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Motion, Matter, Force, and Writing???: Creating Space for Writing in a Secondary Physics Classroom

“In my opinion I wonder about how you’re never really touching anything and you’re never really saying anything because it’s pretty interesting. This is important because apparently electrons repel each other and that’s why we don’t technically feel things. This makes me think of a time when it makes me think of textures and how strange it is that we aren’t really feeling those textures.” This entry is from a student’s writing journal in an eleventh grade physics class where writing was incorporated during the spring semester as a mode to promote inquiry, thinking, and learning. The entry illustrates the student’s thinking and meaning making through writing.

Disciplinary literacy is defined by Shanahan and Shanahan (2012) as the specialized knowledge production by experts to engage and communicate in the field of work. While benefits of applying writing-to-learn has shown to be unequivocal, incorporating specialized writing for specific disciplines has been exhibited to be challenging (Fisher & Ivey, 2005; Smagorinsky, 2015; Dobbs, Ippolito, & Charner-Laird, 2016). With increasing demands from work forces and colleges, adolescents graduating high school should have skills beyond basic literacy by accomplishing proficiencies in specific disciplinary literacies (Chauvin & Theodore, 2015; Pitman, 2010; Carnegie Council on Advancing Adolescent Literacy, 2010).

Although there have been influential studies conducted on writing in content areas, there is a limitation of research on writing-to-learn in specific disciplines through an authentic secondary classroom environment. Consequently, the issue of disciplinary writing remains pivotal to the field of literacy. Specifically, the goal of this study explores:

1. In what ways does engaging in writing-to-learn influence students’ perceptions regarding their ability to understand content presented in their eleventh grade physics course?

2. How does the intentional integration of writing-to-learn activities inform students' perceptions of themselves as writers and physics students?

Theoretical Framework

Sociocultural Theory

Sociocultural theory is predicated on the idea that learning is embedded within social events and interactions with other people (Vygotsky, 1978). The theory emphasizes how peers, cultural beliefs, and outlooks influence one's learning (Vygotsky, 1978). Vygotsky (1978) further claimed that an individual's development may occur on two levels: first, on a social level with other people and second, at an individual level within themselves. This social aspect is necessary as a part of the learning process in science when scientists socially communicate and collaborate to explore and explain ideas. Therefore the theory helped form the research questions with the stance that literacy is a socially applied concept for learning to take place (Perry, 2012).

All disciplines have a unique social community where knowledge is explored and experimented with; students may take part in such a community through social interactions to develop as critical learners (Yore, Hand, & Florence, 2004). Sociocultural theory views writing as a social action, not only a form of communication (Prior, 2008). To create this form of social community, writers can share their compositions with peers to receive feedback, create new meaning, and discuss academic content. Specifically in physics, scientists write to share and rationalize new knowledge as well as to record and analyze phenomenon. In this study, writing was used as a means for learners to reflect on their understanding of concepts in physics. As a way to check for their understanding, learners were asked to participate in low-stakes writing to explain what they learned in class and how it connected to previous ideas learned.

Literature Review

Disciplinary Writing

Conley (2007) termed college readiness as having critical thinking strategies, understanding content area knowledge, and being aware of metacognitive skills. Despite this definition, according to the U.S. Department of Education (2010) fifty-three percent of high school students register for college remedial courses. Likewise, Thesen & Van Pletzen (2006) asserted that only one-third of college students are ready for analytical and argumentative writing tasks. As a result, many college students struggle to meet literacy expectations for colleges, thus making high school preparation incompatible with higher education (Conley, 2007; Donham, 2014; Gruenbaum, 2012).

Specifically, writing across the disciplines permits students to reflect on their current knowledge and improve learning by stimulating their metacognition, abstract understandings, and learning the language structure of specific disciplines (Yore, Hand, & Prain, 2002; Newell, 2006). Fisher & Ivey (2005) described learning as language based since it requires significant time to explore, apply, and reflect. Klein, Piacente-Cimini, and Williams (2007) findings built on this notion by exploring how non-science college majors had a higher level of understanding scientific concepts after spending time writing to process the new content.

Moreover, Wolsey, Lapp, and Fisher (2012) explored tenth grade students' perceptions of academic writing and suggested students needed various models of the specific language discourse with explicit teacher instruction to help make instruction effective and establish teachers' expectations of academic writing. This stance of disciplinary discourse is visible through Draper's (2002) implementation of literacy in a math classroom where he argued math teachers should go beyond teaching students how to be literate with a textbook to understanding the specific language of the mathematical discipline. Lampi & Reynolds (2018) expressed that explicit instruction of writing is necessary within specific

disciplines in a contextualized learning environment; writing has social roots and may be developed through social interactions in the discipline. Further, Zulfah & Senam (2018) conducted a study to understand that disciplinary literacy instruction improved and supported students' problem-solving learning.

Wilson-Lopez & Minichiello (2017) introduced disciplinary literacy in a seventh grade technology and engineering class through reading, evaluating and interpreting texts, and brainstorming ideas to redesign the school parking lot. During this unit, students engaged in literacy practices similar to engineers such as creating math models, using spreadsheets to test their ideas, and creating charts, tables, and lists of criteria. In a similar study, Kucan, Rainey, & Cho (2018) worked with middle school students to explore a purposefully designed unit on how historical events informed current and future events in the students' neighboring town. Teachers used text sets designed by the researchers to support their history practices and use of historical resources. Students located sources to read, analyze, and connect to historical events in the neighborhood and completed informal writing reflections over readings to understand historical thinking. Consequently, providing opportunities for students to engage in discipline specific inquiry with explicit strategy instruction, and examining ways of thinking and doing among discipline communities offers essential skills for college readiness (Rainey, Maher, Coupland, Franchi, & Moje, 2017).

As each discipline has its unique forms of discourse, science has forms of literacy that can be integrated to improve inquiry, comprehension, and metacognition (Yore, Bisanz, & Hand, 2003). For instance, with junior and senior students Stewart, Myers, and Culley (2010) implemented microthemes with their psychology curriculum. The microthemes were short writing assignments in class to create active learning. Students participated in discussions to encourage active learning, preceded with the teacher's feedback to students writing content

and quality. Students felt the in-class writings were effective for their retention of information and they had higher class scores than students who did not participate in writing.

Disciplinary Writing in Science

Drew, Olinghouse, and Faggella-Luby (2017) investigated teachers' incorporation of writing in science across the nation. Although teachers purposively incorporated writing, it was with limited learning opportunities. Similarly, Levin & Wagner (2006) noted writing in the science curriculum might be effective if conducted as an ongoing form of learning.

Bangert-Downs, Hurley, and Wilkinson (2004) also emphasized writing-to-learn through a meta-analysis study of forty-eight writing programs. Findings of the meta-analysis suggested that writing-to-learn offered a positive effect on students' academic achievement. Further, the examination of forty-six peer-reviewed articles allowed researchers to understand the purpose and format of various writing-to-learn assignments across different science classes.

Assignments that showed increased learning incorporated the writing process and provided opportunities to make meaning and monitor one's thinking through writing (Gere, Limlamai, Wilson, MacDougall, Pugh, 2019). In another study, an extensive review of literature was conducted by Miller, Chyllis, & McTigue (2018) to understand how writing activities promoted students' learning and acquisition of knowledge. Prevalent research themes on writing centered on students' cognition with writing, students' ability to address content in writing, and the context in how writing was taught and implemented. The result of their analysis explains when writing is carefully planned with opportunities for metacognition it may positively influence learning outcomes.

Subramaniam (2010) suggested exposing students to scientific writing and its particular forms allowed learners to develop in scientific literacy and language. The genre of scientific writing was different from what students were commonly used to because it avoided, "any actor, the personal, the scene, the motives, temporality, colloquial forms and

metaphoric and figurative language” (Subramaniam, 2010, p. 31). In response to this challenging genre, Subramaniam (2010) discussed writing frames as a method to incorporate writing in the science content and to guide student learning. Writing frames are a template with sentence starters and sentence modifiers which guide students in their writing. Additionally, writing frames may be a guide to help students learn the style of scientific conventions and linguistic patterns, introduce new language, and also help teachers guide and diagnose student learning. Understanding academic language skills is crucial in order to write coherently. In order to produce comprehensive texts with specific academic jargon, one would need a strong comprehension of science texts and a proficiency in academic language (Galloway, Qin, Uccelli, & Barr, 2019). Similarly, Avalos, Secada, Zisselsberger, Gort, & Secada (2017) observed writing features and patterns in a third grade science classroom where students wrote an explanatory paper about the water cycle. The study found students with lower writing scores tended to use fewer scientific language patterns to express their understandings compared to higher scored samples.

Methods

This qualitative narrative (Connelly & Clandinin, 1998) case study was part of a larger project that was conducted during the spring semester. Over the course of five months, I thoroughly collected data from six different sources: (a) Students’ writing samples, (b) interviews, (c) observations, and (d) surveys. These data sources permitted me to discover students’ perceptions and writing abilities in their physics classroom through a narrative qualitative design (Denzin & Lincoln, 1994; Merriam, 1998; Spradley, 1980).

The participants were three students and one teacher from one class period of 11th grade physics in a suburban public school district in South Texas. All participant names are pseudonyms. The student participants were not purposefully selected, but rather the individuals conveniently returned their assent forms to participate in the study. Yet, this did

not keep the remainder of the class from participating in writing. The classroom teacher, Mrs. William, was assigned to me by the principal for this study because of her fun and outgoing personality. Mrs. William did not agree to engage in professional development or to receive support with her teaching to incorporate writing in her physics class. Therefore, this study solely focuses on the students' response. The student participants presented a broad range based on race, gender, academic performance, and personal insights with writing: Haley was an eighteen-year-old Anglo European female student. She was in her senior year and an honor student. Chip was a seventeen-year-old African American male in his junior year at the high school. Anthony was a seventeen-year-old Hispanic male in his junior year. He described himself as an average student who enjoyed physics because the teacher was fun. The classroom teacher was Mrs. William in her first year of teaching.

Data Collection

During the spring semester, the class covered three separate six weeks of physics curriculum over: (1) waves, sound, and light, (2) refraction, and (3) circuits, circuits and elements, and electromagnetic induction. Curriculum content was determined by the school district which Mrs. William was required to teach. Writing was not incorporated into the lesson plan until I began the study. This was Mrs. William's first year of teaching and through interviews she shared she was unfamiliar neither with strategies to incorporate writing in her science class nor with understanding how physicists wrote in the discipline. Specifically exploring Mrs. William's knowledge of disciplinary writing is not the focus of this study but may be examined in closer detail as a part of a future study.

Mrs. William provided students with orange folders at the beginning of the year for them to keep track of their daily notes and worksheets. She decided to use the folders as writing notebooks by placing writing paper in the brads. The writing paper included scaffolded sentence starters as a tool to support and guide students' thinking (Subramaniam,

2010) as they wrote and reflected on the lecture. Mrs. Williams wanted to use sentence starters because of concerns with students' writing abilities and using complete sentences. The entire class participated daily by writing using the sentence starters during the last ten minutes of class. As the researcher, I was the only one to read and provide responses to students' writing. Collected writing samples are from participants who signed their assent forms.

The four sentence starters provided to students in their folders were the following:
(1) *In my opinion I (agree/disagree/don't understand/wonder, etc.) about _____ because _____.*
(2) *This is important because _____.* (3) *This makes me think of a time when _____ because _____.* (4) *This lesson can be connected to my previous knowledge by _____.* The prompts were structured to be basic since the intention was to guide students to write complete and comprehensive sentences in order to understand their ideas.

In addition to collecting writing samples, students completed a pre- and post- survey during the semester. The surveys were anonymous with four open response questions that asked students how they felt about writing in general and having to write during physics. The surveys provided an understanding of students' perceptions for writing in science and how they viewed themselves as writers. Further, I collected detailed observation field notes four days a week during four months. Notes were typed, read, and re-read for recurring elements. Last, I used a qualitative approach to conduct interviews that were structured, unstructured, and grand-tour questions.

Data Analysis

While collecting my data I read, re-read, examined, and re-examined to create meaning of the data (Erlandson et al. 1993). First, I transcribed interviews and then reviewed the transcripts to circle words and/or phrases that seemed pertinent to my research questions. The circled words and phrases became initial categories that I re-examined. Similarly, survey

responses and field notes were typed and organized using a spreadsheet. Spreadsheets were read several times and examined for reoccurring concepts which were highlighted. Table 1 illustrates a preliminary outline of how initial categories were discovered when the data was re-read and re-examined. Although the list of initial categories was extensive, the purpose of this table is to demonstrate how data analysis was primarily prepared.

Table 1 Initial Categories

Words, phrases, or concepts	Type of Data
Participants glancing at peers' writing journal	Observations
Participants not willing to complete a writing entry	Observation and writing sample
"more freedom to what to write about"	interview
Writing for "like homework, yeah."	Interview
"This lesson can be connected to my previous knowledge by learning how my chargers interact with outlets because I'm just curious."	Writing sample
"I learned that Issac Newton was on the verge of discovering light waves but didn't."	Writing sample
"doesn't really make a difference."	Interview

Further, I held several member checks with participants to share if my results were conceivable to them. During member checking participants helped me reframe the codes through discussions; I would read sections of the categories and ask for feedback for necessary reframing of codes. Last, using the initial categories I developed my final themes as major findings.

Findings

Creating Space for Disciplinary Writing

Writing was introduced to students through Mrs. William and me, the researcher. I explained that writing could be used for various purposes and one avenue was to learn and explore new ideas. Mrs. William further shared how the orange folders would be used to begin incorporating daily writing and she went over the sentence starters with students by reading them aloud. An analysis of the data produced three themes: (1) students did not acknowledge a disciplinary learning community from writing-to-learn (Freire, 1968), (2) writing helped students remember a surface level of physics content rather than become disciplinary writers (Frey, Fisher, Hattie, 2016), and (3) during class students did not see a connection between writing and physics, which led to their lack of engagement as writers. The following three narratives expand the above themes.

“I am okay at it but I am just like I don’t enjoy it”: Haley’s Story. Eating peanut butter cookies and drinking water in class, Haley thumbed through her iPhone while Mrs. William began the class with announcements. She remained mostly oblivious to Mrs. William’s introduction of the lesson and ate her snacks while focused on her iPhone. “All right, get out a sheet of paper to take some notes,” (Mrs. William, observation notes) requested Mrs. William and while a few students found their previous notes, Haley remained otherwise occupied until the lecture began, and Mrs. William started writing information on the screen.

Haley equated writing in physics to copying information directly from the projector screen (Applebee, 1981): “I like writing notes and stuff” (Haley, interview). For instance, she explained that writing about the difference between anti-notes and notes helped her understand the meaning of anti: “When I wrote that, then I remembered that.”

Haley felt the sentence starters used for writing hindered her ability to openly share what she had learned in class: “I am just trying to base it around what the other words are ... I feel like I have to think of something based on what that starter is rather than just think of something on my own” (Haley, interview). I encouraged Haley to write freely without the template of sentence starters. Her writing displayed a developing ability to monitor her metacognition and question the lectured content; yet, she still did not feel writing helped her learning in any way: “You’re kind of writing just to write” (Haley, interview).

Unless I used the term ‘writing journal’, Haley referred to writing in physics as directly copying notes. In her other classes, writing to reflect was not emphasized; instead, “if we want to write to remember it, then we can” (Haley, interview). Haley saw writing as an activity to fulfill the expectations in class, rather than a tool to help develop her thinking and learning. However, according to Haley if you have to “personally write something down, then it’s like you’re paying more attention than if like the class is just talking and you’re ignoring her” (Haley, interview).

Haley had been praised by her journalism teacher for her writing skills, however writing never appealed to her. The formation of her identity as a writer *in physics class* was likely hindered because of the way in which writing was carried out in the classroom with a lack of questioning, modeling, sharing, and discussing.

The following writing entry by Haley was written by using the sentence starters to guide her writing:

This is important because the things that we’ve learned about light have enabled us to figure out a lot of things about space such as specifics regarding the big bang theory. Figuring out distances in space teaches us a lot (Haley, writing journal).

This journal entry repeated what Haley learned on that day about light; Mrs. William discussed how light related to space and the Big Bang theory. In Dewey's (1938) discussion of reflective writing, Haley's sentence may not be considered reflective because she never provided her thoughts about light and space. Instead of giving her thoughts, Haley began another topic about distance and space without any form connection with ideas.

Haley's writing showed her focus was on memorizing facts which kept her from making deeper disciplinary connections to create meaning of the content. However, her journal writing reflected the opposite since she focused more on sharing facts she had learned in class rather than expand her thoughts.

“It helps me remember stuff” – Chip's Story. As the bell rang, Chip calmly strolled into the room and collected his orange folder from the front of the class. Quiet, soft-spoken, and shy, Chip was a tall and thin African American junior who kept to himself during class.

“How do we calculate wave velocity?” (Mrs. William, Observation). As Mrs. William continued to lecture during a typical day in physics class, Chip looked up to copy what was written on the projector. Writing in his other classes was “pretty much just tests [and] assignments” (Chip, interview) while writing in English class involved responding to teacher prompts. Accordingly, writing at the end of physics class was the only time during school in which Chip was provided the personal space to reflect and think about his learning.

Chip: I am an okay writer.

Interviewer: Do you ever write outside of school?

Chip: Like for homework, yeah

Interviewer: Just for fun?

Chip: No

Interviewer: It's all for academic?

Chip: Yeah

Interviewer: Give me an example of writing academically.

Chip: [pause] (Chip, interview)

Restating information from his notes into his writing journal helped Chip remember concepts from class: “It helps me like remember it” (Chip, interview). He could not expand on what specific concepts he could remember from writing in his journal, though; instead, it was just “stuff.” Chip viewed his journal as another assignment he was required to complete during class that incidentally helped him remember information at a superficial level: “It doesn’t really make a difference at all” (Chip, interview).

During one class session about electricity, students were able to spend time shocking themselves with a Van de Graaff generator. Chip wrote: “In my opinion I wonder about whether you can get sick from being electric shocked too many times because of the effect it has on our bodies” (Chip, writing journal).

I responded to his entry by praising him for thinking about the effects of what he had seen in class and encouraged him to “describe the effects” to expand his thinking and make connections with concepts. This entry illustrated the importance of presenting disciplinary literacy as not just as knowing information, but also being able to apply knowledge (Hobson, 2006).

Chip struggled with the physics content which stopped him from sharing his knowledge through writing. Consequently, writing did not influence Chip’s learning or identity as a writer; rather, his learning was a repetition of facts he had learned from class, as opposed to developing a depth of disciplinary understanding.

“Like they could be like, I don’t know like us having more freedom to what to write about” – Anthony’s Story. Anthony was a bilingual student who spent most of class scrolling through his phone and whispering with his neighbors. Anthony felt he was an average writer and was unsure how to express his thoughts through writing.

When writing, Anthony did not find the sentence starters helpful to guide his thinking: “I don’t know like us having more freedom to what to write about”; although he quickly added, “No, it’s good to have guidelines, though” (Anthony, interview). During the final month of the semester, Anthony decided to stop writing in his journal.

When he seldom did write, most of his brief entries were a restatement of class notes that lacked any personal extensions of his learning. For instance, he wrote: “my opinion about resonance is a vibration and tesla that created a device to make a street block shake” (Anthony, writing journal). This entry was written after students watched a video about Tesla’s law and the Tacoma Narrows bridge collapse. Anthony did not complete the sentence starter because he failed to fill in the blank space to state whether he agrees/disagrees/does not understand/wonders about the topic. In addition, the second part was incomplete because he neglected to extend his thinking after the *because* phase. Writing information in this manner may have alluded to his disinterest in writing since he struggled with it.

Anthony’s lack of participation with writing in the journal mirrored his behavior during class. Since learning was a passive behavior in the classroom, having to participate with an untraditional assignment did not seem important to him, especially given his obvious struggles with writing. His behavior suggested it was okay to come to class and be unreceptive. As long as he was seated and not disruptive, he was being a ‘good student’.

Anthony did not have a positive experience with writing and he viewed it as work to complete in order to do well in school. As a result, he saw writing in physics in the same

way. Since using writing as a way to learn and making connections was beyond the boundaries of traditional learning, Anthony was uncomfortable and uncertain about what to write and how to structure his thinking through writing.

Interviewer: What do you think about writing that makes you feel okay about it?

Anthony: I don't know [pause]

Interviewer: Do you like to write? Do you write outside of school?

Anthony: No, not really

Interviewer: So, you just write for school stuff?

Anthony: Yeah

Interviewer: Tell me what kind of school stuff you write?

Anthony: Like prompts that we have in class for English (Anthony, interview)

This lack of identity as a writer and his struggles with writing prevented him from participating with the writing journal because he did not acknowledge a value or need to write; the journal was irrelevant to his learning in physics: "some days I forget about it" (Anthony, interview). To illustrate this detachment, Anthony rarely had paper or a writing utensil in hand to copy notes. In addition, his lack of concern about writing and learning is further explained when he shared his dislike of writing in class:

Anthony: I didn't like the idea

Interviewer: Can you tell me why?

Anthony: [pause] I don't really have a reason why

Interviewer: It's just more work?

Anthony: Yeah, pretty much (Anthony, interview)

Considering writing to be additional work as opposed to a learning tool prevented Anthony from participating. Without suitable writing skills and attitude, writing in the disciplines cannot become a successful tool for learning.

Discussion

Writing Experiences in School

Most notably, Emig (1977) posited that writing is a distinctive form of active learning that is referred to a productive function. This productive function is established with continual feedback to create ongoing learning. Similarly, Yore, Bisanz, and Hand (2003) described writing as either knowledge telling, where learners write a surface level response, versus knowledge transforming, where learners write at a deeper level to develop understanding. Although the scaffolding with sentence starters was not effective toward students' disciplinary learning and writing in this specific classroom, it may be an effective strategy when incorporated with sufficient teacher modeling and classroom discussions.

For instance, participants from this study viewed writing as knowledge telling and lacked the process and product format (Emig, 1977) of writing to progress their learning. As a result, students' participation with the writing journals was a form of fake writing (Gallagher, 2004, p. 89); they wrote anything in their journals as a way to comply since writing was viewed as another, "school induced hoop to jump through" (Gallagher, 2004, p. 89). Nevertheless, students' attitude of learning from writing may have been different if the concept of disciplinary literacy was approached with better understanding from Mrs. William.

Consequently, writing has become an endangered subject lost to traditional forms of writing for testing purposes. The educational system has become consumed with standardized testing that students are limited with their understanding of what it means to be and grow as writers and most importantly view writing as a tool for the discipline (Muhammad, 2012).

This view of learning lead participants to misunderstand how writing may be used for multiple learning purposes across disciplines (Hand, Prain, & Yore, 1999) beyond just taking notes. As a result, to begin an innovation with writing in classrooms, educators across disciplines may help to develop or to foster students' identities as writers through motivation and creating an environment where writing is a learning tool (Jeffery & Wilcox, 2014).

In this study, several participants judged their identity as writers based on their ability to spell or compose sentences; however, National Commission on Writing in America's School and Colleges (2003) stated writing goes beyond these abilities by being able to extend learning through making valid arguments. The labeling of writing skills was created from participants' prior experiences from writing in English classes that were structured with adhering to grammatical rules and the traditional English paper. Consequently, students were unfamiliar with how writing may be applied for various purposes (Hand, Prain, & Yore, 1999) within other disciplines. To expand students' writing experiences, educators should consider establishing opportunities to write in the classroom that goes beyond notes and completing worksheets. Classroom teachers may consider providing opportunities for students to experience writing as a way of exploring new ideas and making connections with existing knowledge. One way to begin this form of writing is to guide students to respond to the reflective questions *What am I learning?* And *Why is this important?* Further, writing in science class may imitate writing done by scientists. Mentor texts may be used to facilitate class discussions and for students to gain exposure to scientific writing they may mimic in their writing.

Effective Disciplinary Writing Requires Understanding of the Content

Implementing writing across disciplines should be carefully and purposefully thought out (Bullock, 2008) to ensure students are building the identity as writers in the field while discovering new and ongoing concepts in the content (Levin & Wagner, 2006). Moje (2008)

suggested a change by building disciplinary literacy programs rather than just focusing on incorporating content area literacy strategies. Disciplinary literacy is not a one-size fits all form of implementation; rather there are particular literacies for disciplines (NCTE report, 2011) where subjects become subcultures by having particular ways of knowing and applying knowledge (Moje, 2008).

Writing proved challenging for participants because they lacked the metacognition, depth of disciplinary knowledge, and agency to compose thoughtful and coherent entries to communicate their understanding of physics. Despite providing sentence starters to scaffold students' writing and thinking (Jay & Johnson, 2002; Bangert-Downs, Hurley, & Wilkinson, 2004; Nichols, 1980) most participants could not produce writing that reflected disciplinary learning; rather they wrote restatements of their class notes. To shift the stance of writing as a routine form of copying notes, Botzakis, Burns and Hall (2014) suggested a balanced approach to literacy that focuses on direct strategy and skill instruction. Further, writing in physics requires an understanding of technical terms, making connections with prior knowledge, and sharing knowledge through evidence and logical connections. For classroom teachers willing to incorporate disciplinary writing, they should first understand how experts in the field utilize writing to communicate, explore, and analyze information. By understanding how experts in the discipline write, teachers may then use appropriate mentor texts as a model for students to follow in their writing.

Creating Identities as Writers

When implementing the journals, participants exhibited confusion with what to write about and how to put their thoughts into sentences. Several students were glancing over their neighbors' shoulders, staring at the empty page before them, or looking around the room trying to make sense of putting what they learned into words. Olson (2008) described our "thoughts are wild" (p. 286) hence we need to relate writing as a method to revisit, develop,

and organize our thinking. Langer (2011) confabulated for students to be literate in a subject they need time to practice disciplinary inquiry by “setting questions, exploring possibilities, developing points of reference, and finding ways to seek answers in all their coursework” (p. 157) to go beyond the surface of information. Stretching beyond the surface information requires becoming highly literate in a discipline in order to use the content’s language forms, ways of thinking and communicating, and being ““in the know”” (Langer 2011, p. 3) with information.

Sentence starters were provided to scaffold students’ writing and guide their thinking which raises the need for writing differentiation. Writing differentiation allows teachers to match instruction with students’ needs by providing different options and structures for students to write (Shea, 2015). Some participants shared they wanted the freedom to write without the structured sentence starters, while for others the structure may have helped guide their thought process. Yet, other students were resistant to participate in writing, therefore may have benefited from differentiating beyond just scaffolding. Differentiated writing provides students with the opportunity to demonstrate their knowledge through several means. Teachers may differentiate disciplinary writing by examining ways experts in the field produce knowledge through writing. For instance, physicists not only write to reflect on information, but knowledge may be shared through lab reports, creating figures and graphs, data analysis, or a field journal.

In addition to students’ struggle to write, they displayed a resistance through their behaviors because of the change of the traditional science curriculum to include demanding forms of writing and learning (Swanson-Owens, 1986). Initiating the study during the second semester of the school year, students already had a set routine with learning in physics; consequently, it was not easy for them to adopt a new structure and learning approach. Some participants viewed the writing activity as extra work to review and remember information

from the lecture, but writing was never seen as an engaging activity that correlated with the discipline. Asking them to reflect on what they learned through writing was outside of their comfort zone. The ability to reflect and make arguments begins with the self, and students should be challenged to think beyond themselves by asking, “What does it mean?” (Gallagher 2004, p. 157) from only “what does it say?” (Gallagher 2004, p.157).

Another reason why it is important for students to have positive identities as writers is to prepare them for the academic literacy demands of college. College literacy expectations are multifaceted and challenging; therefore students need support and preparation (Holschuh, 2019) for these expectations. By providing students the space to develop and self-identify themselves as writers, it may prepare them with college academic literacy skills and to become life-long writers. By engaging in disciplinary writing and developing one’s confidence as a writer, students become a part of the academic community and develop a specific habit of mind (Conley, 2007). Developing a habit of mind aids learners to understand how to think and communicate across various disciplines which is critical to students’ success in college.

Table 2 outlines three levels of writing developed after exploring participants’ journals and behaviors with writing; the final stage was not evident in the participants’ writings, but what may be considered based on the field of disciplinary literacy research. The majority of participants’ writing was at Level 1; Level 1 was a superficial level of writing that demonstrated learning through restating provided information that participants did by copying facts from their notes. Level 2 extended Level 1 by taking general facts to compose a concise summary of what they learned. In the final level, Level 3, a writer would take what they learned to make connections with other ideas to extend understanding with examples.

Table 2 Three Levels of Writing-to-learn Demonstrated in Physics Class

Level 1	Writing is a restatement of general facts. There are limited to no claims or extended comments.
Level 2	Writing to summarize information. Provided information is reworded as a summary.
Level 3	Information is extended with writing by making personal claims and arguments in a logical manner.

Looking Forward

Participants in this study may not have been resistant to writing if Mrs. William had a deeper understanding of interrelating writing with physics (Cantrell, Burns, & Callaway, 2009). Supporting teachers with disciplinary literacy is challenging among a “cultural resistance to change” (Warren-Kring & Warren, 2013, p. 76) since secondary teachers value a teacher-centered learning and view the instruction of disciplinary literacy as time-consuming (Cantrell, et al, 2009; Ness, 2009; Wilson, Grisham, & Smetana, 2009). Future studies in disciplinary literacy may explore the preparation and support of educators incorporating disciplinary writing in secondary classrooms.

Writing in academic disciplines is not a ‘one size fits all’ concept since it involves differentiation in content and structure. Disciplinary writing requires careful, purposeful planning, and modeling in a learning environment that views writing as a way of doing, sharing, and learning new concepts. In addition, writing-to-learn encourages students to develop a specific habit of mind within disciplines which prepares them for the complexity of college academics.

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