories focused on inquiry-based teaching and confidence. While each one of the categories was discussed separately, they both connect in ways that allow teachers to carry out instruction. PSTs discussed that to think of disciplinary literacy as a part of instruction, they must be well versed in inquiry-based teaching or the 5E model (Bybee et.al., 2006). PSTs in this study shared that their experiences in field-based courses, prepared them well to design and implement lessons framed around the 5E model of instruction. For additional details related to the 5E model, refer to Table 1.

Table 1
Summary of the BSCS 5E Instructional Model

Phase	Summary
Engagement	The teacher or a curriculum task accesses learners' prior knowledge and helps them become engaged in a new concept through short activities that promote curiosity and elicit prior knowledge. Activities should connect past and present learning experiences, expose prior conceptions, and organize students' thinking toward the intended learning outcomes.
Exploration	Students participate in activities that provide a common base of experiences through which concepts, processes, and skills are identified and conceptual change is facilitated. Learners may complete laboratory activities that use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct preliminary investigations.
Explanation	Students focus on specific aspects of their engagement and exploration experiences and demonstrate conceptual understanding, process skills, or behaviors. Teachers may directly introduce concepts, processes, or skills, and learners explain their understanding while receiving guidance toward deeper conceptual understanding.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills through new experiences. Students develop deeper and broader understanding, acquire additional information, strengthen skills, and apply their understanding by conducting additional activities.
Evaluation	Students assess their understanding and abilities, and teachers evaluate student progress toward achieving the educational objectives.

To be well versed requires knowledge of applications and real-life problems as well as searching for ways to translate information to students in ways that support disciplinary literacy. The second category was identified as confidence. This referred to confidence of the teacher to be knowledgeable in disciplinary literacy related to their field as well as confidence in students to be open to this type of learning, which is often not familiar to them.

The findings of the two given research questions allowed researchers to inquire how PSTs thought about making literacy a key component of future classroom instruction. In this discussion, PSTs realized they had numerous experiences in their teacher preparation program to think about ways to incorporate literacy. Ernie, a mathematics PST, shared his thoughts about the matter:

“Now being very well aware of what content literacy is – once I’ve made those lessons – saying – oh great it’s covered through 80% of the content literacy I wanted to hit. It’s already covered – I only have to make some small adjustments to get the rest of it in. And I think one of the ways I can make it a key component is [pause] – there’s nothing more fun than watching students debate or argue over why their answer is the right answer and having that discussion in the class. That’s so much more valuable for them than um [pause] any notes I could ever give them or show them. So – keeping the classroom open to that.”

Ernie had given thought to how the ideas of mathematics literacy could “fit” into his perspectives and actions of teaching. He expressed interest in having students take on more responsibility for their own learning and understanding of concepts and recognized the positive value of having students discuss varied opinions, solutions, and points of view.

Terrance, a biology PST, shared his thoughts with the class on including literacy as a part of instruction:

“I think understanding that knowing what content literacy is – isn’t difficult trying to incorporate even a little bit of it in each lesson. It doesn’t have to be a big – you know – lab or experiment in every single class or unit. It can be something as simple as a live demonstration or a video or something in the news they may have heard. Um – just making those connections to the real world and just not being in front of a class lecturing -- ahh – all period.”

As a result of Terrance sharing his points, other PSTs were motivated to discuss ways of starting small – taking baby steps – to gain confidence in integrating literacy into classroom instruction as well as trying to balance ways to make it work in light of required standards and benchmarks. This discussion was revealing in that it provided an opportunity for PSTs to imagine how they could engage students in their own learning while covering required curricula and adhering to school district supplied pacing guidelines.

DISCUSSION & CONCLUSIONS

Literacy is important for all disciplines, but is a known challenge for STEM fields, especially when teachers attempt to include it in classroom instruction to engage learners (Colwell & Enderson, 2016). Research (Draper & Siebert, 2010) has shown that teachers of STEM disciplines often do not model instructional practices that align with literacy, which impacts the perspectives of PSTs. One technology education PST indicated that “literacy in my field is broad and captures so many content areas. This makes it difficult to really grasp what technology education literacy encompasses.” This is further compounded when PSTs do not see mentor or veteran teachers integrating the literacy piece as a part of their instruction.

In this particular case, participants indicated the importance of their early and continued field experiences throughout their program of study contributed to their own understandings of disciplinary literacy. For some participants, they noted this as soon as they became better informed of literacy, but for others, it was not until they got into small focus groups that they realized this exposure. The preparation program that all STEM teachers in this study complete has PSTs teaching from their first year of university work until their final student teaching experience. These teaching experiences are immersed in using inquiry-based teaching methods and as a result, many participants noted that they believed these experiences helped them in thinking more like a scientist, technologist, engineer, or a mathematician. It was the support they received in carrying out such instruction that let them reflect on how all their field work related to what disciplinary literacy means for their disciplines. This revelation allowed researchers to see the importance of promoting inquiry-based teaching and/or PBL lessons in exposing PSTs into recognizing what disciplinary literacy looks like. This was a win-win for this group of future teachers.

The study also illustrated that in-service teachers often do not incorporate the literacy of their discipline into classroom teaching due to factors such as time constraints, lack of materials, unfamiliarity, and state testing. What PSTs took away from this experience was that the PBL lessons provided opportunities for teachers and their students to see literacy in action. Their lessons were student-driven and required interactions that aligned with the work and vocabulary scientists, mathematicians, technologists, and engineers carry out. This was an important point for PSTs in this study. Jessica, a mathematics PST, summarized it well when she stated:

“Including literacy into the lesson opened my eyes to the importance of literacy. It also reinforced the fact that literacy is more than just reading, writing, vocabulary words and formulas. Without the literacy component of our lesson, the students would have just regurgitated the information they already knew without digging any deeper or making the connections.”

We considered that this is a common sentiment among teachers. Most teachers want to prepare their students to become critical thinkers and problem solvers for tomorrow's world. This PBL course, steeped in literacy discussions and assignments tied to lessons, helped PSTs find ways of preparing their students for the future.

Lastly, as was identified earlier in this manuscript, researchers wanted to use student voice in searching for ways to adjust the PBL course they take as part of their teacher preparation program. This group of PSTs brought out the importance of 5E lessons in promoting disciplinary literacy, which is now a major focus in the course. The actions that are part of a 5E lesson align very closely with the literacy components for the STEM disciplines – exploring, investigating, proposing, graphing, testing, reporting, analyzing, and concluding, to name just a few. Such activities are vital to the study of the sciences and support secondary students in talking and working like scientists. Researchers believe it is critical to prepare future STEM teachers to embrace disciplinary literacy into classroom project-based instruction so that secondary students are prepared to tackle and solve real world STEM problems.

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