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A Study on the Use of Reflective Writing Assessments to Indicate the Level of Knowledge College Industrial Technology Students Possess Related to the Three Elements of Technological and Engineering Literacy

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A STUDY ON THE USE OF REFLECTIVE WRITING ASSESSMENTS TO INDICATE THE LEVEL OF KNOWLEDGE COLLEGE INDUSTRIAL TECHNOLOGY STUDENTS POSSESS RELATED TO THE THREE ELEMENTS OF TECHNOLOGICAL AND ENGINEERING LITERACY

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ABSTRACT

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The problem of the study was to determine if the use of a reflective writing assessment at the beginning, middle, and end of a college semester indicated an industrial technology student's knowledge and skills related to technological and engineering literacy. Experiences gained during project-based learning activities were used as the basis for this study. This descriptive study examined the reflective writing abilities of junior and senior year college students enrolled in a university's industrial technology program of study by administering a reflective writing assignment three times over a semester of science, technology, engineering, and math (STEM) course, STEM 320, Manufacturing and Construction Technology. Participants included industrial technology student participants from this course and an instructor interviewed during the fall 2022 semester. Students enrolled in an industrial design class, STEM 382, during the spring 2023 semester were interviewed to provide support for the written reflection portion of the study. Results indicate that using reflective writing assessments during project-based learning assignments throughout the semester with students who are experienced in performing projects demonstrates students' abilities to articulate the foundational core of what it means to be technologically and engineering literate.

Keywords: Reflective writing, technological/ engineering literacy, project-based learning.

This dissertation is dedicated to those who supported me throughout this journey. There are so many more people to thank. I have endured much personal loss over the last several years but have also prospered in the way of personal growth when dealing with those losses and rebuilding relationships that had been somewhat detached over the years. To my mother and father, who showed me the value of hard work, instilled an outstanding work ethic, and taught me so much growing up, thank you for everything. To my late wife Vera, who started me on this journey many years ago and was my rock, thank you for your love and support through the 22 years we had together. We had quite the adventure. To my late sister Patty, thank you for always making me laugh. Whenever I was down, all I had to do was get on the phone with you, and my day just got better. Thank you for your upbeat spirit and always being there when I needed someone to talk to. I miss you every day. To my brother Michael, your humor and quick wit are always welcome in my house. You have always been there, through the good and the bad. Finally, to my fantastic wife, Lisa. If not for you picking me up over the past several years and giving me all the love and support I could have ever wanted and needed, I would not have been able to complete this journey. I love you.

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INTRODUCTION

The ability for students to communicate understanding of learned materials begins as early as kindergarten, when students learn about symbols, icons, numbers, and words to communicate ideas and concepts (ITEEA, 2020). Students build on their prior experiences to expand their knowledge by learning how to spell, form sentences, and begin to write short essays. When they reach the 5th or 6th grade, they are provided opportunities to reflect on their learning.

The purpose of this study was to provide students an opportunity to demonstrate reflective writing skills after completing project/problem-based learning activities/units of instruction. This study investigated college industrial technology students' abilities to articulate their knowledge of what it means to be technologically literate through a repeated assessment at the semester's beginning, middle, and end. Participants taking an industrial course called STEM 320, manufacturing and construction technologies, and students from another industrial materials course, STEM 382, industrial design, were invited to this study. The instructor of both courses was also invited to participate in this study.

Reflective writing is a teaching strategy to assess a student's comprehension of presented content through a book report, journal, or essay. Students are given an outlet for processing their learning experiences to understand what they accomplished, why they completed a task, or how they worked through a given problem. Reflection is essential to learning, and instructors should provide opportunities for students to develop reflective writing skills. Assessments should be provided as part of the grading criteria, similar to other assessment methods/instruments such as quizzes, tests, and exams.

Instructor feedback is provided to address good writing techniques and sentence structure and cover the main points of the activity they just completed. This feedback also provides students with information and recommendations in areas where writing needs improvement. Reflective writing assessment instruments may contain these details. However, as required by each state's Departments of Education, a method for measuring a student's technological and engineering literacy development as they progress throughout the semester should also be included. For example, this study used a Problem-Solving (VALUE) Rubric developed by the Association of Colleges and Universities (Rhodes, 2010) to rate students' reflective writing skills relating to technological and engineering literacy. An industrial technology instructor and I used a scoring rubric for each assessment and provided specific instructions for what we sought during the study.

Research Questions

This study aimed to determine whether using a repeated assessment of reflective writings by college-level students would indicate the level of knowledge related to technological and engineering literacy. The elements that encompass technological and engineering literacy are technology and society, design and systems, and communication technology (NEAP 2018), as well as the use and development of technology and how "technology extends human capabilities" ITEEA (2020, p.2). This study used project-based learning units of instruction as the learning environment. The following two research questions to be answered were:

RQ1: How much emphasis does an instructor with a university's industrial technology program of study place on student written reflections? Are the reflections considered an essential part of the assessment strategy for their students?

RQ2: Do targeted, repeated written reflection assessments administered upon completing various projects throughout a college semester indicate students' ability to articulate their engagement with the core elements of technological and engineering literacy?

Background and Significance of the Study

We are a nation that depends greatly on technology. Unfortunately, many of our population cannot articulate what technology means or how it is designed and developed. Many people fall into the category of end-users, those who can manipulate or operate several different devices…but they do not possess “technological and engineering literacy” (ITEEA, (2020). Technological and engineering literacy is described as needing: “to increase society’s overall understanding about an area that impacts all facets of our lives, yet about which few people have a deep knowledge” (p. 2). They must also display the ability to articulate their thoughts via written communication. Instructors should consider developing curricula, activities, and units of instruction that move students towards a broader development of technological and engineering literacy skills for them to become more proactive in all aspects of technological development. This includes abilities relating to problem-solving, brainstorming, and collaboration, as well as the impacts technology has on society and the environment. These are factors that not only come to bear in school but are especially useful in the workplace.

There is a gap in the research literature on technological and engineering literacy. This is especially true when it comes to instructors using reflective writing assessments to determine the impact project/problem-based units of instruction have on students’ demonstration of technological and engineering literacy skills. For example, in 2018, a ninety-two-question, nationwide assessment of eighth-graders across America was conducted on the level of Technological and Engineering literacy students possessed. More than 15,000 students from over

600 schools participated in this assessment. The assessment consisted of 15 scenario-based questions and 77 multiple-choice and fill-in-the-blank questions (National Assessment of Educational Progress, 2019). No questions required students to provide a reflective writing sample relating to technological and engineering literacy. This may have provided insight into their ability to articulate what it means to be technologically and engineeringly literate. My study will help to increase the literature on this vital topic.

Learning Theories and Reflective Writing Frameworks

Students use concepts from different learning theories and theorists when working on project-based learning content. First, they use much of the cognitive learning theory, which refers to the idea that as students mature, they build on previous experiences and use those experiences to frame their perception of the world (Piaget, 1936). They also use concepts derived from constructivist learning, designed to foster learning using knowledge developed from previous life experiences and applying those experiences to new concepts (Dewey, 1910); (Vygotsky, 1978). By working in groups, elements of cognitive-learning theory, such as the social and environmental elements of social cognitive theory (Bandura, 1986). Individuals are given opportunities to utilize the self-reflection aspects of behavioral and cognitive theories (Brownell & Jameson, 2004). So, how do students develop reflective writing excellence, and how do instructors present and assess their writing?

Moon's Level of Depth Within Reflection Model

One example is the Moon Model, a four-level reflective model, which provides a framework for assessing students' reflective writing based on the depth the student's reflection offers (Moon, 2004). I selected this model for its ability to show students how to learn and reflect on their learning experiences, including their learning environments. This is especially important when students reflect on group projects, as reflections consider how group members worked together, the impact individual group members had on the project, and opinions they may have shared during the project. These are essential elements of project work and provide the instructor with insights relating to group dynamics (how well they worked together to overcome obstacles), project progress, and the quality of the final product design selected by the group. This model may also help instructors new to reflective writing as an assessment method to help build their pedagogical strategies for using reflection in their classes, including developing assessment instruments to improve students' reflective writing skills.

Figure 1

Levels of Depth Within Reflection. From "A Handbook of Reflection and Experiential Learning: Theory and Practice" (Moon, 2004, p. 216)

Levels of Depth within Reflection

Surface

1. Descriptive writing – descriptive and contains little reflection. It may tell a story, but generally, from one point of view.

2. Descriptive writing with some reflection – a descriptive account that signals points for reflection while not actually showing much reflection. What little reflection there is lacks depth.

3. Reflective writing (1) – description, but it is focused, with aspects accentuated for reflective comment. Shows some analysis, some self-questioning.

4. Reflective writing (2) – Clear evidence of standing back from the event. Shows deep reflection. Self-questioning and the views and motives of others are also considered.

Deep

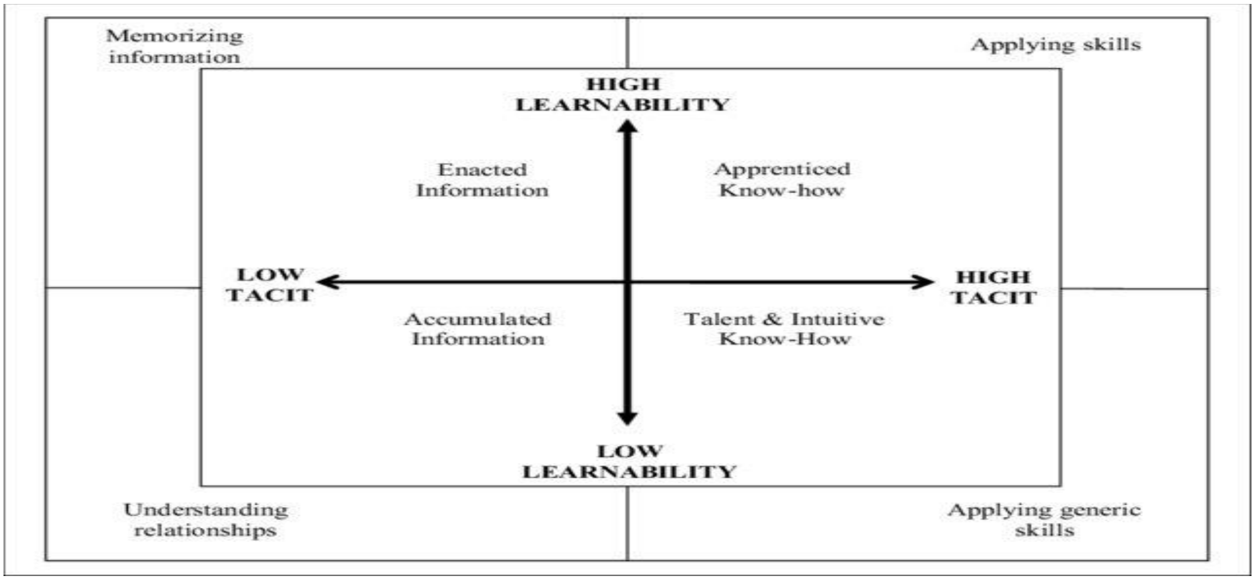
Knowledge in Practice Framework

Instructors work diligently to help students connect to foundational knowledge related to specific course content. They must also consider connections to the future and real-world applicability of the learned content. This connection is valid for classes relating to technological and engineering design (Moore et al., 2014). A study by researchers discussed that students develop skills, knowledge, and attitudes that lead to "desired organizational performance outcomes" (McIver et al., 2015, p. 49). These researchers proposed a Knowledge in Practice framework (Figure 2) that offers the best chance for students working in groups to achieve goals set in the learning objectives for an activity/project. They suggest that how learning objectives are structured will, by default, drive an instructor to develop specific learning activities or instructional methods to support the objectives. They believe this approach will lead to positive outcomes for students.

A four-step approach is used and includes: "use of broad course learning objectives; classifying the underlying knowledge structure of each learning objective by its knowledge-in-practice; map knowledge-in-practice of learning objectives to learning processes; and choose instructional methods to trigger the learning process" (McIver et al., 2015, p.50). The quadrants indicate the level of knowledge and ability to apply learned skills in real-world environments. Enacted information refers to the student's ability to memorize information, not necessarily perform tasks associated with newly learned content. The accumulated information is when the student can connect to learned content and understand relationships between delivered instruction. Apprenticed know-how is where the application of skills begins to appear. Instructors develop student skills through repeated exposure/practice and instructor feedback to help students successfully perform a learned task.

Figure 2

Knowledge-in-practice framework. (McIver, et al., 2015, p. 57)



Finally, talent and intuitive know-how demonstrate the students' abilities to move from the apprentice to leading teams through various projects and other team-related activities. Content mastery occurs due to the reinforcement of basic skills learned throughout a course or a series of courses on their program/major. While the emphasis for selecting this model is on its ability to help students develop written reflection skills related to their experiences with project-based learning environments, instructors may implement this framework in every educational setting.

Project-Based Learning

Project-based learning is a vital learning delivery method, as it creates dynamic learning environments, incorporates various stimuli, and allows students to gain valuable experiences that extend to real-world applications. It develops student technological design skills. Project-based learning began in the 1960s when small groups of medical students worked together to solve patient medical ailments, which, over time, greatly enhanced their development of diagnostic skills. The strategy included group communication and collaboration and the development of the teamwork skills needed to solve complex medical problems (Scott, 2017). Project-based learning soon began to move into K-12 education and post-secondary classrooms (Hung et al., 2008). This learning strategy allows students to reflect on the processes involved in developing ideas and artifacts and has been an effective learning strategy for all students.

The application and benefits of using project-based learning in industrial technology classes are limitless. Students gain team-building skills through collaboration and brainstorming. They create strategies to achieve a goal or objective and develop problem-solving, leadership, and critical-thinking skills. These are valuable attributes for students in the classroom and the workforce. These functions are vitally important when working on a project. Managing everything that goes into the design and production of artifacts is an arduous task. Teams develop trust over time, and motivation will rise and fall as teams progress through the different development processes. Conflicts may occur, but with the right attitudes and instructor intervention, teams navigate back to working together and produce results. Teams must understand that while frustration and personal differences may occur when it comes to the design of a product, the goal is to finish the project, articulate why they chose a specific design, and explain, in detail, how they came to develop the final product.

Steps of the Problem-Solving Process

Students must develop working knowledge of the steps of the technological problem-solving process. The number of steps depends on the scope of the problem students are solving. The example provided below (Wright et al., 2019) is from a textbook used by the department for its STEM 110T course, Technology and Your World, and uses the following six-step problem-solving process:

1. Identify and define the problem or opportunity.

2. Gather information (research data, surveys/interviews).

3. Devise a plan for solving the problem.

4. Develop a model/prototype of the design.

5. Implement/Evaluate the plan.

6. Communicate the plan/solution

These steps are not always completed in an exact sequence, as design teams may have to repeat steps depending on issues they encounter during the design process. This is explained in more detail below. Each step of the process will now be presented.

1. Identify and Define the Problem or Opportunity

Identify and define the problem/opportunity: What are they seeking to accomplish? Teams develop, or in some cases, are given a problem statement and begin to build a plan/strategy around the concept. Problem statements give groups a sense of ownership, especially if they identified the problem/opportunity in the first place. Problem statements provided to a group offer instructors and course designers opportunities to determine if the statement is clear enough for students to work toward a solution. From a STEM instructor's or designer's perspective, a strategy might be to purposely present to the group a somewhat obscure problem statement with unclear descriptions relating to the problem they are trying to solve (Stefanou et al., 2013).

2. Gather Information, Establish Criteria and Constraints

These scenarios allow teams to fill in the gaps, develop criteria and constraints, and gather information about the technological, scientific, legal, and societal knowledge required to develop the solution. Establishing these goals sets the tone for the project and requires groups to work together immediately rather than waste time socializing or not taking the project seriously. Teams need to gather as much information as possible to help them understand the issue(s) and may help lead them to move in the right direction. There are several ways to gather the needed information, such as market analysis and surveys.

Market data analysis is one method. Teams may look at sales figures to see current trends and whether sales are increasing or decreasing. Customer feedback is essential, as consumers will provide feedback about a company's product and may suggest ways to improve quality, safety, availability, and cost concerns. Surveys are also helpful when determining a potential solution. These are important, especially when companies introduce a new product. Companies may call or email consumers to see how their new product is performing and whether they are satisfied with the purchase. They may also conduct short face-to-face surveys in the retail environment to help understand the motivation for a consumer to purchase a specific product or service. These methods help a company keep its finger on the market's pulse in which it competes.

Once all required information/data are acquired, teams must establish criteria and constraints. Examples include costs, production capabilities or limitations, availability of production materials, and establishing testing and evaluation procedures/specifications. With criteria and constraints finalized, teams may move on to the next step of the problem-solving process, devising a plan for solving the problem (developing preliminary design solutions).

3. Devise a Plan for Solving the Problem

Devising a plan for solving the problem is critical to the problem-solving process. The plan must provide specific details of the work, including the distribution of work and establishing priorities and deadlines. Team members must clearly understand their roles to give the project the best chance of succeeding. Selecting the best solution takes time. Team members make multiple suggestions to consider for a potential solution. An open-ended, rapid-paced, throw caution to the wind exercise occurs, where all ideas are presented and recorded for further discussion later. These situations are called brainstorming or what-if scenarios. We begin to see the connections to Experiential Learning Theory (Kolb, 1984), which means students will attempt to tap into previous experiences to connect to the new problem/opportunity. Using the developing/designing of solutions process provides teams with options for tackling the problem. From the original brainstorming meetings, ideas are put on paper as simple sketches or drawings, then refined into detailed sketches, giving the team a three-dimensional representation of their technological artifact/product. Once the team approves a design, they move to the next step of the process, Implementing and evaluating the plan.

4. Develop a model/prototype of the design

Team members decide how to model the artifact/product they are developing. Examples include 3-D graphic models, which illustrate the relationship between components; physical models, or mock-ups, to provide a structural and aesthetic view of the proposed design. They can be as straightforward or complex as the team deems necessary to evaluate the design. Teams may decide to create mock-ups or models of their design or go so far as to make a prototype of their design. Prototypes are full-sized, functional models of the design whose purpose is to operate as the final developed product should (Cavalcante et al., 2018). For STEM-related (including industrial technology) projects, prototyping is a crucial element in the learning process. When the model or prototype is complete, the team will analyze the artifact by performing tests to determine if the artifact meets predetermined specifications.

Team members transition from primarily cognitive-related skills to more behavioral or constructivist skills. These skills are vital to the project and pave the way for individual team members to develop self-efficacy by being challenged to perform tasks that take them out of their comfort zones. Project-based learning is unique, as it provides a short-term benefit to a student and a long-term learning opportunity that leads to mastery of the problem-solving processes (Brownell & Jameson, 2004).

Team members can showcase industrial technology skills gained by previous experience. They may also learn new skills such as using essential hand tools, operating machinery (CNC, 3-D printers, laser cutting), performing molding and casting functions, assembling, or assisting with other manufacturing-related processes. The key in this project stage is to give students a sense of ownership in the creative, hands-on aspects of the project. Teams may run into obstacles during the project. Some issues might be relatively small and easy to fix, while others may require extensive work to repair, which could lead to the team deciding to develop an entirely different design. For example, while running performance tests, the team discovers flaws in the structural integrity of the artifact, which indicates that a component or several components are out of specification.

Team members must make the right decision for themselves and the company (if included in the scenario). They must prepare to deal with these types of situations. However, these setbacks may negatively impact a project's outcome depending on the team dynamics, age of the students (especially elementary-level students), individual egos, maturity, and level of team cohesiveness. With the instructor's assistance, the team leader must work together to help the team develop a strategy to get them back on track. A good instructor will devise a way to refocus the team on developing a workable solution and help redirect their negative energy towards a more positive one.

Students need reminders that the purpose of following the steps and procedures of the problem-solving process during technological design is to make discoveries, both good and bad, and working as a team to develop strategies that will help them overcome adversity is just part of the learning process. They must also remember that the activity is a team effort, and their commitment is to the project, not themselves. Keeping teams motivated to perform and work through tricky situations is vital to the success of a project. When teams are focused, they can overcome many obstacles thrown at them. When doubt begins to creep in, projects stall, team members are not working well together, and blame for the errors starts to surface. A counter-productive attitude hurts the team so much that it may cause a permanent stop to the project (Stolk & Harari, 2014). Students must learn the value of continuing and completing the project. Giving up in the outside world may lead to reprimands or even termination from the company. These are essential teaching points and opportunities for students to develop cognitive, psycho-motor, and affective growth.

Teams face numerous challenges throughout the project, and keeping team members motivated is a crucial element of the project. One area of concern is individual and team stress. Whether stress is deciding on a design, types of modeling to use, prototype production, or missing preset deadlines, teams must be mindful of its ability to overwhelm team members and the group. Instructor intervention may be needed. Instructors may briefly take over the leadership role and ask for feedback on what the issue/issues is/are. They may reassign individuals to different duties, create distance between workstations for members who need to display teamwork or offer suggestions to change some of the design features (Savelsbergh et al., 2012).

Instructors must act in these cases, especially when the stressful atmosphere among individuals or teams is tangible or disruptive to the project. Otherwise, project success will be almost certainly unattainable.

5. Implement the Plan

Teams may have to tweak or completely overhaul their design concept, create a new model, and test and re-evaluate the newly produced item. Through dissecting/disassembling and analyzing the individual components, the team may discover design or manufacturing flaws and make the necessary changes/adjustments to perfect the product. Teams may need to step back and evaluate their situation and decide not based on student grades but on making the best attempt to create a product that meets the initial design specifications. In these situations, teams enter a new dynamic in the project: situated cognition and the potential effects on the team if they must dissect or scrap the entire design. Students may take time to reflect on what led to the failure of their product. When the team successfully tests/evaluates the product, it is time to bring the completed project to the approving authority, which in this case would be the instructor.

6. Communicate the Plan/Solution

The methods of communicating the results may vary. A brief discussion from a selected team member will suffice for simple designs. At the same time, extensive and complex projects may require much more detailed information to be shared/presented by the entire team. Individual members will discuss their contribution to the design and development of the product. Data obtained via documents and written reports create talking points; detailed engineering drawings with specifications, assembly, and other information assist with formal presentation development. The idea is for the team to articulate the processes they went through during the project, what worked well for them, what challenges they faced, and, more importantly, how well they responded to those challenges. The product/solution the team produced should be prominently displayed for discussion via question-and-answer format to critique and evaluate the team's mastery of the tasks required throughout the project. Each team member will discuss their involvement in each phase of the project. These presentations conclude the concept part of the project. If approval is authorized to bring the product to complete manufacturing, engineering drawings, and other relevant information will be sent to the engineers for production.

Reflective Writing

What is reflective writing? For this study, written reflection, according to Fink (2003), 'focuses on the writer's learning experience and attempts to identify the significance and meaning of a given learning experience, primarily for the writer (P. 301). Educators have used reflective writing for decades to assess student comprehension of delivered classroom content. The purpose of reflective writing from an instructor's perspective is to gather as much feedback from each student as possible to help capture their experiences and comprehension of project/problem-solving concepts and to allow them to think about new learning during the project. Another reason is to determine whether they grasped the concepts of technological and engineering design and whether these activities enhance a student's technological and engineering literacy skill development.

Reflection allows students to express their thoughts, ideas, and new learning that occurred and helps them enhance their meta-cognitive skills. Written reflection helps students improve their performance and increase their motivation to learn, even when dealing with complex or challenging learning content.

While student-written reflection is an essential part of learning, according to Cavilla (2017), the research literature on student reflection is limited, with much of the research focusing on instructors' reflections on their own experiences and performance during the classes they teach. This study will provide additional literature showing the effectiveness and value of using written reflection to assess a student's demonstration of technological and engineering literacy through problem-solving and design processes. So, how or when should instructors incorporate written reflection into their lessons, which in the case of this study is during project/problem-based learning activities?

One problem instructors need help with is where or when to introduce a written reflection during project-based learning activities/units of instruction and how to implement it properly. Instructors may need help explaining what reflective writing should look like or what the instructor is looking for (Wong, 2016). Instructors must consider several factors before implementing a reflective writing assessment method. For example, the amount of weight a written reflection as compared to the overall activity or instruction unit may vary, as determined by the instructor. Another issue relating to reflective writing is the way instructors grade a reflection. Do they have experience using written reflection, or have they taken classes that prepared them to use this type of assessment for their classes?

How, or what is the proper way to score a written reflection? Do instructors have a rubric that points out the key elements expected in the write-up, and are the rubric elements detailed enough for students to fully grasp what the instructor wants? Do they provide this to the student prior to the assessment? Lastly, the instructor must clearly explain to the student the purpose and expected outcome of the written reflection. Considering these elements is vital to ensure students have all the information required to produce a quality reflective paper.

SUMMARY

Chapter I outlined the topic of the study via a problem statement, discussing the issue of project-based learning and student-written reflections. The stated objectives that helped guide the study were introduced and discussed, as well as the background and the significance of conducting the study. The following chapter describes the research studies on this topic and instructors' different strategies when using reflective writing assessments.

CHAPTER II

REVIEW OF LITERATURE

This literature review details the studies on reflective writing assessment strategies and using project/problem-based learning environments to achieve a desired goal/outcome. Several methodologies, results/data obtained through researcher assessment instruments used to demonstrate technological and engineering literacy skills during these studies are presented separately, as they are unique from one another and bring different conceptual frameworks to the literature. Discussion of research relating to the steps of the problem-solving processes and the methods used to assess student written reflections relating to demonstrating technological and engineering literacy skills are provided. Teaching strategies related to reflective writing assessments, examples of different rating tools, and their effectiveness are discussed.

Technological and Engineering Literacy

Technological and engineering literacy, as defined by the International Technology and Engineering Education Association (ITEEA), is "understanding technology's impacts on their lives, society, and the environment, as well as how to use and develop technological products, systems, and processes to extend human capabilities (ITEEA, 2020, P 13)." Students often need more opportunities to learn about technological and engineering literacy. A synopsis of a study and a recent nationwide assessment of eighth graders illustrates this point.

A study conducted by a researcher surveyed college students taking a general education class relating to technological and engineering design over two years. Students answered questions about their knowledge of what it meant to be technologically and engineering literate. Students responded to items about their experiences with technology-based classes, including their awareness of how technological products are designed and developed, technological systems and the impacts technologies have on society. Findings provided insights into how students perceive their knowledge level relating to the designed world (ITEEA, 2020). The resulting data revealed a need for more technology classes the study participants took in college or high school. Approximately 70% of students reported they had not previously taken a technology class (Ritz, 2011).

Similar findings occurred in 2018 when the National Assessment of Education Progress (NAEP) T&E (technology and engineering) Literacy Test was administered to over twenty-one thousand 8th graders (NAEP, 2019). The results revealed that nearly 50% of these students had yet to take a technology and engineering class.

Design and Systems

Systems thinking is the concept of seeing the whole, not just components, AKA the big picture (Shaked, Schechter, 2019, p. 19). Participants who are tasked to create products as part of their academic studies, as well as in the future while on the job, are required to know not only how to work through the steps of the technological and engineering problem-solving processes but must also possess the ability to articulate these processes by utilizing a systems thinking approach. However, this is not always the case.

The lack of ability to demonstrate and articulate systems-thinking skills is a common issue with college students, particularly those seeking industrial technology degrees. This can apply to both undergraduate and graduate students. This was seen during a mixed-methods study that surveyed nearly fifteen hundred current students and graduates from a research university in Israel. This study aimed to identify multiple teaching and learning methods and determine which delivery method matches 21st-century skill requirements. Participants comprised 648 final-year students (undergraduate and graduate) and 930 alums from the University of Technion. Current students were selected from the STEM department's undergraduate and graduate programs of study. Former students/alums, some of whom graduated more than 30 years ago, also participated.

Data were collected via a survey in which both sets of participants were to self-report and rank, in order, using a Likert scale of 1-5, from a list of fourteen skills, those that were more developed than others during their time at the university (Lavi et al., 2021). Skill choices included critical thinking, complex problem-solving, engineering design, systems thinking, and others related to 21st-century workforce skill requirements. Before distributing the survey to participants, researchers asked several faculty and graduate students to review and validate the survey. Upon receipt of the initial response, STEM experts reviewed participant responses. When their review was complete, they determined that responses displayed satisfactory knowledge of the skills presented and that the survey was valid.

A repeated measures ANOVA was conducted to compare multiple dependent variables (within-subjects comparison) to determine how alum participants self-reported and ranked their development of the 14 skills presented in the survey. Mean scores were much higher for individual learning, complex problem-solving, and critical thinking skills (M= 4.61), (M= 4.43), M= 4.04), compared to systems thinking, which landed at (M= 3.75 and 3.70) for both alumni with an undergraduate degree, and those with a graduate degree. Results show that both groups self-reported and ranked systems thinking lower than six other skills. The skills were STEM knowledge application, question posing, engineering design, and the three additional skills mentioned above.

Data relating to the teaching delivery methods preferred by participants for each of the 14 skills presented were also obtained. Researchers identified nine categories ranging from revising course material, projects, research, lectures, course assignments, and four other methods. A table was created to show each teaching method, and the percentages were shown to delineate each skill with the corresponding preference. Several skills, as they related to teaching methods, showed high levels of preference. For example, entrepreneurship using project teaching methods comprised 94% of the total for that category, individual learning and revision of course material comprised 64%, and oral communication using course assignments was 61%.

For the systems thinking skills, participants chose lecture (43%), research (24%), and projects (19%) as their top three categories, with three methods receiving only 5% of the total. The final three categories were shown as having less than 1% of the total. To put this into context, of the nine categories of teaching methods, the top three methods preferred for systems thinking comprised only 27% of the total amount preferred by all participants.

These data are essential, as they convey the teaching and learning environments current and former students found to be more impactful for developing their 21st-century skills, including systems thinking. The importance these participants placed on systems thinking from the list of 14 skills indicates that students focus less on this skill than others. This may explain why participants in my study found it difficult to articulate what systems thinking is, even though the industrial technology curriculum provides them with many lectures, projects, and research opportunities throughout their undergraduate industrial technology courses to help them develop this skill.

Human Capabilities

Lousberg et al. (2019) conducted a study similar to mine that required participants to respond to four different questionnaires over the third year of an academic design reflection course. Their goal was to determine if students' reflection ability increased when given multiple papers to write relating to an architectural design project throughout the school year. Researchers established their methodology using the Moon (2004) model, which consists of four levels of reflection: descriptive writing, descriptive reflection, dialogue reflection, and critical reflection. Their research design focused on assessing their student's abilities to connect to the given project, which was to make an interior design of a museum. Four written papers were assigned to assess the students' abilities to reflect on the four elements of the project: "(1) the design situation, (2) the design theme, (3) the design process, and (4) the relation between design and academic research" (p. 886). This "reflect on-action" approach (Schon, 1987) was appropriate for this study, as the researchers set predetermined goals for the participants, as opposed to the "reflect in-action," which requires participants to document their experiences while they are performing tasks during the project (p. 26).

Researchers used two different evaluators to score the reflections during the study. One was a direct supervisor/instructor of one group of students, while another was a supervisor/instructor of a group they evaluated but not for the group. Evaluators used a reflective writing questionnaire/rubric consisting of sixteen inquiries, broken into four different levels found in the Moon (2014) model discussed previously. Evaluator feedback was recorded on a Likert scale, ranging from A-D, with A= strongly agree, B= more or less agree, C= more or less disagree, and D= strongly disagree. Researchers should have included the first assessment from the dataset during the assessment process, as they felt it needed to correspond with their four-part evaluation model. They deemed it more of a warm-up exercise for the remaining assessments.

Results indicated that mean scores for the three assessments increased for each round of testing. This was discovered via repeated measures one-way ANOVA, which not only showed an increase in means between both raters but also showed that the supervisor/instructor who scored their students gave higher scores than the instructor who rated their non-student scores. This correlates to my study's reflective writing assessment results, as the instructor scoring their students gave slightly higher scores than I did during the three-phase reflective writing assessment process.

Technological Development and the Impacts on Society and the Environment

A recent study by researchers in Australia sought to change the pedagogical methods for developing students' critical thinking skills relating to the environment in higher education. The goal was to present alternate teaching methods to improve students' critical and reflective thinking skills in various courses. The methodology for this study was a review of student reflective essays and course evaluations to show a justification for a multi-disciplinary approach to how students learn about humans' impacts on the environment.

Participants were from a school in Brisbane, Australia, taking a first-year course called sustainable development, which is part of these student's environmental degree programs. Researchers cited and selected three of the five education for sustainability goals listed by the Commonwealth of Australia (2009) and made them the focus of their research. Goals included: "interdisciplinary content, critical thinking and reflective thinking, and their effectiveness in deepening student learning through an undergraduate sustainable development subject (Howlett et al., 2016, p. 307). Reflective thinking was the most applicable and relatable goal of this study.

Data collection occurred during the semester of a newly designed class called sustainable development. Several faculty members and project leaders brought their individual experiences with reflective thinking to develop the course and teach various topics to provide a transformative experience for study participants. As part of the data collection process, researchers asked participants to write a short essay about their sustainability knowledge, how they knew this term, and where they obtained the information. This gave researchers insight into the student's level of knowledge related to this topic and a baseline to compare to the reflective essay participants were required to write at the end of the semester.

They also included lectures from the university's School of Environment, covering economic, cultural, and societal issues relating to sustainability. Students were tasked, via reflective essays, to develop arguments for and against nuclear energy use using the previously covered topics. This was done to stimulate students' thinking about a controversial environmental issue and allow them to think critically about future nuclear energy use. The last task given to participants was to write a reflective essay relating to their transformation of thoughts and ideas relating to sustainability and the environment during the semester.

Results indicated that researchers, using a constructivist teaching approach and reflective writing assessments, observed significant improvements in participants' learning about sustainability, going so far as to say that participants' learning abilities had transformed over the semester. They discuss transformative learning as how our mindset changes when introduced to concepts that challenge our current understandings or previous viewpoints (Cranton, 2006). This study demonstrated that reflective writing after topics related to sustainability as it relates to the environment is highly beneficial in higher education settings. It helped move students towards a critical-thinking approach when dealing with controversial issues relating to global sustainability and the environment.

Strategies For Assessing Technological and Engineering Literacy

The following few pages discuss research on using multiple-choice and fill-in-the-blank assessment instruments to assess technological and engineering literacy. They also discuss instructors' different strategies and methods to administer and assess reflective writings. They include different technologies and tools used to deliver these assessments. Research findings and outcomes related to the use and effectiveness of these technologies are discussed. The following research points out the importance of instructors using reflective writings to assess how much technological and engineering literacy is being developed by students during the school year and whether assessments are required weekly, monthly, or quarterly, as determined by the instructor.

Multiple-Choice and Fill-in-the-Blank

One study aimed to introduce a new model for assessing technological and engineering literacy. The researcher looked at the benefit of using multiple-choice and fill-the-blank questions as the primary method for assessing knowledge related to technological and engineering literacy (Asivek, 2015). Many of the studies reviewed by the researcher focused on these assessment methods. A test bank inspired by the Standards for Technological and Engineering Literacy, a publication from the International Engineering Education Association (ITEEA, 2020), was used to develop the assessment instruments for the study. Three questions from each technological and engineering literacy standard benchmark for grades 1-12 were developed, with difficulty measured from Bloom's Taxonomy (Bloom, 1956) and Quellmalz's Taxonomy (Quellmalz, 1987). The goal was to increase the content validity of this model. Multiple-choice questions served as the basis for the study.

There were several reasons for this assessment method. The researcher cited the quick response aspects of these assessments and the ability of students to make immediate connections to learned content. The researcher also discussed the negatives related to this assessment method. They were explicitly citing the opportunity for students to guess answers rather than knowing the answer or concept of what the question is asking. The difficulty of creating distractors and misinterpretation from students reading too much into the question was a factor. The problem with these assessments is that they need to allow students to articulate what it means to them to be technologically literate, which is at the core of technological and engineering literacy. When using multiple-choice assessments, knowledge is constrained to the items included for each question, and there is no way to assess the affective traits of the student with multiple-choice questions (Asivek, 2015).

Pilot testing for the validity and reliability of this model was performed, and a content validity rubric was developed to help determine the sample size for the study. Two tests using five forms (A through E) were developed to determine the more reliable form. The first test used 116 students, while the second used 23 students. Three different schools participated and took the tests. Cronbach's α (Alpha) analysis determined which of the forms had the most internal reliability. Upon completion of the tests, form C had the highest score of 0.71, and Form E had the lowest score of 0.54. The results indicate that focusing on these assessment instruments' internal consistency and test-retest reliability was effective (Asivek, 2015).

Assessment models of this nature may help instructors find ways to advance technological and engineering literacy at every level of the K -12 education system. While the approach discussed above may contrast with this study's reflective writing perspective, it provides insight into the literature on this topic and the amount of emphasis instructors place on these assessments. The following section will discuss instructors' various high school and college reflective writing strategies.

Instructor Perceptions

Reflective writing is becoming more prevalent in higher education, especially in experiential learning environments like those offered in STEM and Industrial Technology disciplines. An exploratory, qualitative study was conducted to investigate instructor perceptions of using a reflective writing method as an assessment tool. Several research questions were posed, ranging from instructor understanding of written reflection, understanding the assessment of reflective writing, instructor preparation to assess student reflections (professional development), and improvements that could be made to the process (Chan et al., 2020). Three instructors and three teaching assistants participated as scorers of the written reflections. They were given scoring sheets to grade each reflection. The scoring range was 1-5, with one being poor and five being excellent. Before initiating the study, researchers used two coders to validate the different coded categories relating to the research questions, who achieved an excellent rater agreement (Cohen's Kappa .896). Data were also collected via instructor interviews to determine their level of knowledge and opinions on assessing student writing.

Participants were first and second-year college students from various disciplines, engineering science, selected from several universities. A total of 135 students participated in the study. During the five-day program, participants were given several activities to test their skills across different categories/subjects. The goal was to analyze their reflective writing capabilities to determine what they learned and what they would do differently next time.

Results showed that four out of six instructors believed reflective writing was valuable for assessing student performance. Instructors pointed out that reflection allows students to consider more than just learning content but the individual's abilities to articulate their experiences meaningfully. When asked about the level of reflection they observed during the scoring portion of the study, instructors rated student proficiency at a descriptive level (1,2), which aligns with the four-category Moon Model (Moon, 2004) discussed in chapter one.

Researcher data showed instructors believed reflection was dependent on the individual student and that results would vary from student to student. For example, one instructor noted: "Learning outcomes in experiential learning are highly personalized, as each student has different experiences, and hence different learning outcomes." Instructors who did not believe reflective writing was an appropriate assessment method felt that students were being forced to reflect and found it challenging to assess written reflections. One instructor said, "We cannot force students to reflect." "…because I find it difficult to assess students' reflection in a written form for this assessment" (Chan, 2020, p. 9). There was consensus among instructors that reflection, when used as a reviewing process, is vital to provide opportunities for students to gain insights into their daily assignments at school, that it can increase their self-awareness, and to identify areas needing improvement.

Researcher data indicated that instructors had yet to receive formal training in reflective writing assessment methods, which they felt made them less confident. All instructors indicated that they needed to familiarize themselves with how to score student reflections. Confidence levels varied between instructors, with an even split of three having some confidence and the other three having little to no confidence. Some instructors also revealed that this was the first time they had performed this task. This led to many instructors needing help with scoring student reflections.

The final data point provided information relating to instructor recommendations for improving reflective writing assessment procedures. One suggestion was to have course assessment standards differ between reflective writing and standard assessment (multiple-choice, fill-in-the-blank, group projects) practices by incorporating a pass/fail for reflective writing. Another suggestion was to provide students with exemplars to assist them with their writing, examples of reflections for each grade level, and guidelines (rubrics) for each assignment. Lastly, instructors suggested that no grading should occur, as reflection should focus on the learning process and not be limited to what an instructor may want from students. In other words, it allows the students to write freely and not be confined to instructor guidelines or rubrics. These data show that instructors have varying opinions about reflective writing, with some believing it should be used as both a learning tool and a "cognitive, affective and social process " (Chan, 2020, p15)." From these differences, researchers concluded that there was an urgent need for instructors to be afforded training in this assessment method as part of their regular professional development to help them engage with their students during the semester.

Reflective Writing and Discussion Groups

The focus of one research study was the use of individual student experiences from a case study conducted by the author. However, with a twist, she conducted the case study based on her experiences in online learning environments in 1998. Her experiences helped frame her current instructional/course design approach to her current profession. The emphasis of the study was to illustrate how reflections are not only a means to report/document learning or individual feelings related to learned content but also how interactions and collaboration with other students may lead to individual growth, including new learning or self-discoveries that occur during these units of instruction.

The author discussed the use of reflection in an online, Open-University setting. The first part of the case study was a review of a master's level degree program in open, distance education, with a focus on content delivery methods, which in this case were via discussions of print-based materials, with tutorial support tools used as needed for the student. Several activities were discussed, such as moderating a conference, synchronous conferencing, conferencing and assessment, and a final assessment on reflective thinking. During the moderated conference, three groups participated in varied activities, based on moderator guidance, to allow students to discuss, collaborate, and consider ways to improve the learning experience in the open education system. Moderators were from varying backgrounds and experiences. One moderator was a multimedia professional; another was a primary and secondary school instructor; and the author was, at the time, an exhibition organizer.

Several vital issues relating to online conferencing discussed among the three groups were: 1. Improving the capability of currently-used conferencing tools to newer, more capable tools currently unavailable. 2. The way that interactions clarify meaning (group discussions ensure everyone is on the same page). 3. Cultural considerations while conducting a computer-mediated conference. 4. Censorship, freedom of expression, and individual and group responsibilities during conferencing. These were new topics, especially in 1998 when open education, mainly conducted in distance learning environments, was still emerging, which the author perfectly conveys through discussing these issues (Roberts, 2002).

One of the main findings from this case study was the use of peer-to-peer discussion groups/feedback to bring authenticity to these types of activities in the distance learning environment. Along the same lines was how the interaction provided perspective to the author and allowed her to use these peer-to-peer interactions to gather perspectives from others rather than just forming arguments, defending, or having counter-positions to other ideas offered by group members. Here is where collaboration and teamwork come into play. Motivation is also a factor, as demonstrated through the author's discussion regarding the two types of discussion boards used during this study. One discussion board was conducted synchronously, and the other asynchronously. Students could reply or interact in either of the available threads. The author noted that the asynchronous threads were often unused, as students were more motivated to interact than to leave a message and hope for a reply.

Another result discussed by the researcher is the need for students to be prepared to reflect. A lack of prior experiences or opportunities to reflect on their learning experiences had been discovered in previous courses. How instructors are supposed to guide students was another issue, as many instructors need to learn how to prompt or guide students in reflecting on the essential points instructors are seeking. The question becomes: How much is too much guidance, and how little is too little, especially if there is an assessment element to the reflection? When asking students what they thought reflection was or how it is defined, they often under-valued it (Roberts, 2002). The following few pages discuss potential methods and strategies to guide student reflection.

Reflection Prompts

The use of high-level prompts during problem-solving activities is highly effective in a variety of learning environments. In one study, 157 university students from Taiwan were assigned to 14 different groups, with group sizes ranging from 6 to 20 participants. Groups were divided, with seven groups assigned as the treatment group and seven as the control group. The goal was to measure the response differences between the treatment and control groups within a three-category set of prompts/conditions: high-level prompts, high-quality peer observation, and peer feedback (Chen et al., 2008). The peer observation and feedback conditions varied by group, with some receiving no observation or feedback, some receiving low-level observations and positive feedback, and groups receiving high-level observation and negative feedback.

Three procedures were used in this study, one for each condition, with the number of steps ranging from four to six, and each experiment only lasted about an hour. Reflections were administered upon completion of a reading assignment on a biology topic. They were conducted in two ways: the "with high-prompt" groups, guided by pre-drafted questions to assist them with their reflections, and the "without high-prompt" groups, who had to create questions and develop answers independently. Two opportunities were provided to the participants to write their reflections once they finished reading the given article and the next after they received peer observation or feedback, as applicable.

Results indicated that the groups in the high-quality prompt and high-quality observation scored moderately higher than those in other groups. Participants in the peer feedback group showed no change in their reflection performance. Researchers noted that strategic prompts will result in higher reflection skills and abilities.

Researchers from another study used prompts differently. They investigated how participants would perform during activities using hypermedia learning tools consisting of two verbalization methods: a reflect when-prompted technique and a review of video technique showing participant's performance during these activities. The goal was to conduct a dual study, with one study to determine participant's metacognitive abilities when working in an online activity using hypermedia while interrupted. The second study examined participants' performance while being prompted to reflect during a hypermedia activity. Seventy college participants, mainly women (83%), were selected for the study. Participants filled out a questionnaire to help researchers gather student's characteristics. Once researchers reviewed the questionnaire, researchers placed participants into three groups: two treatments (N=24/group) and one control (N=22). Students were administered baseline tests to establish their strengths and weaknesses in several learning areas. A student's prior learning strategies experience was measured using the Literacy Intelligence Structure Test (LIST questionnaire) (Wild et al., 1992), used to test a student's metacognitive knowledge using a multiple-choice test. The Intelligence Structure Test (IST, 2000) (Amthauer et al., 1999) measured verbal, numerical, and figure intelligence, reasoning, and overall knowledge of these items. Lastly, motivation for achievement and fear of failure assessment was administered using the Leistungs Motivation Test (LMT). This test assesses how students rationalize their success or fear of failure due to external and internal factors and how these fears affect their performance during assessments (Hermans et al., 1978).

The first part of the study was to show students how to navigate in a hypermedia program using HTML scripts in a search engine called Netscape. The next phase of the study was a learning session, which included each group performing a task to review several nodes selected by researchers. These nodes consisted of learning content in text, pictures, and hyperlinks that led to other materials. Researchers used interruptions every minute to prompt the students to discuss what they had read. Another researcher believed interruptions should occur every 5 minutes (Drewniak, 1992). Treatment groups read and thought aloud while performing the activity. In the event of silence during the activity, the researcher would encourage them to continue. Other treatment group prompts were set at various pre-arranged stopping points, with researchers asking students why they selected the specific node(s). Control groups worked silently, receiving no prompts to use any verbalization techniques. All group sessions were recorded. The study concluded with a testing phase, which included participants filling out a questionnaire called the Scale of Perceived Disorientation regarding their perceptions of interruptions during the learning phase (Beasley & Waugh, 1995). This was followed by the LIST questionnaire (Wild et al., 1992).

Results of the disorientation and interruption questionnaire showed significant differences between treatment groups and the control group, with the reflect-when-prompted group scoring higher than the control group, as predicted by researchers in their hypothesis.

Results relating to student strategies during activities indicated no significant differences between groups concerning knowledge, recall abilities, or transfer. Researchers had hypothesized that there would be significant differences between groups using different online verbalization methods (read and think aloud, pre-arranged prompts), so their hypotheses were rejected.

Researchers discussed the content validity of their two questionnaires by explaining how trained raters coded each participant's work. In the event of an obscure response by the participant, a second rater would review the work and collaborate with the original rater to record the final score. Finally, analysis of the questionnaires indicated they could have been more effective in gathering data for predicting learning performance compared to data gathered from researcher observations. This study showed another way for instructors to use reflective prompts to enhance learning. Next, reflection triggers as a strategy for assessing reflective writing are discussed.

Reflection Triggers

Researchers have used reflection triggers or structured opportunities for students to examine and evaluate their learning (Verpoorten et al., 2011). In one example, researchers performed a comparative study incorporating reflection after an activity or unit of instruction. Students could express their feelings about the learning content and address other issues they may have encountered during the assignment. What was significant here is that the triggers, delivered at multiple intervals through built-in pop-up knowledge checks, were used to stimulate reflection. At the same time, learning took place instead of being presented as an add-on at the end of an instruction unit. The goal was to determine if using these triggers and including an opportunity for students to reflect on their experiences increased student metacognition and contribution to learning. A concise study conducted during a two-hour block of instruction emphasizes three types of student reflections: receiving information, giving information (student's perspective in the form of feedback to the researchers via a five-part questionnaire), and verbalizing information.

The first trigger was a comparison of actions taken during the course by one student and compared to the number of actions taken by previous course participants. The second trigger was a self-perception of mastery of learning using a self-reporting rating scale. The third trigger was a comment box for students to use at the end of the learning module before exiting the class to discuss what they learned. Fifty-four participants were placed into five different groups. Three groups received only one of the three referred-to triggers, one group received all three triggers, and one group received no triggers.

Results showed that groups receiving triggers reported that they felt a higher sense of engagement in reflection compared to those who did not receive triggers. The overall result was that triggers did not significantly enhance student learning, assessment performance, or retention of information given during the activity. However, feedback from students did demonstrate one positive result. Participants reported that instructors using reflective triggers enhanced their knowledge of the strategies involved in the study. The study's small sample size and brevity were cited as potential limitations to the data collection portion of the study.

One qualitative, descriptive study looked at reflection triggers at four public and private universities in Iran. A total of 58 participants, consisting of nursing seniors (N=32), their instructors (N=17), and newly graduated nurses (N=9), participated in the study. The study aimed to gather participants' opinions on using reflection triggers in nursing education environments, emphasizing reflection dialogues as the learning strategy. This study was conducted over one year, with researchers collecting data via 26 semi-structured interviews with newly graduated students and instructors and four focus groups with current students.

When appropriately used, reflection dialogues (triggers) or verbalized reflections can improve reflection effectiveness in most learning environments. This is especially true when instructors and students interact, and an instructor introduces a trigger. Triggers in this study were induced in a clinical learning environment (Murphy, 2004). The amount of experience an instructor has using triggers is also critical. The trigger may catch the student off-guard and generate a wide range of emotions, such as anxiety, anger, and even happiness (Howatson-Jones, 2016). The instructor must prepare to remove adverse reactions and emotions and get the student to stay focused and work through the problem. Reflection triggers are influenced by factors such as the context in which the trigger is used and the thinking and learning styles of the student (Smit & Tremethick, 2017).

Researchers developed an interview guide using existing materials from previous studies and conducted a pilot test with two instructors and two students. Researchers collected data via interviews and focus groups in 45-to-60-minute blocks and recorded on a digital audio recording device. Interview and focus group content were reviewed and transcribed after each iteration. Data were analyzed using a coding software program, with frequently-used terms placed into four main categories, with several sub-categories.

Results were presented in a numerical format and based on the following triggers used in the study: conscious comparison of actions, confrontation with influential realities, emotional and moral involvement in patient care, and demanding accountability. Each part was discussed and included interactions and reflections relating to the scenarios presented during the study.

Comparison results indicated participants who, when given different scenarios during class, were allowed to compare current situations with previous experiences or even prompt themselves to think of future events related to the topic discussed. Nurses face many different situations during their careers. The ability to tap into previous experiences can help them successfully navigate various health issues patients present.

Confrontation with influential realities helped participants better understand what they knew about patient care and what they did not know due to their lack of experience. Instructor/student interaction is essential. Instructors with years of medical experience could share and guide participants through complex scenarios by sharing those experiences to help build a connection to new learning and a greater sense of confidence for the participant.

Emotional and moral involvement in patient care provided the most significant insight into how participants perceived their awareness of the emotional and moral issues relating to patient care. Instructors asked participants to discuss their emotions after performing a task during a given scenario. The critical element was the instructor's asking participants how they felt they had performed, how they administered care to a patient, and the treatment results. Instructors also asked participants to think of patients as family members, which achieved a higher level of reflection by the participants than any other category (Bagheri et al., 2019).

The last category, demanding accountability, was used to trigger reflections on the individual participant's accountability to themselves, their chosen profession, and their patients. Participants shared their beliefs and motivations for doing the right thing for their patients. Beliefs included providing quality care, understanding their motivations for pursuing this profession, and taking responsibility when something goes wrong. Instructors used a reward/punishment prompt as a strategy to entice reflection. They even went so far as to use participant's religious beliefs as reminders that God sees all. A great deal of reflection was extracted from participants. For example, all participants willingly shared their motivations for becoming a nurse, with many expressing their connections to their consciences and the need to ensure they always kept their patients safe. In their minds, this was a serious life/career choice.

Researchers observed instructors engaging and prompting individual participants with different medical and clinical scenarios to encourage reflection. They discovered that during all group activities, individual reflection was triggered. Using scenario-based group discussions, including opportunities for individuals to reflect on the processes/procedures they encountered, made the situation more realistic and meaningful for the participants. These learning environments allowed participants to explore their emotions, motivations for wanting to become a nurse, and their priorities when dealing with patients. This study demonstrated the ability of instructors with years of experience in the medical field to encourage participant reflection and extract rich data for researchers to analyze and expand the literature on this topic.

Project-Based Learning

The goal of project-based learning is to help individuals or teams, through collaboration, develop strategies to achieve a goal or objective, which in this case would be completing a task relating to the steps of technological and engineering design processes. These processes would be supported and evaluated via the design of learning activities, various assessment instruments, and an evaluation/observation on the part of the instructor of the teams' overall effectiveness relating to the project. Students must have the proper mindset towards the project. As noted by (Johnson et al., 2018), "Individuals who approach a learning situation to develop their skills, rather than the goal of performing well, are said to have adopted a Mastery Goal Orientation

(MGO) in that context (also referred to as a learning goal orientation) and are, therefore, more likely to benefit from that learning experience" (p.2).

Researchers conducted a meta-analysis of seventeen studies based on five-part selection criteria to determine the effectiveness of project-based learning and content knowledge outcomes. The main selection criteria, based on the researchers' use of team-based learning sequence strategies called the Individual Readiness Assurance Test (IRAT) and Team Readiness Assurance Test (tRAT) as a preparatory measure to determine if students could perform group work. Not all students took both tests. TA comparative analysis was conducted to determine if one group would perform better than the other based on whether they took both tests or only the tRAT test.

This pretest, or formative assessment, allowed instructors to judge student performance and use it to assign students to groups. Pretests are an effective strategy for activities involving competition between groups. While reviewing the studies, researchers noted that instructors conveyed a secondary purpose for the quizzes. When placed into their permanent groups, students were readministered the quizzes. This time, groups rather than individuals discussed and agreed upon answers. This strategy was an interesting twist to the project-based learning process, as it required cooperation and accountability within the groups and factored in individual accountability. This is crucial when designing instruction for project-based learning scenarios: controlling for group sizes and establishing a collaborative learning environment.

Results from twelve of the thirteen analyzed studies indicated that groups who took both tests outperformed those who only took the tRAT test. Students who received team-based learning also outperformed students who did not receive team-based learning. Class grades, including final grades, were higher for those who received team-based learning instruction compared to those who had not received team-based learning instruction (Swanson et al., 2017).

Instructors should consider that students bring their experiences to the project/problem. They allow students working in these environments to communicate, collaborate, and share ideas and thoughts in a peer-to-peer setting. So, how do educators create these dynamic learning environments? Depending on the team's size or the project's length, individuals are placed into groups, with informal leaderships and team dynamics forming to maximize performance cooperation and, ultimately, deliver a result that meets or exceeds the goals or objectives of the project. These environments offer students a rare learning opportunity, and educators must consider all of this and approach activities and project designs around these tenets.

Project-Based Learning in Online Learning Environments

Distance education is an area where project-based learning faces many challenges. First and foremost is the need for physical interaction between students and instructors that students in face-to-face learning environments experience. This ties directly to the theory known as the zone of proximal development: The distance between students, peers, and instructors and the potential for students to develop new problem-solving skills under the guidance of an instructor or peers who have developed advanced skills from previous experiences (Vygotsky, 1978).

Educators must consider that students bring their own previous experiences to the project/problem. During online courses, instructors may use various interactive media for students working in group environments to communicate thoughts and ideas in a peer-to-peer setting, depending on the technology available (Zoom et al., WEBEX). Like face-to-face courses, individuals are placed into groups, with informal leaderships and team dynamics forming to maximize performance cooperation and, ultimately, deliver a result that meets or exceeds the goals or objectives of the project.

Product development may need to improve, as students cannot access physical materials to create models/prototypes. However, instructors can overcome this issue by providing access to 3-D software programs (Tinker et al.) to allow students to collaborate in these settings to develop models of their proposed product while working in simulated conditions. Keeping students motivated to complete the project is also vital. Deadlines may be created at various pre-designated intervals to check on team progress. Instructors are provided opportunities to evaluate which teams are working well together and those who are falling behind and need guidance. Feedback on progress is vital, especially for those teams needing to catch up with the project. An instructor's teaching strategy of incorporating student-written reflections can help identify and potentially alleviate these issues and make project-based learning experiences worthwhile in distance education learning environments. Working in online environments offers students a rare opportunity to perform group projects.

Project-Based Learning and Adult Students

Much of the literature review up to this point has focused on project-based learning and instructional design from a seemingly introductory-level approach, with an emphasis on educational environments at the secondary school level. However, several studies were conducted to determine where the field stands regarding project management and leadership development with content designed for adult students and situations related to workplace settings. These are essential areas for instructors to consider when developing project-based learning activities for environments that include adult students.

One researcher whose literature review cited well over a dozen recently conducted studies highlighted the effectiveness of project-based learning designs that focused on developing highly valued professional skills (social, critical thinking, and problem-solving) in the workplace (Scott, 2017). The researcher points out that to meet the needs of workforce leadership development; many larger companies have entire sections of their human resource departments dedicated to designing instruction and training employees through leadership learning activities aligned with project-based learning and action learning in non-traditional learning environments. Computer-based training models provide companies with a highly effective way to develop the critical skills managers need. However, there has been some pushback from researchers regarding the need for evidence-based guidance on processes and outcomes or what improvement programs such as this need.

The researcher does offer a solution to the naysayers who point out the empirical shortcomings/gaps in research on the effectiveness of project-based learning and action learning. Each part of the design process is discussed, pointing out the need for evaluation/measures to be in place throughout the project/problem to better understand what pieces of the course design practical and what items require improvement. The researcher discusses the need for flexibility to meet the training goals/outcomes the company or organization desires. There is discussion about the leading learning theory associated with project-based learning, constructivist theory (Dewey, 1910), and recognition of the need for cognitive skills, which are also critical to project-based learning. This study has set the tone for future research on project-based and action learning in adult education learning environments. The researcher urges additional studies to be taken on this topic, offering recommendations on evaluating the effectiveness of instructional design, citing that individual and group analysis should be examined. They also point out that to truly capture appropriate levels of measurable data, longitudinal studies should be conducted.

Social Loafing During Project-Based Learning

One issue frequently occurs in group project work is that some students blend into groups, contribute very little to the project, and become "social loafers." This concept was first discussed in 1979 when Latane, Williams, and Harkins used social loafing, deeming it a "disease" due to its impact on individuals, social institutions, and society (Latane et al., 1979, p. 831). In 1993, researchers Steve Karau and Kipling Williams conducted a meta-analysis of 78 studies using several predetermined keywords (social loafing, free-rider, collective task, collective performance, motivation loss/decrement) to obtain data relating to social loafing, and the magnitude of this phenomenon across society. Karau and Williams point out that other researchers have offered interpretations of social loafing (social impact theory, arousal reduction, evaluation potential, and self-attention). While important, they discuss that these interpretations focus on dealing with social loafing but not the factors contributing to social loafing.

After the study using a Collective Effort Model (CEM), which generates predictions for the meta-analysis, researchers determined that social loafing is most prevalent in group work. Social loafing was present across many business sectors, and various tasks were being performed by the groups. Especially if tasks are mundane, seen as insignificant within the scope of the overall project or job, or there is no feedback mechanism (workers need to feel valued). It was also determined that social loafing cuts across different demographics (gender, culture, age), though researchers report that the level is lower with women from Eastern cultures. The closeness of workers was also a determining factor regarding the level of social loafing. Researchers pointed out that workers who were friendly towards one another and considered each other teammates significantly reduced the effect of social loafing compared to those workers who were merely acquainted with one another (Karau, Williams, 1993).

One solution to prevent social loafing is to design activities that incorporate individual assessments, thus allowing instructors to close this loophole. During this study, researchers took it one step further. During the group assessment, team members brainstormed and offered alternative solutions to their current design. If the instructor disagreed with their new proposals, additional solutions had to be developed, which forced all team members to participate in discussions and new design concepts/ideas. This teaching strategy prevented social loafing from happening with this group of students.

Another potential solution to prevent social loafing is incorporating written reflections into the assessment process. When guiding student writing, instructors may solicit writing via questions requiring them to write about specific points relating to their work during the project. Instructors better understand who completed work and who did not, which may be helpful, especially in cases where the instructor could only observe some group members throughout the project.

SUMMARY

This literature review discussed the technological and engineering literacy research, which is extremely limited in scope from a theoretical and practical perspective. The reflective writing teaching strategies and how to assess reflective writing using different assessment tools/instruments were discussed. This chapter discussed the origins of project-based learning and a breakdown of the steps of the problem-solving processes. Issues relating to project-based learning activities in online learning environments were also discussed.

Throughout this literature review, researchers presented a common theme and how they approached their study of this topic: They sought to create learning environments and outcomes that were developed from frameworks emphasizing a need for learning that goes beyond the traditional lecture-formatted classroom, where so much of the learning focuses on individual learning and individual outcomes. Researchers also point out the need for reflective writing to be meaningful, with students provided proper guidance and motivation to perform these tasks in class. Chapter III addresses the method, participants, and procedures used in conducting the study. Scoring rubrics' validity and reliability will be presented, as well as study limitations.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

The purpose of this study was to examine how industrial technology students' written reflections were being utilized during problem-based learning units of instruction, emphasizing the amount of technological and engineering literacy students developed through these assessments. Chapter three discusses instructor opinions relating to the use of reflective writing assessment strategies. The research design, population selection process, administration of the assessment instruments, safeguarding of collected data relating to human subject privacy, and how it was analyzed will be discussed.

Research Design

This study's goal was to answer two research questions. Research question one asked: How much emphasis does an instructor with a university's industrial technology program of study place on students' written reflections? Are they considered an essential part of their assessment strategy for their students? Research question two asked: Do targeted, repeated written reflection assessments throughout a college semester indicate that the industrial technology program of study adequately educates its students in the three elements of technological and engineering literacy?

Research question two asked: Do targeted, repeated written reflection assessments throughout a college semester indicate that the industrial technology program of study adequately educates its students in the three technological and engineering literacy elements? Assessments were administered to participants during and after a project-based learning activity/instruction unit. The goal was to capture the mindset of student participants while their experiences were occurring, completed, and still fresh in their minds. Data gathered from these questions will provide insights into written reflections and their value as a learning tool for students assessed in reflective writing in project-based learning activities.

Interpretive Phenomenological Approach Research Design

I used a qualitative and quantitative research design to answer the research questions for this study. The qualitative process of the study was conducted through a series of three interviews with an instructor guiding students through an industrial materials class and eleven students enrolled in their class. I used an interpretive phenomenological approach (IPA) for these interviews. A phenomenological research approach uses individual experiences and perspectives, which, in this case, relate directly to their current experiences in both pedagogical strategies (classroom practices) and student learning. According to Alase (2017) and Smith et al. (2009), three of the most acknowledged modern-day minds (theorists) in the IPA approach, stated that "IPA is a qualitative research approach committed to the examination of how people make sense of their major life experiences" (p. 1). Additionally, they asserted that "IPA shares the views that human beings are sense-making creatures, and therefore the accounts which participants provide will reflect their attempts to make sense of their experience" (p. 4).

Participants

Participants for this study were from the faculty and student body of a university in the southeastern United States. One industrial technology instructor with years of experience in Industrial Technology Education, twelve junior and senior students enrolled in a manufacturing and construction class during the fall 2022 semester, and seventeen junior and senior students enrolled in an industrial design class during the spring 2023 semester were invited to participate in the study. Only one instructor from the industrial technology faculty was interviewed, as they were the only ones who taught 300 and 400-level courses that emphasized technological and engineering design.

Fourteen student participants majoring in the STEM Department's Industrial Technology program were selected due to their extensive experiences in performing project-based learning assignments as part of their degree program, with two participants pursuing technology education and electrical engineering degrees. Participants ($N = 29$) were selected as a convenience sample due to my ability to access these participants. Convenience sampling is widely used in research and allows researchers with limited financial resources or access to total populations an opportunity to select participants randomly or non-randomly. While this may limit the scope of the research to only sub-populations and not to total populations, they offer high internal reliability if the results are credible (Andrade, 2021).

Limitations and Assumptions

Limitations of this study include the instructor's and my lack of training in reflective writing or how to teach students to reflect. Inviting students from other university colleges would have provided a larger population for me to choose from to increase the power of the study. However, since this study emphasized junior and senior participants enrolled in the industrial technology program with vast experience in performing project-based learning, limiting invitations to these participants was the best option. Lastly, participants were not offered formal instruction or lessons to prepare them before administering the three writing assessments. Further details are provided in the methods section below.

One assumption was that students needed to be formally trained to write a reflection correctly, especially when dealing with the complexities of project-based learning environments related to technological and engineering design and development. Another assumption is that students would be either juniors or seniors, as the courses were 300-level. Another assumption is that these participants have vast experience performing tasks related to project-based learning activities/units of instruction.

METHODS

The purpose of this study was to examine the way instructors were utilizing student written reflections during problem-based learning units of instruction. The assessments focused on the three elements of technological and engineering literacy: design and systems, human capabilities, and the impact of technological development on society and the environment. Data on instructor opinions and assessment strategies for reflective writing assessments were also sought. Additionally, interviews with one group of participants were conducted during the study. Administration of the assessment instruments and other data collection methods will be discussed.

This qualitative and quantitative descriptive study approach is well suited for this type of research and was selected to broaden the scope of the study by combining statistical trends with lived experiences instead of focusing on a single methodology (Bryman, 2006). I had the opportunity to gather data from multiple sources instead of limiting the focus to one section of the subpopulation. Three interviews were conducted with an instructor presenting an industrial materials class. Each session was recorded, transcribed, and coded using descriptive coding procedures. Similarly, a single interview with students was conducted during the spring 2023 semester, which was also transcribed and coded.

Instructor Interviews

The initial qualitative data collection was conducted via three interviews with an industrial technology instructor from the STEM Department of a large university in the southeastern United States and a single interview of eleven students enrolled in the department's STEM 382 industrial design course. Instructor interview questions may be found in Appendices D, E, and F, and responses in Appendices G, H, and I. The instructor was informed via an emailed letter regarding the nature of the study, the information they would be asked to provide, and the methods taken to protect their privacy. A copy of this informed consent letter may be found in Appendix C. Several interview questions were developed in alignment with the research question, one of which focused on how instructors use reflective writing as part of their assessment strategies during project-problem-based learning units of instruction. Instructor interviews were conducted via Zoom meetings.

I conducted instructor interviews using questionnaires I developed prior to the study. The interviews aimed to gain insight into the individual instructor's opinions, experiences, training, and teaching strategies, if any, for using reflective writing practices to assess student performance during project-based learning units of instruction. I interviewed the instructor before commencing the written reflection assessment process, which allowed me to understand their pedagogical beliefs. I knew the instructor used written reflection as part of their assessment strategy, but I needed clarification on their use. Once the interviews were completed and recorded, they were coded and analyzed using a descriptive coding method.

Student Interviews

Student interviews were conducted to supplement/support data from participants who performed the written reflection assessments the previous semester. I used the same questions for the reflective writing assessments, which may be found in Appendix J. They were conducted online via a Zoom Meeting Room and in face-to-face settings. Interviews were not given a numerical score. Additional qualitative data were obtained via descriptive coding of the responses provided by participants and my written feedback on the questions posed during the interviews.

Reflective Writing Tutorial for Participants

Before commencing the reflective writing portion of my data collection, I interviewed the course instructor to gain insights into their use of reflective writing strategies for their Industrial Technology courses. I initially planned to include a brief tutorial to help guide the participants through the assessment process. After careful consideration, I decided not to provide a tutorial or guide on writing reflectively for participants to use during their three assessments.

This decision was based on several factors. I provided them with a scoring rubric during their assessments, specifically designed for the types of questions being asked. Also, during the first instructor interview, I learned that their reflective writing strategy was to allow students to think freely and not be limited by preset parameters or expectations. Providing them with a list of items for them to respond to would potentially limit their writing to only those items and not include other topics the student may have wanted to discuss. I felt this was the best option, as I wanted participants to respond to questions without restrictions and provide as much information and details as possible.

Reflective Writing Assessments

Quantitative data collection was conducted via three reflective writing assessments (Appendices L, O, Q) given to participants at preset intervals during the fall 2022 semester. The assessments focused on the student's ability to articulate their experiences during the problem-solving process associated with project-based learning units of instruction, emphasizing the technological and engineering design processes, not an assessment of the results of a specific outcome or developed product. Assessment questions were strategically developed and aligned with technological and engineering design processes as they relate to the three elements of technological and engineering literacy, how technology shapes society, and students' overall opinions of what it means to be technologically literate. The assessments were given at each preset interval for consistency purposes.

Before collecting data, I applied (see Appendix A) for and was approved by the College of Education's Human Subjects Review Committee to conduct the study. Several preliminary steps were needed to organize the proposed study. First, I emailed one Industrial Technology instructor in the department. I requested a Zoom meeting to discuss the intent to use their students in an upcoming research study during the fall 2022 semester. During the initial discussions, the instructor was asked to participate beyond their usual role as an instructor for this study. They were asked to consent to be interviewed three times over the semester. A consent letter was emailed as an attachment for them to sign and return. I also requested and was granted access to each class as a teaching assistant (TA) by the instructor. This was done to facilitate the coordination of administering the reflective writing assessments at set intervals during the semester and to reduce the administrative burden on the instructor.

As part of the initial coordination efforts, I requested that the instructor offer their students extra credit for participating in the study. This required negotiation about the amount of credit they were willing to offer, enough to incentivize the participants while giving only a little credit to take focus away from instructor-related assessments given as part of the course. The instructor agreed to give from one to three credit points to those who participated in the study. One point was given to each student consenting to be interviewed, and three points to those who participated in the three phases of reflective writing. I also offered participants gift cards ranging from ten to twenty-five dollars, ten for being interviewed and twenty-five for completing the three assessments. The repeated measures assessment plan was presented to the instructor a month before the semester. I provided them with a copy of the assessment questionnaires and the scoring rubric they would be using to grade submitted work.

I met with students taking a manufacturing and construction course and an industrial design course and explained the nature of the study. Consent letters (see Appendix C) were handed out in class and emailed to online students, collected, and counted to determine the number of participants available for the study. Data analysis focused on students demonstrating reflective writing skills relating to technological and engineering literacy during project-based learning activities.

The quantitative data collection process included a repeated assessment via a reflective writing instrument I created to assess student demonstration of technological and engineering literacy skills throughout a college semester. This assessment used project-based learning units of instruction as the learning area. A dependent t-test was used to analyze the results. As two different scorers were used to grade assessments, I conducted an interrater agreement correlation analysis and paired sample statistics to check for interrater reliability.

Three writing assessments were administered to measure student reflective writing skills on pre-designated dates during the fall 2022 semester. A post-assessment questionnaire was included as part of the final round of questioning to obtain student feedback relating to the assessment process and how they felt about this assessment strategy. After performing project-based learning activities, data analysis focused on students demonstrating reflective writing skills about technological and engineering literacy. The instructor and I graded submitted materials and researcher descriptive coding techniques to capture keywords used by participant responses as a data source. My involvement in scoring the assessments would provide additional scrutiny to the assessment scoring process. My individual bias was taken into consideration. Since I was not directly involved in the student evaluation process for the course, using the same scoring rubric as the instructor to assess participant performance would eliminate most, if not all, biases relating to the assessment process.

Assessment Questionnaires

Three assessments were structured to allow me to direct participants to focus on the three elements that make up technological and engineering literacy. These elements are design and systems, technology and impacts on society and the environment, and "how technology extends human capabilities" (ITEEA 2020, p.2). Each questionnaire focused on one of these three elements. Assessment questionnaires were administered using a prompt method, where I dropped questionnaires to coincide with student's completion of one to two small projects at the beginning of the semester. This allowed students to respond to selected questions while the details of their completed projects were fresh in their minds.

Questionnaire One (Design and Systems)

Questionnaire prompt one consisted of five questions and emphasized their experience with project-based learning, reflective writing, and their abilities to articulate the design and systems element of technological and engineering literacy. Participants were required to articulate the steps, strategies, and processes to complete projects requiring a result or product that included a workable design based on established criteria and constraints and testing/evaluation procedures. This included discussions about their ability to collaborate, brainstorm, distribute workloads, and establish formal or informal leadership during the project to increase their chances of a positive outcome.

The first three questions required single-response (yes, no, unsure) answers relating to the terminology/phrases mentioned above. I framed the final two questions as extended and more comprehensive responses to capture student experiences during their recently completed project. Student responses required a written response relating to technological and engineering design and systems processes.

Questionnaire Two (Human Capabilities)

Questionnaire prompt two consisted of three questions requiring a written response. They focused on their experiences with project-based learning and how these activities helped them realize their capabilities to complete a project and perform tasks they may have never previously attempted. They were asked to identify things that worked well during the project, areas where obstacles occurred, and how they collaborated as a group to overcome these challenges and move forward with the project. Design teams must work together to find common ground to produce a final result that meets the standards established at the project's onset. Each member is responsible for completing their work tasks/assignments on time. These are critical aspects of project work as they relate to human capabilities. They were also asked how these experiences helped them become more technologically and engineering literate.

Questionnaire Three (Societal and Environmental Impacts)

Questionnaire three consisted of four questions requiring a written response. The first two questions asked participants to provide their insights on how technology impacts society and the environment and the importance of learning how technological products are designed and manufactured. They were also asked why it is essential for them to learn how technological products are designed and manufactured. Technological development may require using materials containing dangerous substances, chemicals, and other hazards. Production workers and technicians must be aware of these hazards and attempt to mitigate potential dangers to consumers and the environment during production. The last two questions were related to their experiences during their participation in the study and the impact these reflections had on their beliefs relating to reflective writings and their abilities to articulate what it means to be technologically and engineering literate.

Assessment Management and Grading

Assessments were plugged into Canvas, and participants were given three weeks to complete and submit for evaluation. Participants were explicitly asked to refrain from searching the internet to answer questions as it might skew the study data. Once each assessment was graded, I collected the writing samples, removed individual identifiers, and assigned each participant an anonymous alpha-numerical combination to protect their identity. Once the deadline was met or participants had all completed the assessment, further access to the assessment was denied. This was repeated for each iteration of testing.

Assessment scoring was completed using a Reflection/Essay Rubric (Appendix M). This rubric was developed by the American Association of Colleges and Universities (AAC&U) to help college-level instructors evaluate a student's ability to apply problem-solving techniques and strategies to achieve a goal (Rhodes, 2010). The course instructor and I scored completed assessments using the provided scoring rubric. Both scores were entered into a statistical data software program for analysis. All materials were kept in a secure location to protect participants' personal information further and maintain a proper chain of custody.

SUMMARY

Chapter III discussed the methods and procedures used in the study. The population selected, instrument design, data collection methods, and statistical analysis methods were discussed. Data was collected via instructor interviews and a repeated measures reflective writing strategy was developed to align with the research questions and the knowledge gained from the literature. Chapter IV will address the findings from the data gathered from the written assessments and instructor interviews and will conclude with a chapter summary.

Chapter IV

RESULTS

This chapter discusses the qualitative and quantitative study results, the various data collection methods, and their findings. First, statistical analysis of student performance results will be presented during the study's three-phase reflective writing assessment portion. I will discuss my observations and provide input relating to the individual responses to the questions posed during the three testing phases. The chapter will end with a breakdown of results relating to instructor and student participant interviews using descriptive coding techniques and researcher observations.

Student Written Reflection Analysis (Part One)

Quantitative data collection for the written reflection part of the study relating to research question two was accomplished during the fall 2022 semester. To facilitate my study, the course instructor added me as a teaching assistant in Canvas, which gave me direct access to their students. I posted a reflective writing assessment and a scoring rubric (Appendix M) for the assessment at three different intervals during the semester. Both the instructor and I performed the assessment scoring for the three assessments.

During each testing cycle, I retrieved completed written reflections, removed individual identifying information, and replaced proper names with an alpha-numerical code assigned to each participant for tracking purposes. I entered the individual scores into a statistical analysis software program (SPSS) for analysis to generate data relating to the differences in student scores for the three repeated iterations to answer research question two. Measures of central tendency and collection and processing of other statistical data were conducted using SPSS statistical software.

Single Response Questions

The first analysis looked at the frequency rate relating to responses made by the participants to three single-answer questions posed in assessment one. Option choices included yes, no, and unsure for each question. Question one asked: Have you heard the term technological and engineering literacy? Participants responded yes four times, with one responding unsure. These responses show that participants' response rates for this question were eighty percent yes and twenty percent unsure.

Table 1

Percentages for question one

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	4	80.0	80.0	80.0
	Unsure	1	20.0	20.0	100.0
	Total	5	100.0	100.0	

For question two (performed project-based learning), responses were yes four times, and unsure was given once. The response rates were eighty-six percent, and twenty percent were unsure about this question.

Table 2

Percentages for question two

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	4	80.0	80.0	80.0
	Unsure	1	20.0	20.0	100.0
	Total	5	100.0	100.0	

Question three: Have you completed reflective writing as part of the degree program? Responses were yes three times and unsure two times. The response rate for this question was sixty percent, yes, and unsure was forty percent.

Table 3

Percentages for question three

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	3	60.0	60.0	60.0
	Unsure	2	40.0	40.0	100.0
	Total	5	100.0	100.0	

A descriptive analysis of the first three questions provided additional data relating to responses, with means for each question being 1.40, 1.40, and 1.80, respectively. Standard deviations were .89, .89, and 1.10.

Table 4

Descriptive Statistics for Single Response Questions

	N	Minimum	Maximum	Mean	Std. Deviation
Have you done reflective writing as part of industrial materials courses?	5	1.00	3.00	1.40	.89
Performed project-based learning in college?	5	1.00	3.00	1.40	.89
Heard the term technological and engineering literacy	5	1.00	3.00	1.80	1.10

Valid N (listwise)

Dependent t-Test (Extended Response)

Quantitative data for the eight extended response questions were collected via a dependent t-test to determine if mean scores increased over the three assessments. An interrater agreement analysis was also conducted, including an interrater correlation and an interrater reliability using Cohen's Kappa. The final quantitative data are presented as a bar chart format breakdown of individual responses to the extended questions. These data supported the themes I developed at the end of my data analysis.

Statistical analysis relating to test scores for the remaining questions was conducted as part of the data collection process (*N*=5, 3). Results show test means increased incrementally between the two scoring raters for participants for test one (rater one *M*= 81.00, rater two *M*= 79.00), for test two (rater one *M*=86.67, rater two *M*= 81.33) and test three (rater one *M*= 94.67, rater two *M*= 87.67) over the three assessments. These data indicate that when provided opportunities to reflect on their experiences in writing after working on projects during the semester, more participants were able to demonstrate/articulate the essential elements relating to technological and engineering literacy (systems design, human capabilities, and impacts on society and the environment).

Table 5

Between Rater Mean Scores

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Rater1Test1	81.00	5	7.41	3.31
	Rater2Test1	79.00	5	5.47	2.44
Pair 2	Rater1Test2	86.66	3	15.27	8.81
	Rater2Test2	81.33	3	20.13	11.62
Pair 3	Rater1Test3	94.66	3	6.11	3.52
	Rater2Test3	87.66	3	13.65	7.88

A follow-up paired samples t-test was conducted to determine if there were significant differences in means between scoring raters for the three reflective writing assessment grades during the study. There were no significant rater differences in mean scores for test one (M=2.00, SD=2.73) condition; $t(4)=1.63$, $p>0.05$. There were no significant differences in mean scores for test two (M=5.33, SD=5.03) condition; $t(2)=1.83$, $p> 0.05$. There were also no differences in means for test three (M=7.00, SD=7.54) conditions; $t(2)=1.60$, $p> 0.05$.

Table 6

Paired Samples T-Test

Paired Differences									
				95% Confidence Interval of the Difference				Significance	
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1 Rater1Test1 Rater2Test1	2.00	2.73	1.22	-1.40	5.40	1.63	4	.09	.18
Pair 2 Rater1Test2 Rater2Test2	5.33	5.03	2.90	-7.16	17.83	1.83	2	.10	.21
Pair 3 Rater1Test3 Rater2Test3	7.00	7.54	4.35	-11.75	25.75	1.60	2	.13	.25

An interrater reliability test was also conducted to determine the amount of agreement between the two assessment raters throughout the three phases of the assessment. Results indicate a moderate level of reliability between scoring raters, Kappa = .50 ($p<.05$).

Table 7

Interrater Reliability Results Using Cohen's Kappa

Symmetric Measures	Value	Asymptotic Standard Error	Approximate Tb	Approximate Significance
Measure of Agreement Kappa	.50	.19	2.89	.004
N of Valid Cases	5			

A paired samples correlation t-test was conducted to determine the interrater agreement between the three phases of assessments. Results showed a significant correlation between raters for test one r(3)= .95 $p<.05$, test two r(1)=.99 $p<.05$, and for test three r(1)=.99 $p<.05$.

Table 8

Paired Samples Correlations

		N	Correlation	Significance One-Sided p	Two-Sided p
Pair 1	Rater1Test1 & Rater2Test1	5	.954	.006	.012
Pair 2	Rater1Test2 & Rater2Test2	3	.997	.024	.048
Pair 3	Rater1Test3 & Rater2Test3	3	.999	.013	.026

Written Reflection Analysis (Part Two)

Over the semester, participants responded to eight questions (Appendices L, N, O, P, Q, R) requiring a written response relating to technological and engineering literacy skills gained through project-based learning as part of their degree program. They were asked to discuss their experiences using the technological and engineering problem-solving steps, including group strategies for distributing work, overcoming obstacles, and identifying new learning during these projects/assignments. They were also asked how these projects helped them to recognize what technological and engineering literacy encompasses. Participant responses provided insight into how they view technology, its development, and its impacts on human capabilities, society, and the environment. Responses given by participants for each assessment were analyzed using descriptive coding techniques and were placed in table format.

Additional qualitative data are provided from individual responses to questions from the three questionnaires. This includes exemplars and responses that still must fully address the given question. This study defines exemplars as "key examples chosen to be typical of designated levels of quality of competence" (Sadler, 2010, p. 192). Quantitative data are provided via individual responses for each question via written response feedback followed by individual scores presented in bar chart format to support the results of scored reflective analysis.

Assessment One (Design and Systems)

Questionnaire one asked participants to respond to questions relating to the first element of technological and engineering literacy: design and systems. The extended response portion of the assessment consisted of two questions. I conducted an extensive review of participant responses using a variety of methods. I began by conducting a descriptive coding analysis and discovered that the top keywords/phrases relating to systems design were group (31 times), project-based learning (24 times), and student (24 times). Additional keywords are also provided, as they directly relate to the topic.

These patterns indicate that students consider the importance of group dynamics, the work to be performed, and reliance on each member to perform given tasks throughout the project. These are vital elements of project work, as lack of collaboration or cooperation between team members may lead to delays, missed deadlines, and the potential for projects to fall short of expectations set by the instructor. These are obstacles not only faced in the classroom but also in industry, where project failures would not result in a failing grade but potential unemployment due to individual or team dysfunction.

Table 9

Codewords to Assessment One related to Research Question Two

Group 31	Project-based learning 24	Student 24
Work (load) 14	Team 10	Experience 9
Different 8	Report 8	Assessment 8
Design 6	Improve 6	Plan 5
Write(ing) 4	Technology 4	Leader 3

Next, I divided each question by respondent. I selected three examples to provide feedback—this highlighted areas where respondents made connections to the question content, and some missed the mark. Additionally, participant responses to questions four and five and the corresponding grades they received are provided in bar chart format to support my written feedback. This assessment was worth one hundred points, with questions given a value of fifty points each. Participant scores ranged from a low of twenty to a maximum of fifty points. Lower scores for question four were due to incomplete answers or the responses needed to address the main points of the question entirely. I provide a brief synopsis of high and low-scoring answers and my observations/feedback for brevity.

Only one of the five participants received full credit for their response to question four, which asked: *When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project.* The response that addressed the entire question was from Don, who provided the following response to question four.

> Answer: One project required that we examine the physical characteristics of different types of clay to choose the proper material for our project. I was also expected to think of solutions and implement those solutions. All STEM class problems require this level of problem-solving. I was expected to evaluate my results for most group assignments. Typically, this involves a lab report. When assessing my results, I examine what I did well and could have improved. I have been expected to know what I would do differently if I were to repeat the project.

While this answer was brief, he does touch on all six steps of the technological and engineering design problem-solving process discussed earlier. For example, while other participants failed to mention the communication step of the process, Don correctly identified this step when he mentioned having to write lab reports to discuss team findings/results. He also mentioned what he did well and what he needed to improve upon, all elements tied directly to research question two: Do written reflection assessments indicate a student's demonstration of technological and engineering literacy during and after project-based learning activities/units of instruction?

One low score was given to Bob, who only received a twenty on question four.

> Answer: During one computer literacy class, we were shown how to locate reliable research sources. Once that was explained, we had to choose five topics to write about and ensure we could find substantial information. The information criteria were not just "Google"; it had to be journals, approved articles, and newspapers.

This response did not discuss technological and engineering problem-solving processes and was based on a course that does not use these processes. Bob's response was limited to developing research skills and differentiating between reliable and unreliable source materials. He failed to provide any substance related to the question.

Another low-scoring example is from Noah, who responded to question four this way:

> Answer: For my engineering class, we had to define the problem, list possible solutions, evaluate the possible solutions, develop a plan, re-evaluate and check the plan, conduct the plan, and finally investigate the results. When we were gathered, we discussed each step as a group, eventually made it through each process, and had a finished result for the project.

In this example, Noah correctly identifies and discusses the steps of the technological and engineering design processes. However, he must clearly explain how they used these steps to complete a project. Instead, he briefly describes the team's plan and provides information relating to their discussion about the plan, but he needs to provide the processes they used to solve the given problem. The reader is left to wonder what the team accomplished, how they worked through the problem, the obstacles they encountered during the process, and whether or not they completed the project task. These are critical elements of technological and engineering design, and students must include these concepts in discussions related to this topic.

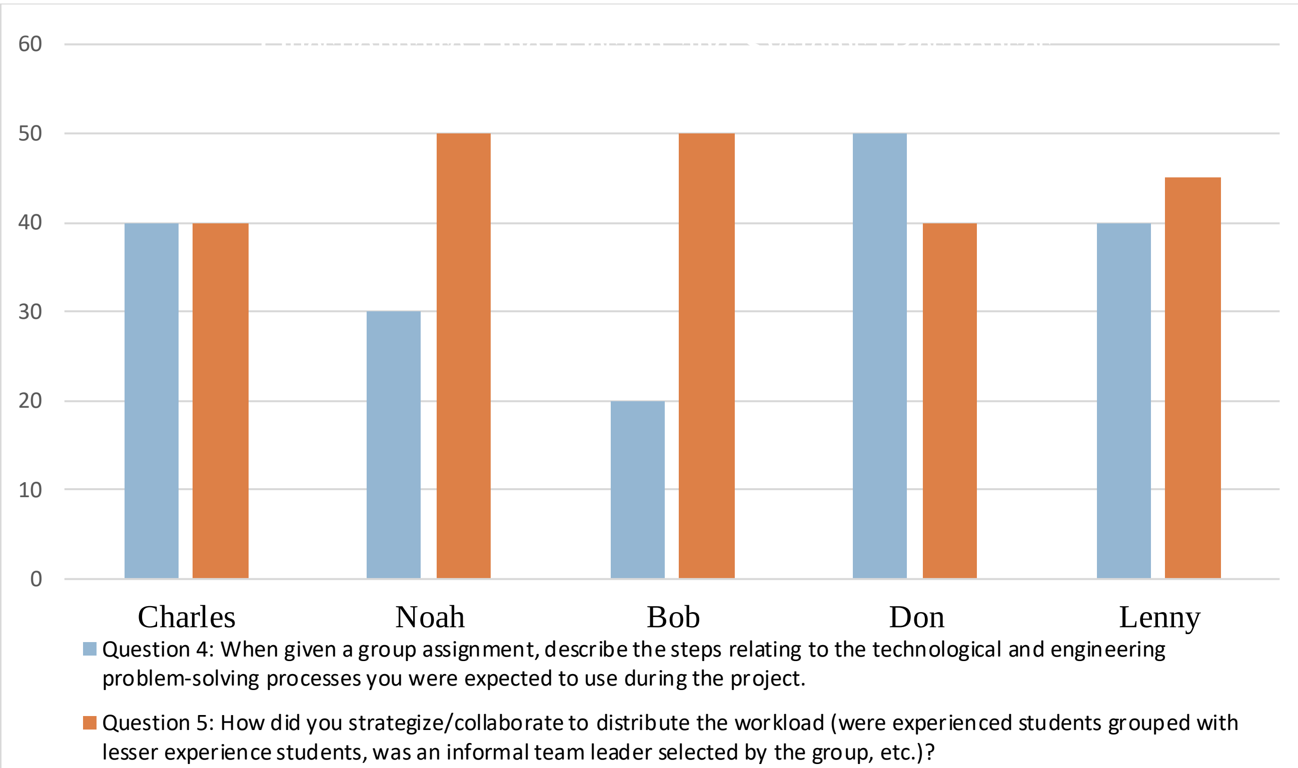
Participants performed better on question five, scoring at least forty out of fifty points. Low-score responses for this question were due to participants needing to provide a complete answer or address specific parts of the question. Question five asked: *How did you strategize/collaborate to distribute the workload (experienced students were grouped with less experienced students, and an informal team leader was selected by the group)?* The response that thoroughly addresses the entire question was from Don, who provided the following response to question five:

> Answer: I took two STEM classes, STEM 221 (Industrial Materials) and STEM 231 (Materials and Processing Technology). Both classes involve hands-on labs. These classes require efficient teamwork to complete and submit the labs on time. We distributed the workload into groups of two. For instance, two group members would work on one part while another pair worked on a separate component. This helped us get projects done more quickly. If a teammate needed to become more familiar with a machine or method, they would be paired up with knowledgeable people who could explain the process.

This response addresses all elements of the question. Don mentions pairing up team members, which is crucial as it provides opportunities for individuals to help one another and brainstorm ideas when they encounter obstacles during the part of the project they are attempting to finish. Leadership roles should have been mentioned, which is typically only an issue if required by the instructor, depending on the team's experience level. The main goal/focus of the team is to complete work according to preset deadlines and ensure that the result is a high-quality product. How they accomplish that may be left up to the team.

Figure 3

Responses to questionnaire one by individual participant



Assessment Two (Human Capabilities)

The following questionnaire requested responses relating to the second technological and engineering literacy element: human capabilities. Participant responses were analyzed using descriptive coding and placed into table format. The top keywords discovered by me relating to human capabilities were project (31), work (23), and experience (11). Several other significant keywords are provided, directly connected to the human capabilities category. The top three keywords may illustrate how participants can connect to this technological and engineering literacy element. They recognize the need for teams to work together to achieve a goal to complete the project and establish work to be assigned and completed during the project based on the amount of experience each team member brings to the project. They may also recognize that people bring different experience levels to the project and the importance of matching those people to the tasks that best suit their areas of expertise. Teams possessing this insight may improve their chances of completing a project outcome with high success.

Table 10

Participant Written Response Codewords to Assessment Two related to Research Question Two

Project 31	Work 23	Experience 11
Different 9	Report 8	Issues 6
Plan 5	Write(ing) 4	Technology 4
Design 3	People 3	

Questionnaire two consisted of three questions and was worth one hundred points. Participant scores ranged from a low of twenty to a maximum of thirty-three points, with two out of three participants providing quality answers to each question. Note: Two of the five participants dropped out of the study and were omitted from this analysis. Data analysis was conducted on each question, by individual responses, with feedback provided. Individual scores, by question, were placed in bar chart format. Examples of exemplars and those still needing to answer the question completely are provided. Lower scores for question six were due to incomplete answers or the responses needed to address the main points of the question entirely.

One exemplary response was from Larry, who deftly responded to question six. Question six asked: *When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress*. Larry's response is as follows:

Answer: Using the last engineering project as an example, we have the task of completing a drone. One thing that went well was the division of labor (human capabilities) for the first portion of the project. We could divide responsibilities as necessary, allowing us to spread out completely different portions of the work as we went. The things that could have gone better were the complexity and how some teams were dividing labor by leaving people unused, which would have been of help.

Larry discussed issues encountered during the process. His complete response described that this was an essential learning experience for this participant, as self-reflection and self-efficacy are necessary for personal growth. This is especially true when students are placed into unfamiliar situations and are required to perform new tasks involving the use of materials they have yet to work with previously. This can be an overwhelming experience. New learning content, specifically industrial materials, requires knowledge of material properties, safe handling procedures, and creating a final product according to predetermined criteria/specifications.

One response that did not answer the question entirely was from Charles, who scored twenty out of thirty-three points on this question. His response was only two sentences long, and did not provide details relating to his specific experiences during projects he worked on.

Answer: What goes well throughout projects is what works, meaning go with what works, then fine-tune and make it even better the next time. Strategies include troubleshooting the whole project to find out what went wrong and how you can fix it.

Charles' answer does not provide specific information regarding a result, team dynamics, workflow, cooperation/collaboration within the team, or any information regarding project outcomes. The information given could be more specific and more accessible to put into context.

He uses the term troubleshooting, which may occur when technical issues are discovered during testing/evaluation procedures but is not the main emphasis of the entire project. Team strategies are essential to the human capabilities factor of technological and engineering literacy and must be carefully considered when designing a new product. The ITEEA states, "Technology and engineering are intricately woven into the fabric of human curiosity and are influenced by human capabilities, cultural values, public policies, and environmental constraints. Students must recognize these influences and understand how their integration can form technological development (ITEEA, 2020, p. 26)." Charles should have considered some of these elements in his response to better articulate how teams work through the many challenges faced during a project.

Question seven focused on the personal experiences of each participant, specifically, any new learning that may have occurred or situations where they were asked to perform tasks they may not have done before. All three participants submitted insightful responses that touched on all the elements of the question asked. A sample of one participant's response is provided. Question seven asked: *What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before)?* Charles responded:

> Answer: Building the last circuit required three integrated circuits, which was tricky. I had some experience, but I only built one, and the additional circuits required far more complicated wiring procedures. The main problem working on this circuit was getting the current information to the LED to perform the blinking light pattern. The overall experience was double-checking and making the correct connections, as I would say, troubleshooting.

Charles' response not only discussed and provided details about his experience with this project, and new learning that occurred. He also provided insight into an essential technological and engineering design element: trial and error. According to the Oxford Dictionary (2014), trial and error is the process of repeated attempts with or without improvements by learning from failures. This may explain why design teams rarely get it right the first time when coming up with new product ideas or technologies. It is not due to a lack of attention to detail or knowledge on the part of the team; instead, it is due to the number of potential solutions available to the team to choose from. In Charles' case, he used trial and error to find the correct circuit connections to relay information to the LED to create the required blinking pattern.

Question eight was the final question for questionnaire two and asked: *Describe how these projects helped you become more technologically and engineering literate*. Two of the responses received the maximum point value, with one response only receiving a score of twenty. One example was provided by Larry, who provided a great example of how students become more technologically and engineering literate. Larry's response was:

> Answer: These projects have allowed me to gain hands-on experience with a few separate <u>machine/workplace tools</u> (human capabilities) that I had fallen out of practice. Overall, I knew many individual pieces, from using the Cad program to making designs (design and systems). However, using them all in a single project has given me better perspectives on finding and fixing potential design defects. By becoming more engineering literate, I have become <u>more able to understand the logic behind the projects</u> quickly, <u>why I am using this wood, and what to use as support</u>. With gaining technological literacy, I have seen myself being able to use the various tools around the workshop more easily from the practice.

Larry's response highlights the importance of teaching students technological and engineering design processes to gain knowledge of product design and development and how these experiences lead to further technological and engineering literacy development. Well-rounded learning experiences, especially the hands-on activities and projects associated with STEM learning environments, provide students with a unique opportunity to learn about different industries, processes, and concepts relating to teamwork and collaboration and access to knowledge not offered in other educational settings.

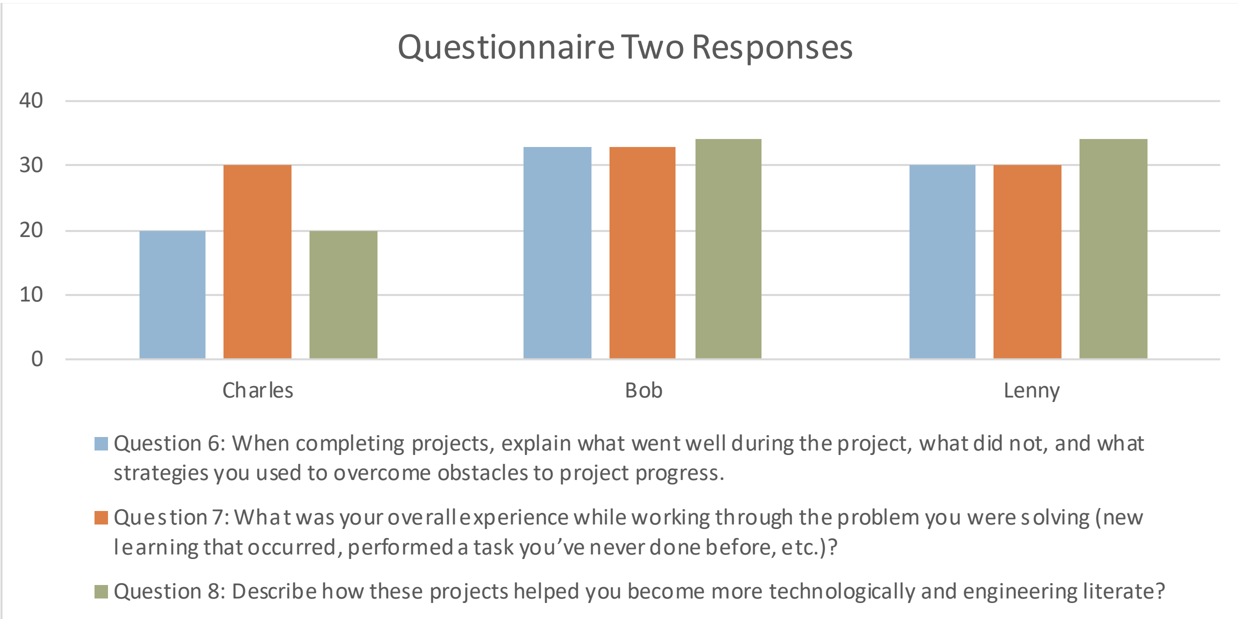
The answer that missed the mark was provided by Charles, who responded:

Answer: These projects have made me more aware to double-check and ensure things are proper before committing to any idea.

Not only is Charles' response extremely brief, but he does not attempt to answer any part of the question. Charles needs to read or understand the question or how to respond appropriately. His response indicated how project-based activities or projects over the past several semesters have increased his awareness of what it means to be technologically and engineering literate. It was unfortunate that he did not provide insight into his learning experiences.

Figure 4

Responses to questionnaire two, by individual participant



Assessment Three (Technological Impact on Society and the Environment)

Questionnaire three asked for responses about technological development's societal and environmental impacts. During the keyword search, it was discovered that technology (26), work (23), project-based learning (19), and process (13) were the top keywords for this questionnaire. Additional keywords related to the topic are also provided. While the questions posed to participants may have guided/directed their responses, they indicate that participants recognize a connection between technological design and development, the work/processes they perform during projects, and their impacts on society and the environment. These keywords are essential, as they show that participants are engaged during industrial technology classes, leading them to become more technological and engineering literate throughout their academic careers.

Table 11

Participant Written Response Codewords to Assessment Three related to Research Question Two

Technology (26)	Work 23	Project-based learning 19
Process 13	Different 11	Society 10
Design 8	Environment 6	Experience 6
Write(ing) 6	Life 5	Impact 4

Questionnaire three consisted of three extended response questions worth one hundred points. Two questions were worth thirty-three points, and one was worth thirty-four points. The follow-up question asked if they believed these reflective writing assessments helped them better understand what it means to be technologically and engineering literate. Scores for question nine ranged from a low of twenty-five to a high of thirty-four, but all three participants provided thoughtful responses.

Charles provided the most detailed and insightful response to question nine: *How does technology impact our lives, society, and the environment?*

> Answer: Technology has made society's lives easier and more compatible; a phone call away or even a flight to Europe is in our grasp. These things make society's lives easier, but at what cost? On the other hand, these industries that manufacture and produce gas motor cars or other gas-powered devices simultaneously hurt and destroy the environment. Technology brings an awkward divide between products over the earth's health due to things we need daily to live versus things that make life easier.

Charles provides several clear examples of how technology affects society and the environment. His explanations of different technological systems and their potential impacts on society remind us of our heavy dependence on technology in all our lives. His examples of the way technology impacts the environment, while brief, are lucid, informative, and in-depth. His conclusion highlights that while technological design and development are essential, we must be mindful of the long-term effects of unchecked, negative consequences of such development and implementation.

Scores for question ten ranged from a low of twenty-eight to a high of thirty-four, but all three participants provided thoughtful responses, which are discussed below.

Question ten asked: *Why is it important to learn how technological products are made/manufactured?* One example from Charles, while brief, does touch on the main point of the question. Charles' response:

> Answer: It is essential to learn about these things to see how you can affect the process and either cut costs or figure out a way to produce less waste. Another reason to learn about it is to understand how a product is made, from design to putting it together and then the finishing details to see what steps are involved in building a particular product.

All participant responses to this question were complete and discussed many manufacturing processes they encountered during their academic careers in the industrial technologies program of study. They felt this knowledge was necessary to help them better understand how different materials are used to create components and parts, how finished products are assembled, and how the final products function. These are all important factors when learning about the vast manufacturing operations around the country and the world.

Question eleven began the wrap-up portion of the assessment process and focused on the participant's experiences with the repeated measures assessment conducted over the semester. I did not provide feedback for this question, though I did score the responses. Scores ranged from twenty-five to thirty-four. Participant responses were positive and diverse, with each providing personal insights on their experiences during this study. Each participant's response is provided.

Question 11 asked: *Please provide your thoughts on the assessment process and your overall experiences relating to the questions posed to you over the semester.*

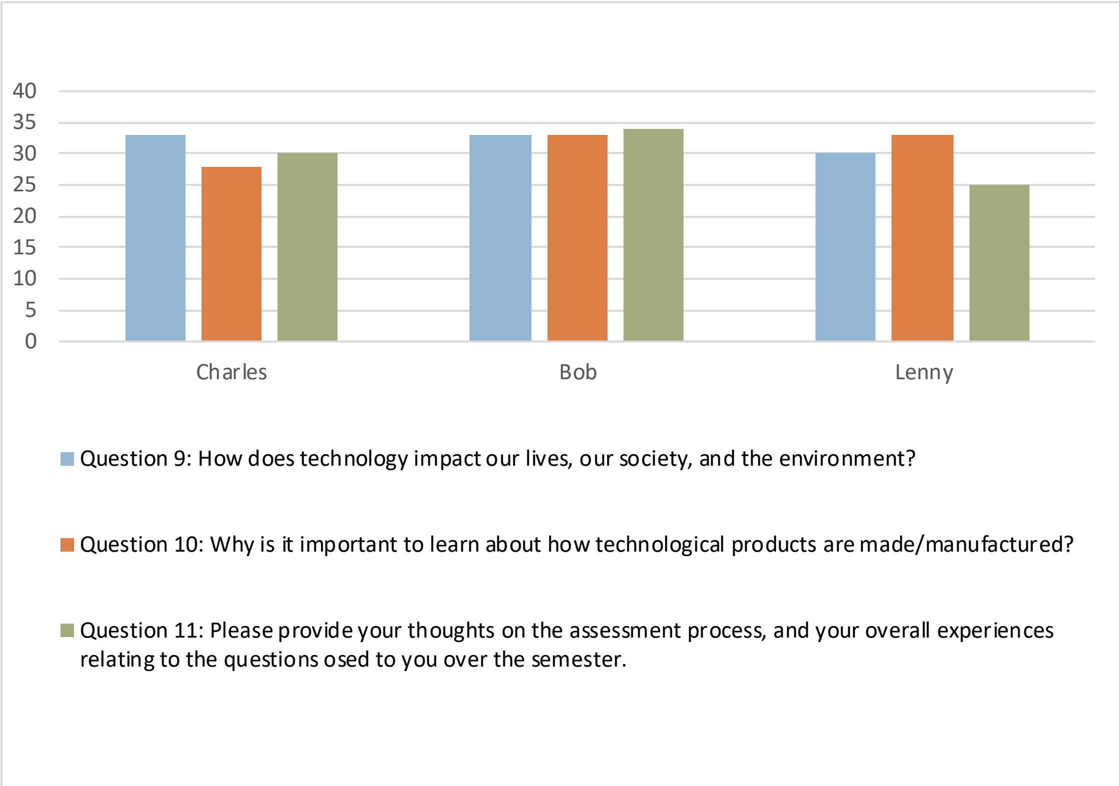
Charles: Over the semester, the questions helped me learn something new and understand the topic while writing it out. Questionnaire two made me realize that projects are mainly designing and troubleshooting the project, and when working with others, sharing ideas is very fast-paced and quicker than if you did it alone.

Bob: The questions have motivated me to think differently and have allowed me to understand what I have learned, why I have learned them, and how they will help me. We often get so caught up in learning the material that we can get through the class and forget why we are learning it and how it can impact our lives and jobs! The questions also allowed me to think critically about previous situations and roadblocks or barriers that I could overcome and did not think about when we were struggling with specific projects.

Lenny: My view on the assessment process is that it has helped put things in perspective and highlight some of the differences between this semester and the last. This semester has had people give me about ninety percent compared to a few previous semesters where people felt like they were giving ten percent. Working in engineering classes these last few semesters has allowed me to gain experience and understand more about what goes into an engineering process, whether metal or woodworking or the prototype/design/ process.

Figure 5

Responses to Questionnaire Three, by individual participant



I performed a post-analysis review of the three questionnaires to determine whether participant responses became more refined throughout the three assessments. While the data show their reflection skills had improved from a statistical perspective, from a personal observation viewpoint, they did improve. Each questionnaire allowed participants to display their knowledge of technological and engineering literacy, design and systems, human capabilities, and the environmental impacts of technological development.

With each question, participant responses reflected individual growth from both an introspective (sharing their personal experiences (new learning that occurred during industrial technology classes) and a retrospective (products they produced) approach. When participants reached the culmination assessment, they created rich, detailed, and descriptive breakdowns of the questions. This was important, as questions from the final assessment required participants to provide their views of how technology affects society and the environment and why it is essential to know how products are made. Their responses discussed the issues related to society and the environment and touched on all three elements of technological and engineering literacy. All three participants referred to the positive and negative effects of technological development (design and systems), the ability of technology to expand our work (human capabilities), and the impacts on society and the environment. They also provided several examples of industries (energy sector, communications, construction, automobile) and products (vehicles, computers, HVAC systems) that we rely on daily to make our lives more convenient and comfortable. This demonstrates that these participants have learned much about what it means to be technologically and engineering literate by taking college industrial technology classes.

Instructor Interview Data Analysis

The first interview consisted of questions related to the instructor's experiences, both in the number of years teaching and the methods and strategies used to incorporate reflective writing as part of their assessment processes given during project-based learning activities. This was done to address research question one: How often do instructors assess student reflective writing skills after performing project-based learning activities/projects? The instructor indicated they had fourteen years of teaching experience at the college level and used reflective writing extensively throughout their various industrial materials classes. They believe students taking industrial materials courses must demonstrate their ability, in writing, to articulate details relating to the various problems/scenarios they were required to solve during the semester. The instructor explained that students are assigned to different groups and are tasked with identifying, developing strategies, and coming up with a solution that, based on established criteria and constraints, provides the best opportunity for success.

Factors include how groups progressed through the project to develop a workable solution, the steps/processes they went through, providing documentation of all work conducted via sketches, reports, and physical models, and discussing obstacles teams encountered during the project. They were also required to discuss any data obtained and how they used that data to create the components for their design. This includes setting up various machines, equipment, and tools needed and discussing the procedures used to create each component, including specifications relating to each part (material, dimensions, assembly instructions). The instructor indicated that these are essential skills, as students entering their respective industries/career fields would be required to have working knowledge of these procedures.

Once the interview was completed, I conducted a keyword search using a descriptive coding technique to extract essential patterns and phrases. The top three keywords/phrases were project-based learning (38 times), student (24 times), and reflective writing (15 times). Additional interview responses are shown for context purposes. These three topics are critical for instructors to consider when using reflective writing assessments during project-based learning activities. The instructor's responses indicate a strong commitment to developing reflection opportunities that help students improve their abilities to reflect while attending their classes.

Table 12

Instructor Interview one codeword relating to research question one

Project-based learning 38	Student 24	Reflective Writing 15
Learning 14	Team 10	Leader 10
Work 9	Report 8	Assessment 8
Improve 6	Rubric 5	Semester 5
Technology 4		

Question 3: *How do you use PBL in your classes? What type of activities do you provide?*

Answer: In all of our classes in the STEM department, especially the industry technologies, our educational models are focused on hands-on learning. Hands-on learning means they have to perform work to create a project, and afterward, they have to generate a report of what they did during the project. By doing that, we know how they can reflect what they did with their hands on paper. This is the best way to see students' learning progress.

Question 4: *How many assignments/projects do you give students during the semester to perform this task?*

Answer: It is fifty percent projects and fifty percent lectures. We have one class with seven projects, a two-hundred-level class. In another class, which is a three-hundred-level class, they have one major project that takes place over the semester. This project is linked with other projects to reach the final production. So, for example, in STEM 320, the result will be to create a mass production of a product. First, the class has to select the product for the class.

The second project is to draw, in detail, the components of the product they intend to create. The next project is to create the facilities design, where they create the material flow, which relates to workstations and cost estimations. After that, the next project is for them to build a functional prototype of the product they intend to mass produce. In the end, they physically set up the machines and stations. From there, they mass-produce the product. So, when you add up those projects, they add up to seven.

Question 6**.** *Do you require students to provide any written reflection during these activities?*

Absolutely. Every report/project has a statement asking what they could do better and what they learned. So, in that statement, at the end of the report, they will write what they learned, what they could do better, and what we could do to improve their learning.

Follow-up question. *When do you require students to perform reflective writing as part of their assessments:*

Every lab or project has a segment, usually at the end of the project, to reflect on their work. If it is a continuous project, they will do their report at the end of the project indicating what they learned, what they could do better, and what we could do to improve their learning.

Question 7. *Do you provide any prompt, guidance, or trigger to help them focus on what you are looking for in their reflection?*

No. This is a free-range reflection. I do not want to limit their thinking. My idea is to have them think freely to tell me exactly what they have in their mind. If I ask them specific questions, their responses will only reflect on those topics.

Question 8. *Are there any specific assessment tools used to score these reflective writing assignments (Rubrics, checklists)? Do you provide students with a copy of the rubric?*

I have rubrics in some projects because I want them to focus on giving me a good product for reporting or physical projects. For some projects, I give them grading points for each element and grade them on those points. The rubric, in general, is available for them to use.

The two remaining instructor interviews comprised questions relating to their impressions of participant responses to study questions and their abilities to articulate what it means to be technologically and engineering literate. These were brief interviews, taking only ten-to-fifteen minutes to complete. No keyword coding was conducted for these interviews. The instructor indicated that students must be keenly aware of both the positive and negative impacts their work (technological development) may have on society and the environment.

For example, they explained that one of the students' main projects for their industrial technology program of study is to select and then mass-produce a toy(s) for children at a local hospital. Child safety becomes the focus for teams, as they must consider safety issues relating to materials, such as the need to use non-toxic finishes or chemically treated wood, removing sharp edges that may cut, and a whole host of other safety considerations. This is one of many scenarios students are placed in during the project that directly ties to one element of technological and engineering literacy students encounter: technological development's impacts on society. Additional elements students encounter are the technological and engineering design processes. Processes include identifying a problem or opportunity, gathering information, establishing criteria and constraints, identifying, and selecting a viable solution, modeling, prototyping, testing, evaluating, and communicating findings (Wright et al., 2019).

The strategies used by the instructor indicate a firm belief in using reflective writing as an assessment tool and project/problem-based learning environments to stimulate and motivate learners to connect with learned content and allow them to reflect on their own experiences. This includes discussing new learning that may have occurred, new tasks they performed, how they were able to collaborate with other group/team members, as well as learning strategies they developed when attempting to solve a given problem. These essential pedagogical learning strategies help guide students toward a heightened technological and engineering literacy level.

Student Interviews

This study's final data collection stage consisted of researcher interviews (see Appendix J) with eleven students enrolled in STEM 382, Industrial Design, during the spring 2023 semester. Interviews were conducted via Zoom and face-to-face environments, lasting from ten to twenty minutes. All but two participants were majoring in industrial technology. One participant was a technology education student; the other was an electrical engineering technology major. I used the same questions for the written reflections portion of the study conducted the previous semester for these interviews.

My intention was not to compare data between groups but to provide additional support for the written reflections completed previously. I wished to gain participant insights, experiences, and challenges faced during projects they had completed during their academic studies in industrial technology. I also wanted to see how they would respond to participating in a spontaneous interview setting. This was especially true for face-to-face interview participants randomly selected during lulls in the classroom. Although these participants were interviewed only once, For consistency purposes, I divided their responses into three technological and engineering literacy categories (see Appendix K), similar to the participants who completed the three reflective writing assessments.

Questionnaire One (Human Capabilities)

Questionnaire one dealt with the human capabilities aspect of technological and engineering literacy (see Appendix L). As with the three written reflection assessments conducted earlier, the first three were single-response questions relating to technological and engineering literacy, project-based learning, and reflective writing.

Interviewee Single Response Questions

The first part of the questionnaire looked at the frequency rate relating to responses made by the participants to three single-answer questions posed during the interview. Option choices included yes, no, and unsure for each question. Results for question one: Have you heard the term technological and engineering literacy? Participants responded yes seven times, and four respondents said no. These responses show that participants' response rates for this question were sixty-four percent yes and thirty-six percent no.

Table 13

Interview percentages for question one

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	7	63.6	63.6	63.6
	No	4	36.4	36.4	100
	Total	11	100.0	100.0	

In question two (performed project-based learning), responses were yes ten times, and no was given one time. The response rates for this question were ninety-one percent yes and nine percent no.

Table 14

Percentages for question two

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	10	90.9	90.9	90.9
	No	1	9.1	9.1	100
	Total	11	100.0	100.0	

Question three: Have you completed reflective writing as part of the degree program? Responses were yes nine times and no given two times. The response rates for this question were eighty-two percent yes and eighteen percent no.

Table 15

Percentages for question three

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	9	81.8	81.8	81.8
	No	2	18.2	18.2	100
	Total	11	100.0	100.0	

A descriptive analysis of the first three questions provided additional data relating to responses, with means for each question being 1.36, 1.09, and 1.18, respectively. Standard deviations were .50, .30, and .40.

Table 16

Descriptive Statistics for Single Response Questions

	N	Minimum	Maximum	Mean	Std. Deviation
Heard the term technological and engineering literacy	11	1.00	3.00	1.36	.50
Performed project-based learning in college?	11	1.00	3.00	1.09	.30
Have you done a reflective writing as part of industrial materials courses?	11	1.00	3.00	1.18	.40
Valid N (listwise)	11				

Responses to Question Four

Additional qualitative data were gathered during the interviews via the two extended response questions. First, I reviewed questions four and five and the responses given by each participant. As these interviews were ungraded, I decided to provide feedback as yes or no as to whether their responses were adequate.

I conducted a response analysis of question four, which asked: *When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experienced from previous classes, as well as this current class*. I discovered that only thirty-six percent of participants provided satisfactory responses, with sixty-four percent of interviewed participants needing to provide an adequate response to this question.

Table 17

Responses to question four

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	4	36.4	36.4	36.4
	no	7	63.6	63.6	100.0

A brief synopsis of incomplete and exemplary responses to question four is provided. As with the first set of participants responding to these questions, many interview responses needed to be sparse and provide more information or make connections to the posed question. Conversely, many responses were highly detailed and included information that contained similar/relatable data to the participants who took the three assessments the previous semester. The first example is an incomplete response from Burl, whose response to question 4 was:

> Answer: All right, so usually, in projects, we start with brainstorming, then we move on to finalizing our ideas and narrowing them down to one idea. Then, once we have that down, we start drafts of a paper or prototypes of a product. And then, from there, we will move on to trying to create a final product. Usually, something is written about that.

This response needs more depth and leaves out many of the critical procedures and processes relating to technological design. Much more detail is needed to convey the totality of technological and engineering problem-solving. Items like criteria and constraints for the design (costs, manufacturing capabilities, return on investment (ROI)) are vitally important and must be discussed to determine the feasibility of the proposed design. Testing and evaluating procedures must be developed to check the function of the prototype to determine if any changes/adjustments need to be made to ensure the final product is safe, reliable, and of good quality.

Another response that missed the mark was from Mary, whose response to question four was:

> Answer: First, you must figure out who will lead the project and who will make sure the project is finished. Depending on the type of class, there are specific criteria you must meet. You must write three pages on what happened during the project. You must structure the paper so it has enough fluff to make it three pages but also include enough information on the project to make it three pages.

This response needs to address a single aspect of the question. No relatable information is provided, and the response focuses solely on the post-project report writing requirements. Leadership roles should have been mentioned in the question. Class types are not a factor, as the steps of the technological and engineering design processes do not change based on the type of material used to create a product; only the procedures within the process differ. Lastly, the mention of 'fluff' indicates the respondent tends to add extraneous wording to their written reflections/reports, which is typically frowned upon in academic writing.

The exemplary response to this question came from Nathan, who responded.

> Answer: It always starts with the team gathering and analyzing the problem so we can try to find a straightforward solution, like brainstorming. Everyone comes up with different ideas and different solutions. The different views help to shape the decision for the best solutions for the problem.
>
> Once all our roles are determined, we start working on individual parts. We also assist each other if we need any help or just briefly with each other, allowing us to know where we are and if there are any problems, other questions, or things we do not understand.

This response does capture most of the steps of the technological and engineering design processes, and outlines the primary responsibilities of group members during the project. It also addresses good teamwork and cooperation during the production/development stage of the process. The statement wraps up with a closing statement relating to the completion step and ensuring the product works as designed. More details could have been provided to give the reader more insight into the brainstorming sessions and the testing and evaluating processes they took to ensure the product met predetermined specifications. This was a common theme seen throughout the responses to this question, which will be discussed in further detail later in this paper.

Responses to Question Five

Similar but slightly higher results were found for question five, which asked: *How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, and was an informal team leader selected by the group)? This can be experienced from previous classes, as well as this current class.* Forty-five percent of interviewed participants provided satisfactory responses, with fifty-five percent not providing adequate responses.

Table 18

Responses to question five

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	5	45.5	45.5	45.5
	no	6	54.5	54.5	100.0
	Total	11	100.0	100.0	

A brief synopsis of incomplete and exemplary responses to question five is provided. One example that was considered incomplete was from Jonathan, who responded:

> Answer: The instructor made our group, but we branched off and would let people with specific skills or experiences in a particular field or who had experience with machinery or materials perform specific tasks.

While there is a primary connection to the question regarding work distribution, it is limited to experience with machinery and materials. There needs to be a mention of how personnel were paired up or whether the team selected a formal or informal leader. These are essential elements of the team's composition, as they must identify the strengths and weaknesses of team members before producing product components. This helps them with quality assurance and provides less experienced team members with learning opportunities. Not only does this strategy provide learning opportunities in classroom settings, but it provides skills that may be applicable in the workplace.

The exemplar for this question came from Diego, who responded:

> Answer: At least one person usually emerges as the group leader when I am placed in a group. Furthermore, they say, hey guys, I think we should do this. Are you guys okay with the plan? I have never had the experience of asking people what their strong suits are. We usually break it up evenly. Then, we learned to do our part of the project. We just become our little experts over the work that we selected. When people say, "I do not know how to do this." Somebody comes forward, and they are like, I have done that before. I could do this part instead of you.

Diego explains how teams distribute workloads and includes leadership roles and how the team establishes both responsibilities. He also points out that the leader seeks feedback from the team members to ensure they are all on the same page before starting work. While he does not explicitly indicate whether teams pair experienced individuals with less experienced members, he points out that if individuals need help with a given assignment, someone will step up and perform the unfamiliar task. This level of cooperation is essential to the design process, as quality control must be considered throughout the project to ensure a positive outcome.

Next, I conducted a round of descriptive coding, as I did for the first group of participants. The top keywords from the participant interviews were work (80), Project (73), and Group (47). Several additional keywords are also presented. These responses are similar to those provided by the participants who performed the written assessments and indicate that both sets of participants share the same beliefs regarding project work.

Table 19

Student interview codewords relating to research question two

Work 80	Project 73	Group 47
Experience 34	Environment 28	Product 25
Team 25	Problem 21	Writ(ing) 19
Technology 18	Engineering 14	Process(es) 12
Ideas 11	Leader 10	Solv(ing) 10

The codewords are very similar to the ones discovered during the analysis of the three assessments conducted during the previous semester. Interviewed participants expressed the importance of focusing on their work to ensure they produce a high-quality product at the end of their projects. This is important, as design and manufacturing teams must complete tasks according to established processes while maintaining quality standards established by the team and following company, industry, or government codes/standards.

Questionnaire Two (Design and Systems)

The second questionnaire focused on the processes relating to the design and creation of technological systems and how they relate to developing technological and engineering literacy skills. This questionnaire consisted of three extended-response questions. I analyzed the data for question six, which asked: *When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress*. I found that fifty-four percent of interviewed participants provided an adequate response, and forty-five percent provided satisfactory responses.

Table 20

Responses to Question Six

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	6	54.5	54.5	54.5
	no	5	45.5	45.5	100.0
	Total	11	100.0	100.0	

Responses to Question Six

A brief synopsis of incomplete and exemplary responses to question six is provided. One example of a response that did not fully address the question was from David, who responded:

> Answer: My best strategy is to work on time and get ahead of it with your group. Please do not wait to start the project until the week it is due. Start making roles right away. If everyone in the group participates, you should be good.

This response needs a connection to most elements of the question. He does not discuss how he or his team performed during a project. He also needs to discuss strategies relating to problems encountered or how the team came together to address and find pathways to solve the problem. These types of situations are common in industry. Teams are tested and suffer failures, especially during the initial product design and development stages. Experienced teams, when faced with these unforeseen problems, whether with personnel, machinery, or lack of materials, must come together to coordinate efforts to determine a course of action to solve the given problem. Diego's answer should have brought these topics to his discussion.

The exemplar for this question was provided by Reed, who responded:

> Answer: What went well? Generally, some team members either do not or cannot fully participate at the same level as others. We generally need to check in with these folks regularly. Furthermore, sometimes they, you know, they, they somehow express their unwillingness or their "laissez-faire" attitudes in terms of getting things accomplished. Sometimes, there is a shift in responsibility, and somebody from the team needs to come in and help. In those situations, it is a matter of someone managing the team.

Reed provides a detailed explanation of how teams, especially leaders, identify a member who is not pulling their weight and adjusts personnel assignments to ensure tasks are completed on time. In many situations, groups encounter individuals who wish to hang back and not participate in the project yet expect to receive the same credit as those who did the work. These individuals are called social loafers (Latané, 1979) and must be dealt with immediately; otherwise, the team may begin to fall behind on production, and the work quality may suffer due to the malaise and potentially unsafe attitude displayed by that team member.

I analyzed the data for question seven: *What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before)?* I discovered that sixty-three percent of participants provided an adequate response to the question, with twenty-seven percent found to have yet to provide a satisfactory response. One participant needed to gain experience performing problem-based learning and was not asked this question.

Table 21

Responses to Question Seven

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	7	63.6	70.0	70.0
	no	3	27.3	30.0	100.0
	Total	10	90.9	100.0	
Missing	System	1	9.1		
Total		11	100.0		

Responses to Question Seven

A brief synopsis of incomplete and exemplary responses to question seven is provided. Seven out of ten participants provided personal experiences that were well thought out and detailed information relating to the work they did, new tasks they performed, and how they overcame personal doubts about their abilities to perform specific tasks in a production lab environment. One participant who provided a detailed answer was Nathan, who responded:

> Answer: Honestly, because initially, when I started, my major was in exercise science. So, I switched my major. When I entered this program, everything was new to me. It was an immersive experience, from learning AutoCAD to doing 3D modeling and stuff like that. So, we talked about the woodshop and how I learned to use different tools like jigsaws or other tools. The equipment, machines, and things of that nature were new to me. I had much help from my team and the professor, who was the professor for both classes. Nevertheless, yes, and it was okay. It is just getting over that hurdle of, like you said, asking for help and being vulnerable, saying, "Hey, I am not sure what I am doing here. Can you help me out?
>
> Nathan provides examples of new learning during his industrial technology classes and how the team made him available when he was unsure what to do. This is

important, as students may project confidence when dealing with new tasks to avoid potential embarrassment. In Nathan's case, he recognized that when it comes to operating machinery, safety comes first, and it is always a priority, even when someone feels uncomfortable asking for help.

I analyzed question eight, which asked*: Describe how these projects helped you become more technologically and engineering literate*. I discovered that fifty-five percent of participants provided an adequate response to the question, with forty-five percent found to have yet to provide a satisfactory response.

Table 22

Responses to Question Eight

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	54.5	54.5	54.5
	No	5	45.5	45.5	100.0
	Total	11	100.0	100.0	

Responses to Question Eight

A brief synopsis of incomplete and exemplary responses to question eight is provided. This question was a challenge for nearly half of the participants, who needed to fully understand technological and engineering literacy and its application. One incomplete example was provided by Harold, who responded:

> Answer: The more we are exposed to the literature when doing research, the more technical terms and things are associated with engineering. Also, the exposure we get from the textbooks and lectures provides additional information.

This answer lacks the fundamentals of what it means to possess technological and engineering literacy skills. Harold refers to literature and research and how they lead to the discovery of technical terms and other information related to engineering. However, the response needs more connection to the definition and application of gained knowledge, as well as the ability of individuals to be critical of technological development and to challenge unethical issues relating to the impacts they have on society and the environment. These are critically important elements of what it means to be technologically and engineering literate.

The best (though incomplete) response to this question came from Carl, who responded:

> Answer: This industrial technology program showed me new ways to do the job. I learned AutoCAD, designing drawings, using measuring tools to see how long things are, and using different materials based on the outside working conditions. The longevity of a product. Things of that nature. Being more innovative, designing and building, and every day, because of my job, this program made me think outside the box, not just thinking this is how we have always done it.

This answer does address a few aspects of technological design and systems development as they relate to technological and engineering literacy. Areas such as the use of new technologies and tools and how to be innovative are discussed. However, it needs more connections to individual/team responsibilities related to the design processes involved in creating technological products. This was found to be a common occurrence during the interview process with participants. Further details will be provided in the themes section of this paper.

Questionnaire Three (Technological Impact on Society and the Environment)

The final questionnaire consisted of two questions relating to the last element of technological and engineering literacy: the societal and environmental impacts of technological design and development. *Question 9 asked: How does technology impact our lives, society, and the environment?* While analyzing question nine, I discovered that seventy-three percent of participants provided an adequate response to the question, with twenty-seven percent found to have yet to provide a satisfactory response.

Table 23

Responses to question nine

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	8	72.7	72.7	72.7
	no	3	27.3	27.3	100.0
	Total	11	100.0	100.0	

Responses to Question Nine

A brief synopsis of incomplete and exemplary responses to question nine is provided. For example, one respondent who missed the mark was Jonathan, who replied:

> Answer: It is mainly focused on how to improve our lives. Also, in the lab right now, we are trying to find ways to improve things, using reverse engineering to discover the function of products and improve people's lives.

Jonathan does mention the positive aspect of technological design's impact on society, Nevertheless, it is a generic response limited to the development and function of products. Reverse engineering is an essential part of technological design and offers the potential for upgrades to existing products and ways to develop new technologies to replace obsolete products. It is not the only factor relating to technology's impact on our society or environment. Negative impacts on society and the environment were omitted from this response, which would have made an excellent rebuttal to the initial response.

Two exemplars were selected for this question, as both respondents touched on many of the factors concerning both the positive and negative impacts technology has on society and the environment. This response came from Carl and Cole, who replied:

Carl's answer: Technology is the foundation of our world. Ranging from the buildings we live or work in to bridges and roads that get paved. Industries are to keep the world moving forward and make it better for everybody to have a more comfortable life. Regarding the environment, we are moving away from oil and using more electric products to keep the environment clean and green. This happens in the shipping industry, as they are trying to move forward with electric freight carriers to reduce oil consumption and waste associated with fossil fuels. That is the big thing being pushed right now.

Cole's answer: Technology impacts us way more than we probably want to admit. A big issue moving forward is automation, and how that will look as far as taking over our jobs, especially in the field that we work in, manufacturing could be more stable. The space as far as automation goes, because like yesterday in class, professor and retrieval are talking about it where he said back in the day when they redid their product line, and they switched to an automated line, they increased productivity by 80% or something like that. Today, 40% of jobs are fully automated. Furthermore, I read a book by Andrew Yang about automation and how dangerous it is to our society.

These responses capture several issues relating to the current and future state of our world. First, to Carl's point, fossil fuels have been a constant source of power and energy for the past hundred or so years, and the environment has paid a hefty price for their use. Alternate fuel sources have been developed, with some functioning on a small scale (wind power) and some on a larger scale (solar power, electric cars). Additional sources are being researched to determine the viability of scalability, such as ocean thermal energy conversion (OTEC), which converts warm sea water into electricity with zero waste generated (Langer et al., 2020), and tidal energy, which would use the changing tides to move turbines to generate electricity.

Secondly, according to Cole's response, automation in industry has exploded in recent years. Everything from the automotive industry to manufacturing plants and service industries like big box stores and fast food restaurants has become automated. Companies see the benefit of replacing human labor with machines to cut costs across their operations, from assembly lines to packaging and customer service. These changes hurt the workforce, as workers must find other jobs that match their current skills or seek training opportunities in new areas to remain hirable (Lima et al., 2021). These are all crucial elements relating to technology's impact on society and the environment.

The final question for these interviews dealt with the importance of manufacturing related knowledge. Question ten asked: *Why is it important to learn how technological products are made/manufactured?* While analyzing question ten, I discovered that ninety-one percent of participants provided an adequate response to the question, with nine percent needing a satisfactory response.

Table 24

Responses to question ten.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	10	90.9	90.9	90.9
	no	1	9.1	9.1	100.0
	Total	11	100.0	100.0	

A descriptive analysis of the final seven questions was conducted to provide additional data relating to responses, with means for each question being 1.63, 1..54, 1.54, 1.30, 1.45, 1.27, and 1.09, respectively. Standard deviations were: .50, .52, .52, .48, .52, .46, and .30.

Table 25

Descriptive statistics for extended response questions

	N	Minimum	Maximum	Mean	Std. Deviation
Responses to question four	11	1.00	2.00	1.63	.50
Responses to question five	11	1.00	2.00	1.54	.52
Responses to question six	11	1.00	2.00	1.45	.52
Responses to question seven	10	1.00	2.00	1.30	.48
Responses to question eight	11	1.00	2.00	1.45	.52
Responses to question nine	11	1.00	2.00	1.27	.46
Responses to question ten	11	1.00	2.00	1.09	.30
Valid N (listwise)	10				

Responses to Question Ten

A brief synopsis of incomplete and exemplary responses to question ten is provided. There were many different thoughts provided to this question. Some answers were brief and provided few details or answer the question. One incomplete response came from David, who replied:

> Answer: Because you cannot go anywhere without them. Everything is manufactured one way or another. From my side of it, I just come from the work side. I have a different brain than many students. Everything has technology in it. Whether it is used to make a drawing, make a product, or teach things. Technology is a part of everything we do.

David's response mentions the word manufacturing but needs to provide an example of manufactured products processes, or why it is essential to attain this knowledge. Instead, David discusses technology and how it is everywhere. The previous question covered these points, and it appears David either needed to have understood the concepts relating to the question being asked of him or needed to learn how to respond correctly. A more straightforward, more concise answer was provided by Cole, who responded:

Answer: It is more of an appreciation thing. I like working on electronic controls and things of that nature. I am curious how things are made. Even when driving by some places, looking at different buildings, and seeing things like exterior HVAC equipment and other systems, I wonder how it was created. In doing this, I gain an appreciation for other people's hard work because of it. I also got a good understanding of how much work went into constructing a building. That follows into just general products. When I see different parts or products, I see how intricate they are and how much time goes into them. You get a sense of gratitude for the everyday things that we have. The cool part for me is that sometimes the parts can be so complex that you wonder how many tiny parts they had to create and still think about the big picture. It is impressive, especially considering computers, processing, and small nano parts.

Cole's response provides examples of his personal experiences relating to manufacturing, Furthermore, the curiosity some finished/construction products bring out in him. For example, he discusses how just driving by a building raises that curiosity and prompts him to think about the construction processes or complexities involved in creating the different features of the building. He also provides a general overview of his thought processes in manufacturing. His discussion on the complexities of how many products are made.

At the same time, though brief, he provides an excellent example of how product and systems design, development, and production require attention to detail to produce a functional and reliable product. These are prime examples of why individuals need to gain knowledge of how products are manufactured. If we know how they work, we can repair or find ways to improve existing products or replace obsolete products with more efficient and sustainable products.

Study Themes

I reviewed the research questions after data collection and analysis. I conducted further analysis of the responses from the instructor and student interviews and the responses provided by participants who completed the three written assessments to determine if each research question had been answered. I was especially interested in the data from the three writing assessments during the fall 2022 semester. I isolated the data collected from the assessments, each dealing with one of the three elements of technological and engineering literacy (design and systems, human capabilities, and societal and environmental impacts of technological development). The data from each assessment indicated that participants struggled with the design and systems assessment while performing well in two assessments dealing with human capabilities and societal and environmental impacts. I wanted to investigate if my data were outliers or if they were commonly seen in the research literature.

While the data answered my research questions, I wanted to dig deeper to discover other meaningful purposes for this research topic. I aimed to identify potential themes/patterns connecting these items and justify why I conducted a study on written reflection. I also wanted to know what the data meant, in other words, how I could use it not only to answer research questions relating to my study but to show how this method of inquiry would help lead me to my conclusions, the implications it may have on the literature, future students, and industrial technology education practices in general. This is discussed later in the implications section of chapter five.

First, I sought to identify a theme relating to the instructor interviews and the connection to research question one. I wanted to see if they had any particular strategies for assessing written reflection (frequency, use of scoring rubrics, or other methods) or even required students to perform reflective writing for projects relating to technological design processes. Upon review of the instructor interviews, I identified a theme relating to research question one: The instructor uses written reflection as part of their assessment process.

Theme 1: Instructor Strategies for Using Reflective Writing

One instructor for an Industrial Technologies course, STEM 320 Construction and Manufacturing, was interviewed thrice over the fall 2022 semester. The goal was to gain insights into how they used reflective writing assessments during project-based learning assignments and projects as part of the assessment process. This was done to answer research question one: How much emphasis does an instructor with a university's industrial technology program of study place on student written reflections? Are they considered an essential part of their assessment strategy for their students?

The instructor provided specific details about the use and the importance of reflective writing to allow students to reflect on their experiences. Interview transcripts are provided in Appendix D. The instructor discussed the need for students to possess reflective writing skills relating to their work during projects. This particular instructor consistently provides reflection opportunities at the end of a given project. They also indicated that a scoring rubric is provided for students to use as a guide during each project. When asked if they provided prompts or triggers for students to focus on during their reflection, they replied no and explained that they did not want to limit students' thoughts or writings about the project. They wanted a free flow of information, student insights related to the project, and their task-completion strategies.

The instructor said they may provide a short blurb to help students think about their work, how they can improve it, and what the instructor can do to improve the class in the future. They believe reflective writing is the best way for industrial technology students to progress during their program of study. Providing students the opportunity to process the work they did as individuals, as well as discussions related to group dynamics through writing and discussing things that went well or wrong during the project, new learning that occurred, and new tasks, machines, or other tools they may not have used before are all essential parts of learning in industrial technology learning environments. The instructor sees this strategy not only as an academic need but also as one applicable to many industrial-related careers.

One study examined instructor attitudes and opinions regarding their beliefs towards writing in STEM disciplines in post-secondary education. The National Research Council (2012) recommended that post-secondary institutions adopt opportunities for students to write reflectively during STEM-related classes to increase student learning outcomes and provide a foundation for developing critical thinking skills. An area of concern was the need for more institutional adoption of this pedagogical strategy and the tendency for writing in STEM-related classes to be determined by individual instructors rather than being mandated across colleges and universities offering STEM-related courses to their students.

This quantitative study examined faculty beliefs towards using reflective writing during STEM-related classes. The framework for the study was adapted from the theory of planned behavior, which states, "the degree to which a person's intentions translate into behavior is also impacted by the control they perceive having over their actions (Azjen, Madden, 1986, p. 2)." This theory "has been used to examine the relationship between behavior and beliefs in many contexts" (Finkenstaedt-Quinn et al., 2022, p. 2).

Researchers developed four research questions for the study, they were:

1. What types of writing do STEM faculty at research-intensive institutions report assigning in their courses?

2. To what extent do STEM faculty at research-intensive institutions believe writing is an

3. effective tool for learning STEM content knowledge?

4. Do the attitudes and subjective norms differ between faculty who do and do not assign
5. writing in their courses?

4. Do faculty beliefs about factors that may influence perceived behavioral control differ between faculty who assign and do not assign writing?

Faculty from 63 research institutes across America (29,430) were invited to participate in the study, with 17% (4891) agreeing to participate, which is consistent with other studies examining STEM faculty populations (Gehrke, Kezar, 2017). Survey data were used for data collection for both a pilot and an actual study. A two-part survey was developed to determine how STEM instructor beliefs determine their teaching strategies and methods. Part one was arranged in single-response questions (yes/no). They also used a Likert scale ranging from 1=not effective to 4=very practical to capture data on instructor beliefs in using writing in their STEM classes.

Part two of the survey used a Likert scale of 1=agree to 5=strongly agree to determine whether instructors believed cultural or social factors impact student writing. Demographic information and an optional open-response option were used to capture additional opinions relating to instructor beliefs in using writing in their STEM classes. Survey validity was conducted via interviews with five STEM instructors from various STEM backgrounds from two research universities. Interviews were recorded and transcribed to identify potential issues with survey categories that researchers may have overlooked.

One of the researcher's institutes collected data in partnership with the University of Michigan. Responses were weighted to ensure that responses were representative of populations across different universities and disciplines. Researchers used a statistics software program (Stata SE) to analyze data. Participant responses were numbered, with non-integers correlated to the nearest whole number (e.g., 4.65 would be considered a strongly agree response on the 1-5 Likert scale). A significance of α <0.05 was set, with a margin of error of 2.5%. Effect size was calculated using omega-squared (α^2), with values ranging from 0.01-0.058 (small), 0.059-0.137 (medium), with 0.138 and above as large.

Results from the first phase of the survey, used to answer research questions one and two, indicated that nearly 70% of instructors used writing in their classes, and 30% did not use writing in classes they taught. For additional analysis, instructors were placed into two different categories, with writing instructors referred to as writing assigners (WA) and writing non-assigners referred to as (WNA). Instructors who used writing in their STEM classes reported that for each course they taught, they required students to perform at least one writing assignment. Goals with the highest effectiveness in supporting student achievements were: "writing to demonstrate mastery" (71%) and "writing to learn" (50%). Instructors also reported that they used "revision based on feedback," "peer review between students," and "scaffolding a long piece of writing" strategies in their classes" (Finkenstaedt-Quinn et al., 2022, p. 5). Peer review between students was reported as the least effective of their strategies. STEM writing non-assigners also rated peer review as the least effective strategy. However, in contrast to writing-assigners, they viewed revision as the most effective strategy for student support during their classes. Writing assigners and non-assigners were asked about their attitudes about the effectiveness and importance of writing and whether they were encouraged or not encouraged to use writing in their classes. Data revealed a small effect size between groups for both questions, which suggested that differences between groups were insignificant.

Results relating to the study's second phase of research questions three and four were mixed. Instructors were asked to comment on the subjective norms of their institution as they related to writing strategies. They were asked if they agreed with the assumption that writing was not an essential factor when teaching their classes. Data revealed that both groups disagreed with that assumption, with writing assigners showing a higher disagreement with that statement than non-writing assigners. They were also asked to comment on the assumption that their departments should have encouraged them to provide writing opportunities to students taking their classes. Data showed that both groups' opinions were neutral on this question, and researchers suggested that their specific discipline played more of a factor in cultural norms than the culture within their institutions. Researchers briefly discussed using a subset of questions posed to participants to allow them to discuss the factors leading them to their beliefs about using writing in their classes. Information from these materials (tables, figures) was inaccessible and omitted from their research.

Researchers from this study presented similarities to my study regarding instructor beliefs relating to writing strategies for their classes. The instructor from my study uses reflection as part of their assessment process, and nearly seventy percent of instructors used writing as part of their STEM classes. Both instructors indicated they used a writing-to-learn (Keys, 1999) strategy for their classes. They found this an effective way to incorporate writing into their classes and support student learning. Another similarity was the connection between all instructors from this study relating to the effectiveness of writing in "developing students' conceptual knowledge and understanding principles in STEM (Finkenstaedt-Quinn et al., 2022, p. 5)." The study does not specify any particular STEM discipline or which instructors believed writing was essential to particular classes. However, all instructors using writing acknowledge that writing is an integral part of student assessment strategies relating to the work they performed during an assignment/project and how they develop their strategies in articulating the complexity of STEM learning environments in undergraduate classes.

A notable difference was observed, as instructors from the researcher's study also used writing to demonstrate mastery as a strategy for their classes. This differs from the strategies used by the instructor for my study, who indicated they use writing to learn. However, rather than using writing to assess student writing mastery, they used peer reviews between students as a writing strategy. This allowed students to document, in writing, team members' performance and whether they did their fair share of the work during the project. This feedback, along with other writings, was used to assist the instructor with grading individual work performed during projects and assess their abilities to articulate processes encountered and the final results of their project.

Theme 2: Participant Difficulty in Identifying Systems Design/Systems Thinking Processes

The three remaining themes are related to research question two: Do targeted, repeated written reflection assessments throughout a college semester indicate that the industrial technology program of study adequately educates its students in the three elements of technological and engineering literacy?

These themes apply to both sets of participants: those who performed the three written assessments and those who were interviewed. Each theme touches on one of the three elements of technological and engineering literacy: design and systems, human capabilities, and the impact of technological development on society and the environment. The first of the three questionnaires asked about systems design, a fundamental technological design and development component.

When analyzing the data, it was determined that two out of three participants needed help understanding what systems design is, the processes involved, and the importance of discovering design flaws. They also needed to identify how to use systems thinking to create new designs and products. Systems thinking is the ability for individuals to look at a product and see it as a unit, or system, with multiple components working together to produce an output. Systems thinking is the concept of seeing the whole, not just components, AKA the big picture (Shaked, Schechter, 2019, p. 19). Participants who are tasked to create products as part of their academic studies, as well as in the future while on the job, are required to know not only how to work through the steps of the technological and engineering problem-solving processes but must also possess the ability to articulate these processes by utilizing a systems thinking approach. Studies with similar results are presented for support purposes.

A qualitative study examined the systems thinking skills of 20 students between the ages of 9 and 12 using a think-aloud exercise relating to the food chain ecosystem. The goal was to determine if these participants could articulate how ecosystems work, using prior systems thinking experiences, both from a personal and educational perspective. One research question was: What factors influence students' reasoning about ecosystems and how they interact? A questionnaire consisting of 14 questions, over three separate categories relating to systems thinking skills, was presented to participants. Questions were broken into three categories: systems organization (8), systems behavior (3), and systems-adequate intention to act (3). Each question was presented individually, with participants given three answers. Systems organization refers to the steps of a process that must be completed to complete a task or solve a problem. Systems behavior refers to the change and effect in a system's characteristics, composition, or events or causes change in other systems (Ackoff, 1971). Systems-adequate intention to act is the process of predicting how specific interventions will impact ecosystems in the future.

Participants were prompted to explain why they chose a specific answer and to provide the reasoning process they used to arrive at that conclusion. Each think-aloud session took as much as 40 minutes to complete. Sessions were recorded and transcribed. Independent of the study, two raters separated responses into categories using coding. The raters discussed differences in ratings until they reached an agreement.

Results showed that participant systems thinking skills were limited to single, descriptive explanations of an individual aspect of the ecosystem but needed help to articulate a deeper understanding of how an ecosystem functions. For example, participants could provide a complex analysis of a single event. One participant responded to one question: "All animals are poisoned and get sick. The snail and caterpillar eat the poisoned dandelion. The bird and mouse eat the caterpillar and snail, which are also poisoned, and the fox eats the bird and mouse, accordingly (Mambrey et al., 2020, p. 86)." While this statement does correctly identify the prey-to-predator cycle, it does not include a feedback loop process related to the scenario, which would indicate deeper systems thinking knowledge. This scenario was observed by researchers throughout the think-aloud activity and indicated that students relied more on their imaginations and preconceptions than actual knowledge. Researchers reported that only two participants (4.3%) provided supporting information based on their knowledge of systems thinking.

Researchers developed a chart to illustrate the participant's development of systems thinking skills, which was broken down into three categories: systems organization, systems behavior, and system-adequate intention to act. Each category contained four sub-categories: level of systems thinking, conceptions, representation, and knowledge. The chart was also broken down into age groups to show whether student systems thinking skills improved throughout their education. Each age group was listed, showing the highest level of achievement across the three categories relating to systems thinking. Scores ranged from monocausal to complex. Black boxes indicate that students used reasoning patterns applicable to each sub-category. White boxes indicate that students did not provide adequate knowledge within each sub-category.

The chart indicates that students' knowledge of systems thinking improved as students moved from grade to grade. There were indications that some younger students displayed complex knowledge abilities. Student relationships to each category increased in all but the system-adequate intention to act category, where students needed to provide examples of representation or knowledge. This finding applied to students, regardless of age, and showed that thinking patterns applicable to this category did not vary over time.

There is a correlation between the findings of my study and the study of Mambrey et al. Participants in my study were presented with the three elements that make up technological and engineering literacy. Participants in this study also needed help with one of the elements presented while successfully addressing the two remaining elements. Although the Mambrey study addressed a different topic, the methodology and findings were similar.

Theme 3: Student Ability to Articulate Work Performed on Projects (Human Capabilities)

The second reflective writing assessment dealt with another element of technological and engineering literacy: human capabilities. Participants performed well on this topic. They offered several examples of working together to establish project strategies, including communicating when dividing work responsibilities. They mentioned the occasional meetings to discuss issues needing attention, especially those slowing project progress. They also discussed how the group worked together to ensure each team member was supported. This was especially true when individuals were tasked to work with specific tools or machines they had never used. More experienced students would show them how to set up the machine and use it safely and would stay with them to ensure they were comfortable using it. Collaboration and cooperation can be critical to a project's success or failure. The following study is provided to support the findings of my study.

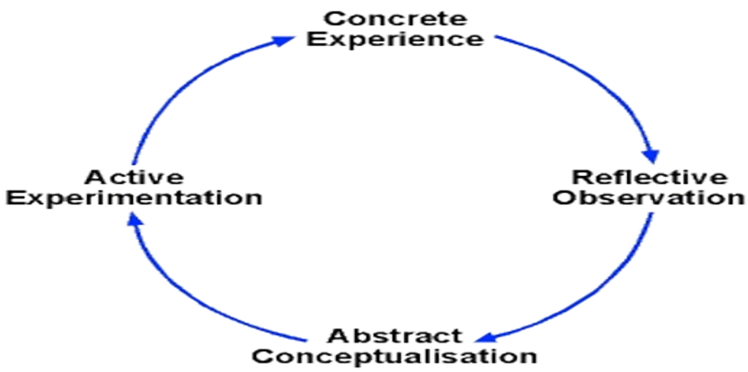
In one study, researchers investigated how limiting student exposure to reflective writing curtails their abilities to produce meaningful reflections. Researchers used a single-cycle action research method, which is used to pose problems and ultimately provide solutions to those problems. In this study, researchers aimed to address the issue of students' lack of ability to write reflectively by using a multifaceted research design through modeling, the 6+1 traits writing rubric, and blended learning environments (Ramlal, Augustin, 2020).

Modeling refers to using learning models to guide students through specific learning methods. Researchers attempted to broaden students' critical thinking and systems-thinking development in this case. This was attempted by using reflective writing models such as Gibbs's (2005) learning by doing and Kolb's (1993) process of experiential learning models to facilitate the reflective writing processes.

Kolb’s framework was developed to highlight how humans connect with skills developed in secondary and post-secondary school and apply them to real-world situations. This four-stage model includes active experimentation, where students may be more willing to jump right in and experiment with specific processes to discover how something works/functions. Another stage is concrete learning, where students complete a new or previous task and, based on prior experience, discover a more efficient way to complete the task. Reflective observation is the stage where students reflect on their new learning to understand better what it means and how it is applicable/relatable to other learned concepts. The last stage is abstract conceptualization, which refers to students developing alternate solutions or pathways to solve a problem based on their prior experiences, observations, and self-efficacy. (Kolb, 1984).

Figure 6

Kolb's Experiential Learning Model (Kolb, 1984)



Researchers also used the 6+1 writing traits developed by instructors across the United States in the 1980s to identify six criteria linked to improved writing proficiency. The six traits are ideas, organization, word choice, sentence fluency, and writing conventions (mechanics). Presentation is considered as the +1 of the model. This model serves as a guide to assist instructors in developing learning materials for students to learn the importance of each step of the writing process. The goal is to improve student writing skills throughout K-12 to prepare them for college and the workforce. Numerous books, articles, and other reference materials are available for instructors to access and use for developing writing-related activities and units of instruction.

The final method used was blended learning environments, which refer to face-to-face and virtual learning environments. This approach allows instructors to reach a broader audience of students and also allows them the flexibility to develop learning content that is appropriate for both sets of students. This includes activities that require collaboration between groups to accomplish a task or project and opportunities for students to provide peer feedback during and after the activity. These three methods were used to determine if students' reflective writing skills improved throughout the intervention.

This study consisted of nine lessons covering the different aspects of reflective writing. Lessons 1-3 introduced students to the reflective writing process, different types of reflection, and the characteristics of reflection. Lessons 4-5 were used to show students how to create deep, rich reflections. This was achieved by introducing students to the Kolb Experiential Learning Model. Lessons 6-7 focused on linguistic skills. This is where the 6+1 writing rubric was introduced. This guided to show students the importance of structure, sequencing of ideas, and other writing conventions. Lessons 8-9 provided opportunities for students to self-evaluate, as well as provide peer review of other student work.

Participants were thirty-seven secondary school students, ages 14-15, with little to no experience performing reflective writing as part of their regular coursework. Students were of high academic standings, including speaking and writing English, with most interested in science-related classes. This group of participants also had similar socio-economic backgrounds but various ethnic backgrounds.

This study used both quantitative and qualitative methods to collect data. A pre-test and a reflective writing assessment were given to establish a baseline knowledge of reflective writing and its purpose. Post-intervention, an identical test was given to determine if their ability to reflect improved throughout the study. A rubric designed to assess student reflections was used to score writings, which were scored using an out-of-15 scale. Researcher quantitative data included mean, median, mode, and standard deviations, and a paired *t*-test was gathered to determine differences in pre-test and post-test scores. Participants were given a questionnaire consisting of twenty questions to provide their feedback. A scale of 1-5 was used to determine participants' feelings towards reflective writing processes, with high scores indicating a favorable (enjoyed the lessons) response and low scores showing less favorable (did not enjoy) responses.

Results from the modeling intervention indicated an improvement in scores for 36 out of 37 participants, with several participants exhibiting significant increases in scores from their pre-test to post-test. For example, two students scored a nine and an eight on their pre-tests and scored a 15 and 10 on the post-test. The overall mean score increased from 8.38 to 12.22. Researchers conducted a paired *t*-test, which showed the calculated *t*-value at 4.7, and the *t*-value from the *t*-table was 2.04. Probability was set at $p< 0.05$, with researchers using a 95% confidence level with *t*-test results less than 0.05 (Ramlal et al., 2020). This indicated that modeling (Kolb Model) was a beneficial learning tool, as it improved participant cognitive levels relating to reflective writing from pre-test to post-test.

The results from these data were nearly identical to the findings of my study. Both studies used a repeated measures assessment approach, showing significant mean increases from assessment to assessment. This is the first correlation between the two studies. Another correlation was using a single instructor to provide guidance and input on their students' learning. This included using scoring rubrics for the seven projects introduced to students at the beginning of the semester. These rubrics established the writing requirements expected for the reports due after each project. Note: These rubrics were separate from the one used to score responses for the repeated measures assessment used throughout my study.

One slight difference between studies was noted. I used the four-part Moon (2004) Model, as well as a scoring rubric developed by the Association of Colleges and University

(Rhodes, 2010) to guide my study, while the other study used the four-part Kolb (1984) Model and an adapted version of the Caribbean Secondary English Certificate (CSEC) rubric. Both of these models are designed to assist instructors in identifying pathways to improve student learning as they relate to student writing, with one model focusing on reflection and the other on experiential learning. The two rubrics were developed for the sole purpose of analyzing students' reflective writing skills.

The next set of results was based on using the 6+1 traits rubric. This rubric was also cited as a factor in improved reflective writing performance during the pre-test; sentence structure and organization of thoughts and ideas needed to be improved in most of the submitted works. Submissions typically consisted of a single paragraph consisting of single, descriptive details, with little to no depth of thought or critical thinking provided. Post 6+1 interventions showed that writing quantities increased from one to three paragraphs, and the writings were far more organized and developed. They demonstrated increased critical-thinking skills compared to their previous writing samples. Participants also displayed much higher levels of phrasing of written content.

The final data on blended learning environments was obtained via a five-point Likert scale survey before and after the intervention. Researchers showed increases in mean, median, and mode scores. A paired *t*-test was conducted to compare means from the two surveys. Results showed the calculated *t* value was 2.68, with the *t* value from the *t* table being 2.04. Probability was set at $p < 0.05$, with a 95% confidence interval, showing the *t*-test result was less than 0.05, indicating significant changes in student attitudes towards reflective writing. Researchers indicated that these results agreed with other studies found in the literature relating to this topic.

Theme 4: How Technological Development Impacts Society and the Environment

This last written assessment focused on how technological development impacts society and the environment. This was one area where all participants from both groups excelled in their responses. Participants provided detailed discussion points relating to both the positive and negative impacts. Examples included discussions about technology making life more convenient and straightforward and easing Internet access to products and services. They also discussed the burning of fossil fuels and their impact on the environment through climate change, pollution, and stripping away natural resources. These were important points, as there is a tendency for many in society to focus only on the good things technology provides.

Study One

As the environment around the world continues to degrade, educators must be proactive and include environmental issues as part of their curriculum. Doing so will increase knowledge and give students a better understanding of technological development's impacts on society and the global environment. Environmental education was conceptualized in 1972 when a United Nations Conference member voiced concern about the future of the world's environment (Nkwetisama, 2020). 1975 the United Nations organized an International Environmental Education Workshop in Belgrade. Two years later, the Belgrade Charter was initiated, outlining six objectives relating to environmental education. They include awareness, knowledge, attitudes, skills, evaluative ability, and participation (Unesco, 1977). The goal was to increase students' environmental awareness to prepare and educate them so they could participate in initiatives to prevent further damage to the world they live in. them for the future

One study conducted in 2021 investigated student views and challenges relating to society and the environment through student essays. Researchers used a case study design deemed appropriate, as the data sought was on a single phenomenon. Participants consisted of 17 students taking an English as a first language (EFL) class at Universitas Negeri Malang in Java, Indonesia. Two research questions were presented for this study: one sought students' opinions on using environmental topics during the essay writing course, and the second addressed student problems writing essays.

Data collection was achieved via chat interviews on WhatsApp and student essay writing. The interview via WhatsApp, related to research question one, consisted of students providing their opinions on using environmental topics to write essays. Once they completed their brief responses, they were asked to describe the environmental topic in one word. Participants were asked to write about their essay problems for research question two.

Results relating to research question one indicate that students' opinions were positive when allowed to write about the environment. The single-word responses most used by participants were informative (24%), significant (12%), and valuable (12%). Several short response samples were provided as background material relating to student opinions. Examples:

1. I do not face any problem with environmental content. Sometimes, it excites me because it also gives me new information. I would think of it as "informative" because we need to do further research before jumping into the writing part.
2. It is a great way to raise our awareness of the environment around us. It is educative.
3. I have no problems with the environmental content, and I describe the content as 'informative.' Sometimes, I need to learn what is happening lately with the environment, but because of this content, I want to find out (more) and, of course, get much new information.

One benefit discussed was increasing participant awareness of this global issue and requiring them to think critically. Researchers also discussed the enthusiasm displayed by participants to include this topic in their writings, with some indicating that the topic would allow them to discover environmental problems they faced in their region of the world and beyond.

Data relating to research question two, which sought participant opinions relating to problems encountered when writing an essay about a topic related to the environment. Several problems were identified from interview responses to this question, including psychological, linguistic, and cognitive problems. Data showed that 60% of participants said they had psychological problems, with 20% having linguistic and cognitive problems. As with research question one, researchers provided samples of participant responses. Here are a few examples:

1. Writing will always cause anxiety for me. It is like feeling uneasiness after submitting an essay, feeling like it was not good enough. I also needed help with grammar and word choices. I tried to use thesaurus and Grammarly for every essay, but I always needed help figuring out what was wrong.
2. My writing problem is mostly about time because I need forever to finish an essay or make it perfect, but it happens because I fear to pour out my opinion. Also, because it is my first time writing essays, I am afraid it does not meet the criteria for a good essay.

Researchers conclude that participants felt optimistic about using environmental topics in their EFL class and that it would increase their knowledge of environmental problems. They also conclude that the issues described by participants are considered typical, especially for students writing about a topic they may be unfamiliar with and are doing so in a language they may barely know how to speak. Researchers also recommend that environmental issues be part of the EFL class. However, it should be presented infrequently, with instructors providing ample time for students to prepare for this topic due to the potential for student self-induced stress.

While this study does not directly correlate with mine, it has several similarities. Researchers discuss the need for students to have a better understanding of the environment and the threats posed to it across the globe. They also discuss technology and industry's impact and the vast exploitation of natural resources needed to support its development. This is the common thread between studies, which adds to the literature and highlights the importance of educating populations about technological development's negative impacts on society and the environment.

Study Two

One study investigated the environmental development (competence) of two hundred first-year biology students in Kazakhstan preparing to become future instructors. Researchers used a test/retest method consisting of a written survey, a questionnaire, and participants responding to questions posed via self-diagnosis sheets and completing an environmental culture test (Amantayeva et al., 2022). The study aimed to determine if these first-year biology students' level of environmental awareness increased over the 2018-2019 semester.

Participants were given the choice of receiving learning content via the materials presented by the instructor, with participants performing individual tasks related to the presented learning content (subject-cognitive/practical application activities) or using the project-based learning environment option. Groups were tested at the beginning of the semester to determine their level of competence related to the environment. The initial test indicated that 82% of participants had low environmental development when performing subject-cognitive tasks, with participants also having low environmental development when completing project-based tasks (92%).

Participants were enrolled in a course called Ecology and Sustainability Development. The intervention focused on several concepts and topics presented during the semester. Seven topics were presented to the subject-cognitive participants, and four topics/projects were selected for those in the project-based learning group. Several instructor actions were listed for those students participating in the project aspect of the study, with reflection as the last step of the project. Reflections focused on processes conducted, insight into the work/tasks performed, and peer feedback. At the end of the semester, researchers compared before and after test scores with the following results. More than 50% of the students receiving subject-cognitive tasks showed high levels of environmental competence, while participants given project tasks showed a 75% level of environmental competence. This was a drastic improvement when compared to the initial tests. Subject-cognitive scores increased by more than 32 percentage points, while project-based scores increased by more than 60 percentage points.

These results indicate that when these students were allowed to perform project-based learning activities, learning outcomes were higher than in the typical classroom setting (lecture format). This is a direct correlation to my study, as project-based learning environments were used as the basis for gathering data relating to the impact of technological development on the environment. Allowing students to work through the technological and engineering design processes allows them to produce products and demonstrate increased environmental competence via written reflection.

SUMMARY

Chapter IV discussed the findings from the data gathered from the three instructor interviews and three written assessments conducted during the study. Quantitative data via descriptive analysis, measures of central tendency, a dependent t-test, and interrater agreement/correlation were conducted. Qualitative data was obtained through a descriptive coding process, and results from individual responses to the three questionnaires given throughout the fall 2022 semester were discussed. Additional qualitative data were collected via interviews of eleven students during the spring 2023 semester. A discussion of common themes was provided, with supporting research to bolster/support my study results. Chapter V will provide discussions relating to the findings, conclusions, and recommendations for future research relating to this topic.

CHAPTER V

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

This study aimed to determine if instructors used reflective writing as an assessment method, whether at the beginning, middle, or end of project work given throughout a semester. Student abilities to reflect on their experiences during these projects and whether their writings improved throughout the semester were also examined. The emphasis was on third and fourth-year college students taking industrial materials classes, with project-based learning as the primary learning environment.

As outlined in Chapter One, two research questions were to be answered during the study. The first research question asked: How much emphasis does an instructor with a university's industrial technology program place on students' written reflections? Are they considered an essential part of their assessment strategy for their students? The frequency and methods used to conduct these assessments were included in this question. The second research question asked: Do targeted, repeated written reflection assessments throughout a college semester indicate that the industrial technology program of study adequately educates its students in the three elements of technological and engineering literacy? My study was framed around these two research questions.

I identified a gap in the literature on instructors' use of reflective writing assessments during project-based activities/units of instruction. When developing my literature review, I discovered that much of the literature focused on instructors and pre-instructors, who were allowed to reflect on their learning experiences during their professional development training. This was echoed by Cavilla (2017), who pointed out during his research that there were similar disparities in the volume of research available as it related to student reflection and instructor reflection. After many weeks of searching through various databases, I located several studies about instructor strategies for using written reflection as an assessment method for students. Strategies included using reflection prompts, which were used to interrupt a student's reading at predetermined/preset intervals and ask them to respond to questions in writing. Researchers using this strategy found that students performed at a higher level than those who were not given prompts Householder, Schaffer (2020). Researchers found Similar results using reflection triggers (knowledge checks). Results across other studies in the literature review, where written reflection was used as an assessment method, showed increased student reflection skills, without exception (Council of Writing Program Administrators, 2019); Grossman et al., (2019); Savicki & Price, 2015).

CONCLUSIONS

This quantitative and qualitative study examined the written reflection abilities of students attending a university in the southeastern United States who were enrolled in the STEM department's industrial technology degree program. They were selected due to their prior experiences performing activities/projects associated with project-based learning. They were also selected as a convenience sample due to their accessibility at the university. The study took place during the fall 2022 and spring 2023 semesters. Several data collection methods were used during this study.

Data collection began via three reflective writing assessments given to one group of participants during the fall 2022 semester during predetermined times to correlate with the completion of projects given to them during the semester. Data collected from the three assessments included responses to single-answer questions and several extended-response questions. Single-response question data were placed into table format. At the same time, extended responses were scored by the instructor and me and placed into bar charts to show individual scores by question for each assessment. Further qualitative data were presented via written comments/feedback by me for several participant responses during the three phases of the assessment. Examples of both exemplar and unsatisfactory responses were provided to illustrate where some participants excelled, and some participants struggled to answer adequate questions relating to the three elements of technological and engineering literacy (human capabilities, design, and systems, and impact on society and the environment). Qualitative data were also collected in descriptive coding to identify topics mentioned in student writings.

Additional data were collected via dependent t-tests to determine mean scores and examine interrater differences in scoring the three assessments. Quantitative results showed increased mean scores, indicating that using a repeated measures assessment strategy in reflective writing is a viable assessment method for checking a student's technological and engineering literacy demonstration. This is especially true when using project-based learning environments (Naimsamphao et al., 2019).

An industrial technology instructor also participated in the study by agreeing to be interviewed and assisting me in grading the three assessments. A separate group of participants were interviewed during the spring 2023 semester, using the same questions to determine the similarities/differences in given responses. Descriptive coding was done to identify topics mentioned during participant interviews. Interview responses were selected from both exemplary and incomplete responses. I provided feedback explaining what was presented well and where participants could have done better.

Throughout the assessment process, the abilities of students to articulate their experiences while performing and completing projects over their college careers were not limited to the work they did or the outcome/result of the project. Their discussions/responses to questions posed to them went beyond the scope of the work performed during a project. They recognized that technological development has both positive and negative outcomes, and their responses included discussions about its impacts on society and the environment. For example, one participant noted:

> "When you think of the environment, you may not think of technology. However, technology plays a huge role in our environment. A few examples include emissions from vehicles, hydroelectric dams, emissions from factories, and recovery of refrigerant in our A/C units. This is just the tip of the iceberg; there are many other ways our environment is impacted by technology."

Strategies to complete a project were also discussed; new learning occurred while working with unfamiliar materials and the different industries using these types of materials. One participant went so far as to say:

> "With the many projects I have had the experience doing while at college, I have been exposed to various topics, materials, processes, technology, and industries. Although I am not an expert on all of them, at least I have been exposed to them and have a better understanding of some of the world's most popular technologies. The projects get you out of your comfort zone and help you gain more knowledge in many fields you may have little knowledge or experience. They help broaden your horizon and knowledge in many different ways."

Using reflective writing as an assessment strategy offers instructors and students insight into how connections are made to learning content and how to apply newly developed skills after performing project-based learning activities/units of instruction. Unlike multiple-choice or fill-in-the-blank assessments, which allow students to potentially guess when they do not know the answer, reflective writing assessments require students to think critically about the activities or problems encountered during projects they were tasked to complete. This includes challenges from working through the steps of the technological and engineering processes. They could discuss team dynamics, problems encountered, and how they overcame them. Participants also discussed new skills they may have developed and a task(s) they never thought they could perform (taking them out of their comfort zones). These writings also offer students a chance to archive their work and review it occasionally to check on their skill development and ponder what and how they learned it. They may also use their archived writings as part of an ePortfolio to improve their chances of getting a job, as many employers are becoming increasingly interested in seeing portfolios as part of the hiring process (Leahy, Filiatrault, 2017).

Assessing reflective writing can be a tricky endeavor. Instructors with experience using this strategy are far more likely to be successful than those with limited or no experience assessing these writings. As noted in this study, the instructor who participated was well-versed in scoring rubrics and possessed years of experience using reflective writing as an assessment tool for project/problem-based learning activities. Opportunities for students to express their experiences during project/problem-based learning activities should be made available as often as possible to allow students to express their experiences, both the highs and lows of a project and, most importantly, demonstrate the elements of technological and engineering literacy.

How students approach or feel about reflective writing can be a significant obstacle to overcome. This is partly because many instructors need to use reflective writing prompts or understand the essential points they seek when asking students to reflect. Professional development in this area is essential, primarily when students are tasked with performing project work. For example, from a student's perspective, when asked about the importance, they often say it is underrated (Roberts, 2002). This is where instructors become critical in helping students develop reflective writing skills.

The teaching and learning strategies discussed in this paper offered a look into reflective writing and how instructors who use them repeatedly may provide additional insights for students concerning technological and engineering literacy. While discussions during lectures, presentations, and meetings may be effective in developing student knowledge of technological and engineering literacy, reflective writing assessments provide a much broader opportunity for students to discover new things about themselves, which can be extremely powerful. The ultimate goal of repeating the assessment was to change the perspective of students who, despite being technically savvy with digital devices, may not be as adept with the way technology is designed and developed or the impact technology has on society and the environment (Whalen, Paez, 2021).

Students who are experienced in these learning environments can showcase their previous knowledge and experiences by responding to questions that not only ask them about learning content provided during the semester but also how they approach technological and engineering design development and how it increases human capabilities. Participants demonstrated that their knowledge and skills are well-developed and possess the skills to understand technology and directly impact technological design and development (Hallström, 2020). These are critical elements of technological and engineering literacy, vitally important to college students and the general public, who are seen as primarily end-users rather than the ones controlling its development and implementation (Bosch et., 2022).

While the goal of this study was to use reflective writing as an assessment method, interview data indicate that using interviews as an assessment method may be just as informative and valuable a strategy as written reflection. I found this especially interesting, as interviewees were not allowed to review questions or provided extended periods to respond. They were required to respond spontaneously, with minimal time to frame their responses, which may have disadvantaged them. Even so, many participants provided responses that were as detailed and, in some circumstances, more detailed than those who completed the written reflection portion of the study.

IMPLICATIONS

During the data collection, it was discovered that neither the class instructor assessing participant written reflections nor I had ever received formal training on teaching written reflection. This is problematic because untrained instructors may teach students the wrong way to reflect while having good intentions. This is especially important for education systems that offer industrial technology courses, as those programs touch on many aspects of technology and its development (Huang et al., 2022).

A possible solution to this problem is for all of the university's industrial technology instructors to receive formal training in reflective writing as a professional development incentive to benefit themselves and their students. This is especially true if reflection training focuses on the three elements of technological and engineering literacy: design and systems, human capabilities, and societal and environmental impacts (ITEEA, 2021). Many organizations offer this training, and the university's Industrial Technology instructors should be provided access to these opportunities as budgets allow.

For example, one organization that provides STEM/CTE instructors professional development is the national non-profit organization called the Association for Career and Technology Education (ACTE). They offer memberships to state and non-state educators and provide in-person and virtual professional development opportunities such as webinars, meetings, and STEM/CTE materials for instructors in their archives. They provide several resources relating to an instructor's development plan, such as links to several STEM/CTE lessons covering a wide range of topics, a career lounge for instructors to collaborate across the country, and a bank of workplace tutorials, which are used to help STEM/CTE instructors improve their general teaching skills (ACTE, 2023).

Another resource is the International Society for Technical Standards (ISTE), which provides training education guidance and support to instructors, including pre-service instructors. This organization is an outstanding resource for instructors to obtain the professional development they need. For example, they offer publications that discuss research on digital learning and education technologies. They also provide instructors with an instructor guide to help them develop learning content, including activities that allow their students to interact with technology.

Their professional learning portal provides a list of networks/organizations instructors can access to get the latest information on instructor professional development opportunities and tools to collaborate with other instructors. Some examples include access to chat rooms, podcasts, and blogs to discuss teaching strategies, exchanging of thoughts and ideas relating to technology in the classroom, and ways they can enhance student learning experiences in their classrooms. Instructors can also access webinars and select from several topics, such as developing, implementing, and evaluating technology used in their classrooms (ISTE, 2020).

These are just a few examples of the resources available to industrial technology and CTE instructors who are beginning or continuing their pursuit of professional development. Access to professional development opportunities such as these may help instructors improve their development of learning content that focuses on a student's ability to communicate, in writing, their experiences during industrial technology projects.

As far as industrial technology students, they should be introduced to written reflection as soon as they begin taking their core courses for their major, especially those that offer curricula related to technological and engineering design. They need to discover the intricacies of technology, how products go from concept to product manufacturing, and the time it takes for teams to go through all of the processes to complete a project. Another essential reason is to introduce them to the negative impacts of technological development on society and the environment. They must understand that technological development does not always result in the most environmentally friendly outcome (Rasa1, Laherto, 2022).

Incorporating written reflections as an assessment method early in a student's education will make them far more technologically and engineering literate when they reach the end of their academic careers. This pedagogical strategy may help curb some environmental and societal damage we currently face. As students graduate and enter the workforce, they will be better equipped to articulate their concerns within their chosen profession or industry (Hommell et al., 2023). As instructors, we are responsible for providing students with as much technological and engineering knowledge as possible, as they may be the future leaders of industries worldwide.

Another item relating to written reflection was pointed out in the project-based learning section of the literature review. I discussed that students may work in group environments during industrial technology classes. However, they must remain cognizant of their individual experiences and responsibilities and how they are developing skills and strategies to complete tasks. Reflection is an integral part of that process. When students are allowed to reflect, in writing, on their work, they can gain insight into their work, the way team members interacted, and how they strategized to complete a project. This builds self-confidence, motivation, and meta-cognitive skills to help them with future projects (Chatzipanteli, (2014). Written reflections that touch on the technological and engineering design processes are not only for the classroom but also for manufacturing and other industries.

For example, individuals tasked with designing and developing technological products must be able to articulate, in writing, work that was accomplished via sketches, technical reports, schematics, graphs, and other methods to convey a product's design concept. These writings are critical to the design team, upper management, partner companies, and other stakeholders (Keshavarz, Baghdarnia, 2013). The goal for the design team is to convince interested parties that approval for the new design will benefit society and the environment and provide a positive return on investment (ROI). The sooner students learn about written reflection, the better.

Another discovery made during the data analysis was the difficulty participants had explaining one of the elements that make up technological and engineering literacy: human capabilities. It was apparent that they needed help to grasp the elements involved with the questions, which merely asked about their experiences, what went well, obstacles faced, and how the team strategized to overcome delays in their progress. This is where course/curriculum changes may help. Suppose schools/colleges/universities are teaching about the steps of the technological and engineering problem-solving process. In that case, teaching material must be developed to increase student's knowledge of team dynamics (individual skills), project strategizing and planning, and how to work through the many problems that may occur during the project (Kilty, Burrows, 2022). This additional training will benefit students greatly, as they will better understand how teams collaborate and may encourage them to be open-minded about performing group work.

RECOMMENDATIONS FOR FUTURE RESEARCH

The assessment strategy discussed in this paper may help other researchers identify gaps in the literature relating to using written reflections as a learning tool to determine group dynamics and document individual student experiences during project-based learning activities/units of instruction. Instructors also benefit from using this strategy, as they can implement reflection at various stages of a project (reflection prompts) to gather information relating to team roles and responsibilities, progress, and obstacles to progress encountered during the project. This can be especially helpful when dealing with younger students who may need to gain experience working in groups or performing project work. Students with prior experience can express concerns with issues like people not helping the team, work needing to be done correctly, and a lack of cooperation between group members. Issues like these occur in groups and may cause apprehension for those students who have experienced these matters in the past (Hennessey et al., 2023). Addressing these concerns at the beginning of a project may help put students at ease and become more open to project work in the future. More importantly, by using repeated assessments, instructors can identify and address these issues early on in the project and may be able to refocus the group and help stave off group failure at the end.

Research of this nature can be introduced gradually. Researchers may target only one of the three technological and engineering literacy elements at a time. This may be especially useful to researchers interested in investigating project-based learning environments at the K-12 level.

They may find using repeated measures of reflective writing assignments a helpful strategy to help instructors improve students' reflective writing abilities regarding technological and engineering literacy (Campbell et al., (2019). These types of assessments may address some of the challenges faced by K-12 students during project-based learning activities/modules, especially as they progress through middle and high school. Establishing a foundation of knowledge will significantly benefit younger K-12 students. When to implement such methods would be left to school administrators, in coordination with instructors, to ensure this method is age-appropriate for students (Chang, 2022).

Researchers having access to college students enrolled in programs of study that emphasize technological and engineering design or similar programs may perform longitudinal studies on this topic. They could track reflective writing skills from inexperienced first-year students and review skill development as they become experienced students (juniors and seniors). Another approach might be conducting a study where one group receives a valid and reliable scoring rubric while the others do not. A comparative analysis may determine the importance of using a rubric for these reflections (Desjarlais, Smith, 2011). A comparative analysis could be conducted between groups similar to my study, where one group completes written reflection, and the others are interviewed. The formal scoring of interview responses could be compared to the scores from reflective writing participants. Research of this type may further the literature on this topic and bolster the argument that reflective writing related to technological and engineering literacy skill development is a viable option, especially when a project-based learning environment is the primary content delivery method.

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Appendix A

OLD DOMINION UNIVERSITY
HUMAN SUBJECTS RESEARCH EXEMPT APPLICATION FORM

Study Title
A STUDY ON THE IMPACT REFLECTIVE WRITING HAS ON COLLEGE STUDENTS' DEMONSTRATION OF TECHNOLOGICAL AND ENGINEERING LITERACY SKILLS.

Principal Investigator (PI)		
The PI must be an ODU faculty or staff member who will serve as the project supervisor and be held accountable for all aspects of the project. Students cannot be listed as the PI.		
First Name: Petros		**Last Name: Katsioloudis**
Telephone: (757) 683-7400		**E-mail: PKatsiol@ODU.EDU**
Office Address: 4100 EDUCATION BLDG		
City: NORFOLK	**State: VA**	**Zip: 23529**
Department: STEM Education and Professional Studies	**College: Education**	
CITI Completion Date: 4/21/2022		

Investigators		
Investigator(s): Individuals who are directly responsible for any of the following: the project's design, implementation, consent process, data collection, and/or data analysis. Investigators must complete the CITI Basic Human Subjects Protection Training.		
First Name: William		**Last Name: Euefueno**
Telephone: (910) 581-8011		**Email: WEuefuen@odu.edu**
Office Address: 4100 Education Bldg		
City: Norfolk	**State: VA**	**Zip: 23529**
Department: STEM Education and Professional Studies	**College: Education**	
Affiliation: ☐ Faculty ☒ Graduate Student ☐ Undergraduate Student ☐ Staff ☐ Other:		
CITI Completion Date: 4/21/2022		
Upload a copy of the Additional Investigators form if more rows are needed.		

Type of Research	
2. This study is being conducted as part of (check all that apply):	
☐ Faculty Research	☐ Non-Thesis Graduate Student Research
☒ Doctoral Dissertation	☐ Honors or Individual Problems Project
☐ Masters Thesis	☐ Other:

Funding

2. Funding Status:

☒ Research is **not funded** **(go to 3)**
☐ Research is **funded** **(go to 2a)**
☐ **Funding decision is pending** (funding decision has not been made) **(go to 2a)**

2a. Type of funding source: (Check all that apply)

☐ Federal Grant or Contract **(Must submit to IRB for review)**
☐ State or Municipal Grant or Contract
☐ Private Foundation
☐ Corporate contract
☐ Other (specify):

Funding Agency Name:	
Agency Proposal Number:	
Grant Start Date (MM/DD/YY):	
Grant End Date (MM/DD/YY):	

2b. List the point of contact at the funding source:

Name:	
Mailing Address:	
Telephone :	
Email:	

Research Dates

3a. Date you wish to start research (MM/DD/YY): 08/27/2022

Research Location	
4. Where will the experiment be conducted? (Check all that apply)	
☒ On Campus	Building and Room Number: Education, Rm 4143
☒ Off-Campus	Site Name and Street Address: ONLINE/Distance Learning Courses

Human Subjects Review
5.Has this project been reviewed by any other committee (university, governmental, private sector) for the protection of human research subjects? ☐ Yes ☒ No **(If no, go to 6)** **5a. List the other committee(s) that have reviewed this project and indicate which IRB is serving as the primary IRB.**

Exempt Categories
NOTE: IRB Review is required for Categories 2, 3, and 4 if your research involves sensitive and identifiable information. IRB Review is also required for Categories 7 and 8.
☐ **Category 1** Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
☒ **Category 2** Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: i. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects. ii. Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or iii. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by §__.111(a)(7).

☐ **Category 3**

i. Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:

- The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
- Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or
- The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by §__.111(a)(7).

ii. For the purpose of this provision, benign behavioral interventions are brief in duration, harmless, painless, not physically invasive, not likely to have a significant adverse lasting impact on the subjects, and the investigator has no reason to think the subjects will find the interventions offensive or embarrassing. Provided all such criteria are met, examples of such benign behavioral interventions would include having the subjects play an online game, having them solve puzzles under various noise conditions, or having them decide how to allocate a nominal amount of received cash between themselves and someone else.

iii. If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in research in circumstances in which the subject is informed that he or she will be unaware of or misled regarding the nature or purposes of the research.

☐ **Category 4**
Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

i. The identifiable private information or identifiable biospecimens are publicly available.

ii. Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects.

iii. The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

iv. The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

☐ **Category 5**
Research and demonstration projects that are conducted or supported by a federal department or agency…
(Not common at ODU)

☐ **Category 6**
Taste and food quality evaluation and consumer acceptance studies
(Not common at ODU)

☐ **Category 7**
Storage or maintenance for secondary research for which broad consent is required: Storage or maintenance of identifiable private information or identifiable biospecimens for potential secondary research use if an IRB conducts a limited IRB review and makes the determinations required by §__.111(a)(8).

☐ **Category 8** Secondary research for which broad consent is required: Research involving the use of identifiable private information or identifiable biospecimens for secondary research use, if the following criteria are met: i. Broad consent for the storage, maintenance, and secondary research use of the identifiable private information or identifiable biospecimens was obtained in accordance with §__.116(a)(1) through (4), (a)(6), and (d); ii. Documentation of informed consent or waiver of documentation of consent was obtained in accordance with §__.117; iii. An IRB conducts a limited IRB review and makes the determination required by §__.111(a)(7) and makes the determination that the research to be conducted is within the scope of the broad consent referenced in paragraph (d)(8)(i) of this section; and iv. The investigator does not include returning individual research results to subjects as part of the study plan. This provision does not prevent an investigator from abiding by any legal requirements to return individual research results.

Study Purpose
6. Describe the rationale for the research project: The problem addressed in the study is to determine the impact reflective writing assessments used during project/problem-based learning units of instruction, have on a college students' demonstration of technological and engineering literacy. Experiences gained during project-based learning activities were used as the basis for this study. This quantitative and qualitative, descriptive study examined the reflective writing abilities of college students by administering a reflective writing assignment three times over a semester of an introductory science, technology, engineering, and math (STEM) course: STEM 320, Industrial Materials. Participants were students enrolled at a large university in Southeastern Virginia.

Subjects			
7. What will be the maximum number of subjects in the study?	**21**		
7a. Indicate the approximate number of	**Males:19**	**Females: 2**	
7b. What is the age of subjects? (Check all that apply)			
☐ Children (Birth-17 years old)	☒ Adults (18-89 years old)	☐ Elderly (90+ years and older)	
7c. Will students be enrolled in the study? (Check all that apply) *If students are under 18 years old, parental consent must be obtained			
☒ Undergraduate students	Department:	☐ Advanced students	Department:

7d. Provide rationale for the choice of subjects. Enumerate any additional defining characteristics, including age, of the subject population. (e.g., symptomatology, history, socio-economic status). The population selected for this study was from the faculty and student body of a large university in the southeastern United States. They were selected due to their convenience in assessing and the wide range of diversity (age ranges, cultural, ethnic, and socio-economic backgrounds) to the study. One instructor and twenty-nine students enrolled in a single STEM 320 Industrial Materials course during the Fall 2022 semester were invited to participate in the study.
Vulnerable Subjects
8. Are research subjects being used whose ability to give informed voluntary consent may be in question? (e.g., children, persons with AIDS, mentally disabled, psychiatric patients, prisoners.) ☐ Yes ☒ No
8a. What type of vulnerable subjects are being enrolled? (Check all that apply)

☐ Critically Ill Patients	☐ Mentally Disabled or Cognitively Impaired Individuals
☐ Prisoners	☐ Physically Handicapped
☐ Pregnant Women	☐ Children
☐ Other (describe):	
If yes, explain the procedures to be employed to enroll them and to ensure their protection:	
Recruitment **Copies of all recruitment materials must be attached to this application.**	
9. Check all types of recruitment that will be utilized in the study.	
☒ **E-mail/social media**	☒ **Letters**
☐ **Newspaper/Radio/Television/Website advertising**	☐ **Posters/Brochures**
9a. What methods will be used to identify and recruit prospective subjects. If an outside agency or organization will recruit subjects on the investigator's behalf, a support letter must be included.	

INFORMED CONSENT FORM

OLD DOMINION UNIVERSITY

PROJECT TITLE: A Study on the Impact Reflective Writing Has on College Students' Demonstration of Technological and Engineering Literacy Skills.

INTRODUCTION

The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research and to record the consent of those who say YES. This project will be conducted throughout the semester, beginning with a short survey, with specific class writing assignments marked for data collection.

RESEARCHERS

Responsible Principle Investigator

Dr. Petros Katsioloudis, Associate Dean for Faculty Affairs and Community Engagement

STEM Education and Professional Studies

DESCRIPTION OF RESEARCH STUDY

Few studies have been conducted to address the role reflective writing assessments during STEM/Technology Education programs have played in the ability of students to demonstrate technological and engineering literacy skills. The purpose of this study is to look at assessments of technological and engineering literacy skills through the use of reflective writings at the beginning, the middle, and the conclusion of the semester. Project-based learning units of instruction are used as the basis of this study. An instructor teaching STEM 320, Manufacturing and Construction, will use a valid, reliable scoring rubric designed for these assessments.

If you decide to participate, then you will join a study involving research of the impact STEM education programs have had on the development of student technological literacy skills. Instructors, you will be asked to participate in three brief interviews to provide insight to the investigator regarding your previous experience using reflective writing techniques. Students, you will be given a writing assessment three times during the semester. The first assignment will establish a baseline on your abilities to articulate how groups formed during project/problem-based learning assignments, the strategies used to identify a problem or opportunity, and how to solve/create solutions. This will be repeated in the middle and end of the semester. The goal is to determine any changes that may have occurred in your ability to articulate technological and engineering literacy skills over the semester.

Your written scores will be collected and analyzed. No individual information will be shared other than with the instructors and the investigator.

If you say YES, your participation will last for the semester in the STEM 320 classroom (face-to-face). Five students from Old Dominion University will be participating in this study.

EXCLUSIONARY CRITERIA

All participants in this research study must be at least 18 years old. To your knowledge, you should have normal or corrected-to-normal vision and hearing. You should be able to read and comprehend the English language. Also, you should have no known cognitive impairments.

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of eye strain or discomfort from using the computer. The researcher tried to reduce these risks by spacing out the writing requirement for the study over several weeks, with breaks in between assessments. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: The main benefit to you for participating in this study is helping identify how well-prepared college students are to articulate their knowledge of technological literacy and how to best apply this knowledge from more than just an end-user perspective.

COSTS AND PAYMENTS

The researchers want your decision to participate in this study to be voluntary. Upon completion of the study, each participant will receive a $25 Visa Gift Card.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, they will give it to you.

CONFIDENTIALITY

The researchers will take reasonable steps to keep confidential all information obtained about you in this study. The results of this study may be used in reports, presentations, and publications, but the researcher will not identify you. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later and walk away or withdraw from the study at any time. Your decision will not affect your relationship with Old Dominion University or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study at any time if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, your consent in this document does not waive your legal rights. However, in the event of harm, injury, or illness arising from this study, neither Old Dominion University nor the researchers can give you any money, insurance coverage, free medical care, or any other compensation for such injury. Suppose you suffer injury as a result of participation in any research project. In that case, you may contact Dr. Petros Katsioloudis (Responsible Principle Investigator) at PKATSIOL@ODU.EDU, William Euefueno (Investigator) at

WEuefuen@ODU.EDU, or Dr. John Baaki, DCEPS Human Subjects Chair, jbaaki@odu.edu, 757-683-5491 who will be glad to review the matter with you.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you and are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, the researchers should be able to answer them. If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. John Baaki, DCEPS Human Subjects Chair, jbaaki@odu.edu, 757-683-5491 at Old Dominion University, or the Old Dominion University Office of Research at 757-683-3460 who will be glad to review the matter with you.

Furthermore, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

________________________ / __________________________________

____

Subject's Printed Name & Signature Date

INVESTIGATOR’S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

_________________________ _/____________________________

____

Investigator's Printed Name & Signature Date

Inclusion and Exclusion Criteria

10 a. Outline the inclusion and exclusion criteria for the study below.

Inclusion:

Students and one faculty member involved in the STEM 320 Industrial Materials class will be invited to participate in the study.

Exclusion:

N/A

Procedures
11. Describe the procedures that will be followed. (Include a succinct, but comprehensive statement of the methodology relating to the human subjects. You are encouraged to include a discussion of statistical procedures used to determine the sample size.) Participants will be selected from one class of a STEM 320, Industrial Materials course. A total of 14 students and one instructor will be invited to participate in the study. Qualitative data collection will be conducted via interviews with the STEM 320 instructor. Instructor participation will be requested via an Informed Consent Letter regarding the nature of the study, the information they would be asked to provide, and the methods taken to protect their privacy. The interview sessions will be recorded by the researcher and kept in a safe location to prevent disclosure of personal identifiers. The instructor will be requested to participate beyond their capacity as a focus group member and will be asked to score the three iterations of a reflective writing assessment, using the scoring rubric provided by the researcher, to gather scoring data relevant to the study. Quantitative data collection will be conducted via three reflective writing assignments for students to complete at set intervals throughout the semester. Scoring of the assessments will be performed via a problem-solving rubric. These rubrics were developed by the American Association of Colleges and Universities to help college-level instructors evaluate a student's ability to apply problem-solving techniques and strategies to achieve a goal. Student's identifiers will be protected through the researcher's use of alpha-numerical tracking by participants to remove any chance of their identities becoming public.

11a. Will the deliberate deception of research participants be involved as part of the experimental procedure?
Subjects must be prospectively informed that he or she will be unaware of or misled regarding the nature or purposes of the research.
☐ Yes **(If yes, explain the nature of the deception, why it is necessary, any possible risks that may result from the deception, and the process of prospective agreement and debriefing of the subject).**
☒ No
Comments:

Compensation
12. How much time will be required of each subject? **30-60 minutes**
12a. Will research subjects receive course credit for participating in the study? ☒ Yes **(If yes, please explain in comments section.)** ☐ No Comments: The instructor will offer participants up to three percentage points of extra credit incentives.
12b. Are there any other forms of compensation that may be used? (e.g. Money, Gift Cards) ☒ Yes **(If yes, please explain in comments section.)** ☐ No Comments: The researcher intends to offer $25.00 gift cards after the study.
Protection of Anonymity
13. Describe in detail the procedures for protecting the anonymity (meaning that no one will ever be able to know the names) of the research subjects. If anonymity is impossible, describe in detail the procedures for safeguarding data and confidential records. These procedures relate to how well you reduce the risk that a subject may be exposed to or associated with the data. The researcher will post related study materials electronically to Canvas for ease of access by participants and the instructor, who will grade the assessment using the above-mentioned scoring rubric. Coordination of the reflective writing assignments for the study will be done by providing participants with detailed instructions via a grading rubric at the beginning, middle, and end of the semester. As the assignments are completed and scored in each phase, the researcher will collect written reflections and remove and replace names with designated alpha-numerical identifiers. The researcher will ensure that assessments are kept secure at all times.

Training
14. Briefly explain the nature of the training and supervision of anyone who is involved in the actual data collection, research design, or conducting the research. This information should be sufficient for the IRB to determine that the RPI and investigators possess the necessary skills or qualifications to conduct the study. The researcher has taken a statistics course at ODU and an ANOVA class as part of their doctoral course requirements. The researcher also used statistical analysis for their thesis assignment as part of their Master's Degree at ODU.

PLEASE NOTE:
♦ You may begin the research when you receive the final WRITTEN notice of your project's approval through IRBnet. ♦ You MUST inform the committee of ANY adverse event, changes in the method, personnel, funding, or procedure. ♦ At any time, the committee reserves the right to re-review a research project, to request additional information, to monitor the research for compliance, to inspect the data and consent forms, to interview subjects that have participated in the research, and if necessary, to terminate a research investigation.

Appendix B

CITI Completion

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)
COMPLETION REPORT - PART 1 OF 2
COURSEWORK REQUIREMENTS*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** William Euefueno (ID: 5266104)
- **Institution Affiliation:** Old Dominion University (ID: 1771)
- **Institution Email:** WEuef001@ODU.EDU
- **Institution Unit:** STEM and Professional Studies

- **Curriculum Group:** Social & Behavioral Research - Basic/Refresher
- **Course Learner Group:** Same as Curriculum Group
- **Stage:** Stage 1 - Basic Course
- **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

- **Record ID:** 48553555
- **Completion Date:** 21-Apr-2022
- **Expiration Date:** 20-Apr-2024
- **Minimum Passing:** 80
- **Reported Score*:** 82

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Belmont Report and Its Principles (ID: 1127)	20-Apr-2022	3/3 (100%)
History and Ethical Principles - SBE (ID: 490)	20-Apr-2022	4/5 (80%)
Defining Research with Human Subjects - SBE (ID: 491)	20-Apr-2022	4/5 (80%)
The Federal Regulations - SBE (ID: 502)	20-Apr-2022	4/5 (80%)
Assessing Risk - SBE (ID: 503)	20-Apr-2022	5/5 (100%)
Informed Consent - SBE (ID: 504)	20-Apr-2022	4/5 (80%)
Privacy and Confidentiality - SBE (ID: 505)	21-Apr-2022	4/5 (80%)
Research with Prisoners - SBE (ID: 506)	21-Apr-2022	4/5 (80%)
Research with Children - SBE (ID: 507)	21-Apr-2022	4/5 (80%)
Research in Public Elementary and Secondary Schools - SBE (ID: 508)	21-Apr-2022	4/5 (80%)
International Research - SBE (ID: 509)	21-Apr-2022	4/5 (80%)
Students in Research (ID: 1321)	21-Apr-2022	4/5 (80%)
Internet-Based Research - SBE (ID: 510)	21-Apr-2022	4/5 (80%)
Research and HIPAA Privacy Protections (ID: 14)	21-Apr-2022	4/5 (80%)
Conflicts of Interest in Human Subjects Research (ID: 17464)	21-Apr-2022	4/5 (80%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

Verify at: www.citiprogram.org/verify/?ke475bf2a-d03b-4d23-93ac-5a95437c4e4a-48553555

Collaborative Institutional Training Initiative (CITI Program)
Email: support@citiprogram.org
Phone: 888-529-5929
Web: https://www.citiprogram.org

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COMPLETION REPORT - PART 2 OF 2

COURSEWORK TRANSCRIPT**

** NOTE: Scores on this Transcript Report reflect the most current quiz completions, including quizzes on optional (supplemental) elements of the course. See list below for details. See separate Requirements Report for the reported scores at the time all requirements for the course were met.

- **Name:** William Euefueno (ID: 5266104)
- **Institution Affiliation:** Old Dominion University (ID: 1771)
- **Institution Email:** WEuef001@ODU.EDU
- **Institution Unit:** STEM and Professional Studies

- **Curriculum Group:** Social & Behavioral Research - Basic/Refresher
- **Course Learner Group:** Same as Curriculum Group
- **Stage:** Stage 3 - SBR 201 refresher
- **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

- **Record ID:** 36472857
- **Report Date:** 19-Jul-2020
- **Current Score**:** 82

REQUIRED, ELECTIVE, AND SUPPLEMENTAL MODULES	MOST RECENT	SCORE
SBE Refresher 2 - Instructions (ID: 12629)	19-Jul-2020	No Quiz
SBE Refresher 2 – History and Ethical Principles (ID: 12702)	19-Jul-2020	1/1 (100%)
SBE Refresher 2 – Federal Regulations for Protecting Research Subjects (ID: 15040)	19-Jul-2020	2/2 (100%)
SBE Refresher 2 – Defining Research with Human Subjects (ID: 15038)	19-Jul-2020	1/1 (100%)
SBE Refresher 2 – Informed Consent (ID: 12620)	19-Jul-2020	1/1 (100%)
SBE Refresher 2 – Assessing Risk (ID: 12624)	19-Jul-2020	1/1 (100%)
SBE Refresher 2 – Privacy and Confidentiality (ID: 12622)	19-Jul-2020	0/1 (0%)
SBE Refresher 2 – Research with Prisoners (ID: 12627)	19-Jul-2020	0/1 (0%)
SBE Refresher 2 – Research with Children (ID: 15043)	19-Jul-2020	1/1 (100%)
SBE Refresher 2 – Research in the Public Schools (ID: 15042)	19-Jul-2020	1/1 (100%)
SBE Refresher 2 – International Research (ID: 15045)	19-Jul-2020	1/1 (100%)

For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

Verify at: www.citiprogram.org/verify/?k038c5ea5-7f9b-4424-b85b-3f4e0bf1aea1-36472857

Collaborative Institutional Training Initiative (CITI Program)
Email: support@citiprogram.org
Phone: 888-529-5929

Appendix C

INFORMED CONSENT FORM
OLD DOMINION UNIVERSITY

PROJECT TITLE: A Study on the Impact Reflective Writing has on College Students' Demonstration of Technological and engineering literacy Skills.

INTRODUCTION
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. This project will be conducted throughout the semester, and consists of three short writing assignments, which will be used to collect data relating to technological and engineering literacy.

RESEARCHERS

Responsible Principle Investigator
Dr. Petros Katsioloudis, Interim Associate Dean for Faculty Affairs and Community Engagement.

DESCRIPTION OF RESEARCH STUDY

Few studies have been conducted to address the role reflective writing assessments during STEM/Technology Education programs have played in the development of student's technological and engineering literacy. The purpose of this study is to look at assessments of technological and engineering literacy through the use of reflective writings at the beginning, the middle, and the conclusion of the semester. Project-based learning units of instruction are used as the basis of this study. A valid and reliable scoring rubric specifically designed for these types of assessments will be used by a single instructor teaching STEM 320, Industrial Materials, to score the writing samples.

If you decide to participate, you will join a study involving research on the impact STEM/Technology Education programs have had on the ability of students to demonstrate technological and engineering literacy skills. For the instructor, you will be asked to participate in several interviews to provide insight to the investigator regarding your previous experience using reflective writing techniques and the importance you place on these assessments.

Students will be given a writing assessment at three intervals during the semester. The first assignment will establish a baseline on your abilities to articulate how groups you have worked with have developed strategies to solve a problem/opportunity and group and informal leadership roles. This will be repeated in the middle and end of the semester. The goal is to determine your abilities to articulate skills relating to technological and engineering literacy.

Your written scores will be collected and analyzed. No individual information will be shared other than with the instructor and the investigator.

If you say YES, your participation will last for the entire semester during STEM 320. Fourteen students from Old Dominion University will be participating in this study.

EXCLUSIONARY CRITERIA

All participants in this research study must be at least 18 years old. To the best of your knowledge, you should have normal or corrected-to-normal vision and hearing. You should be able to read and comprehend English language. Also, you should have no known cognitive impairments.

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of eye strain or discomfort from using the computer. The researcher tried to reduce these risks by spacing out the writing requirement for the study over several weeks, with breaks in between assessments. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: The main benefit to you for participating in this study is helping identify how well-prepared college students are to articulate their knowledge of technological and engineering literacy and how to best apply this knowledge from more than just an end-user perspective.

COSTS AND PAYMENTS

The researchers want your decision to participate in this study to be voluntary. Upon completion of the study, each participant will be given a $10 or a $25 Visa Gift Card. The class instructor will offer up to 3 percentage points to your total grade for participating.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, they will give it to you.

CONFIDENTIALITY

The researchers will take reasonable steps to keep confidential all information obtained about you in this study. The results of this study may be used in reports, presentations, and publications, but the researcher will not identify you. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later and walk away or withdraw from the study at any time. Your decision will not affect your relationship with Old Dominion University or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study at any time if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, your consent in this document does not waive your legal rights. However, in the event of harm, injury, or illness arising from this study, neither Old Dominion University nor the researchers can give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact Dr Petros Katsioloudis (Responsible Principle Investigator) at PKATSIOL@ODU.EDU or William Euefueno (Investigator) at WEuefuen@ODU.EDU, Dr. John Baaki the current IRB chair at (757) 683-5491 at Old Dominion University, or the Old Dominion University Office of Research at 757-683-3460 who will be glad to review the matter with you.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

________________________ / __________________________________ _______________

Subject's Printed Name & Signature Date

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

_________________________ / _________________________________ ________________

Investigator's Printed Name & Signature Date

Appendix D: Instructor Interview Questionnaire One

Purpose: These instructor interviews aim to determine college instructors' experience and teaching strategies relating to reflective writing as an assessment method during problem-solving and project-based learning activities/units of instruction.

Questionnaire one:

1. How many years of teaching at the college level do you have?

☐1-3 Years
☐3-7 Years
☐8-10 Years
☐11-15 Years
☐16-20 Years
☐20 or more years

2. Give me your thoughts on Project/Problem-Based Learning and its importance in technology education.

3. How do you use PBL in your classes? What type of activities do you provide?

4. How many assignments/projects do you give students during the semester to perform this task?

5. What challenges do you and the students face during a PBL activity?

Follow-up. As you mentioned, do you assign leadership positions to prevent students from lying back?

Follow-up. Have team leaders reported that some students are not carrying their weight during the project?

6. Do you require students to provide any written reflection during these activities?

Follow-up: When do you require students to perform reflective writing in their assessments? Are they done before, during, and after a problem-solving or project-**based** learning activity? I ask because one of my projects spans the semester and has three checkpoints. I make them submit written reflections for all three checkpoints. This way, they have a running journal of their experiences during the project, as opposed to having them submit one reflection at the end of the project.

7. Do you provide any prompt, guidance, or trigger to help them focus on what you are looking for in their reflection?

8. Do you use specific assessment tools to score these reflective writing assignments (Rubrics, checklists, etc.)? Do you provide students with a copy of the rubric?

9. What are your beliefs about using reflective writing in learning?

10. What amount of importance/emphasis (percent of grade) do you place on this part of the project?

11. Do you have anything to add? Did I miss something?

Appendix E: Instructor Interview

Questionnaire Two

After assessing the reflective writing samples provided by your students, what is your impression of their abilities to articulate the principles of technological and engineering literacy?

1. Do you believe the writings are original or appear to be copied from other sources?

2. What are your thoughts about using these assessments to this point?

Appendix F: Instructor Interview Questionnaire Three

Now that the assessments are completed, please provide an overview of your experiences relating to how the assessments were delivered and how well the student performed throughout the study.

1. Did you see any improvement in their technological and engineering literacy development related to the assignments/projects you assigned this semester?

2. What changes would you recommend for future studies of this type? What improvements could be made? Follow-up: Do you feel these assessments were essential to student learning?

Appendix G Instructor Interview Questionnaire One Responses

Purpose: These instructor interviews aim to determine college instructors' experience and teaching strategies relating to reflective writing as an assessment method during problem-solving and project-based learning activities/units of instruction.

1. How many years of teaching at the college level do you have?

☐1-3 Years
☐3-7 Years
☐8-10 Years
☒11-15 Years
☐16-20 Years
☐20 or more years

2. Give me your thoughts on Project/Problem-Based Learning and its importance in technology education.

In our field, as technologists or engineers, we always have to write down the results of experiments or trials, and we have to put down the data, create drafts, and create the procedures. Those things are essential for the student’s future when they go outside to work in the industrial technologist field. These abilities are an essential factor in their success. So, reporting, documenting, generating tables, and putting grounds down is essential. If they do not know how to do this, they will not last long in their jobs.

3. How do you use PBL in your classes? What type of activities do you provide?

In all of our classes in the STEM department, especially the industry technologies, our educational models are focused on hands-on learning. Hands-on learning means they have to perform work to create a project, and afterward, they have to generate a report of what they did during the project. By doing that, we know how they can reflect what they did with their hands on paper. In my opinion, this is the best way to see students' learning progress.

4. How many assignments/projects do you give students during the semester to perform this task?

It is fifty percent projects and fifty percent lectures. We have one class that has seven projects, which is a 200-level class. In another class, which is a three-hundred-level class, they have one major project that takes place over the semester. This project is linked with other projects to reach the final production. So, for example, in STEM 320, the result will be to create a mass production of a product. First, the class has to select the product for the class. The second project is to draw, in detail, the components of the product they intend to create. The next project is to create the facilities design, which creates the material flow related to workstations and cost estimations. After that, the next project is for them to build a functional prototype of the product they intend to mass produce. In the end, they physically set up the machines and stations. From there, they can mass-produce the product. So, when you add up those projects, they add up to seven.

5. What challenges do you and the students face during a PBL activity?

Since COVID, we have three different formats for presenting these classes. We have online classes, hybrid classes, and, of course, face-to-face classes. Face-to-face learning is the best way to implement this project learning method because we at ODU provide the students with the tools, lab space, equipment, machines, and supervision. This is a perfect environment to implement PBL. For the students online, they do not have access to the equipment, but they could have access to the equipment. So, when considering the learning outcomes of online students, they are second to face-to-face students. The hybrid class is the hardest because you have two groups of students. You can place them in teams, but there is a tendency for some students to do most of the work while some students will lie back. That is tough. It is still providing them with PBL processes, but the effect of it could be better, but we are not there yet.

Follow-up. As you mentioned, do you assign leadership positions to prevent students from lying back?

The issue with the leadership is that a team leader will show up and indicate themselves as a leader within the group, even though I do not assign roles. Someone will take charge of organizing and leading the group's activities. So, there is no need for me to assign teams a leader. We teach them how to form teams, select a leader amongst themselves, and look at team members' qualifications to be a team leader. That is why I assign no leader, but I assign it within the team itself.

Follow-up. Have team leaders reported that some students are not carrying their weight during the project?

Yes. At the end of the semester, I use an assess your peer/team member tool. I give them five or six criteria, and I give them a scale of 0-10. This allows them to scale each other by making notes relating to the amount of work they did during the project and why they gave the individual that score. Every one of them will do that, and most times, the team leader is the one who will write the most.

6. Do you require students to provide any written reflection during these activities?

Absolutely. Every report/project has a statement asking what they could do better and what they learned. So, in that statement, at the end of the report, they will write what they learned, what they could do better, and what we could do to improve their learning.

Follow-up: When do you require students to perform reflective writing in their assessments? Are they done before, during, and after a problem-solving or project-based learning activity? I ask because one of my projects spans the semester and has three checkpoints. I make them submit written reflections for all three checkpoints. This way, they have a running journal of their experiences during the project, as opposed to having them submit one reflection at the end of the project.

Every lab or project has a segment, usually at the end of the project, to reflect on their work. If it is a continuous project, they will do their report at the end of the project indicating what they learned, what they could do better, and what we could do to improve their learning.

7. Do you provide any prompt, guidance, or trigger to help them focus on what you are looking for in their reflection?

No. This is a free-range reflection. I do not want to limit their thinking. My idea is to have them think freely to tell me exactly what they have in their mind. Their responses will only reflect on those topics if I ask them specifically.

8. Do you use specific assessment tools to score these reflective writing assignments (Rubrics, checklists, etc.)? Do you provide students with a copy of the rubric?

I have rubrics in some projects because I want them to focus on giving me a good product for reporting or physical projects. For some projects, I give them grading points for each element and grade them on those points. The rubric, in general, is available for them to use.

9. What are your beliefs about using reflective writing in learning?

It is essential because some of the elements of the reflection are very valid points, and we utilize them to improve our teaching methods.

10. What amount of importance/emphasis (percent of grade) do you place on this part of the project?

The reflection is an overall project, but the writing from the report. For example, let us take the woodworking project. In the lab, they are going to make physical products. They will also write about the physical product, the machines they used, or the machines they would have used if they did not have access to the machinery. They write materials lists and cost estimations. Each one of those has its weight.

11. Do you have anything to add? Did I miss something?

No. I think you have covered everything.

Appendix H: Instructor Interview Questionnaire Two Responses

1. After assessing the reflective writing samples provided by your students, what is your impression of their abilities to articulate the principles of technological and engineering literacy?

That is an excellent question. Due to the nature of this class, being a hybrid, applying the learning for these two groups is different. The in-class students can see the results of the work they do. The application of technology is there; the assignments allow for concepts relating to the environment and reducing pollution. The hands-on part focused on safety and its impact on children using child-safe materials. They learned different technological techniques and problem-solving skills. How to think out of the box to find a solution. The project went from bulky and non-functional to functional and appealing/aesthetics…mass-production ready.

2. Do you believe the writings are original or appear to be copied from other sources?

I think they were original. The assignment is unique and set up, so they must develop their projects and solutions.

3. What are your thoughts about using these assessments to this point?

The thing is, there are too many things they have to consider,

1. We gave them extra credit for their participation, encouraging them to do it.
2. They must think about their writing as they are being graded.
3. Overall, it was a positive thing, as they were required to think about their work and how they needed to think about what they were doing in the classroom.

Appendix I: Instructor Interview Questionnaire Three Responses

1. Now that the assessments are completed, please provide an overview of your experiences relating to how the assessments were delivered and how well the student performed throughout the study.

Overall, I would give them 80%. Because some of them thought it was unnecessary, not because of the assessment itself but because some students did not participate in the class/performance. PBL classes, we are creating and reengineering products. Reverse engineering can be complex, and students must handle the changes; some cannot. They must be taught how to adapt to changes. The instructor needs to get involved and not give up on them. I made the time to help them get through and complete the project. Those things are new for the student. They are learning new skills, knowledge, equipment, and procedures. The technological and engineering design processes are real-world, real applications, and students need to understand them.

2. Did you see any improvement in their technological and engineering literacy development related to the assignments/projects you assigned this semester?

Yes. They developed new skills and applied them to complete the project.

3. What changes would you recommend for future studies of this type? What improvements could be made? Follow-up: Do you feel these assessments were essential to student learning?

I think the study went well, and no changes are needed. Nothing should stay the same; we always look to improve. Yes. They are.

Appendix J

PARTICIPANT INTERVIEW QUESTIONNAIRE

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☐Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☐Yes

☐No

☐Unsure

Question 4: In your own words: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class.

Question 6: Explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Question 8: Describe how these projects helped you become more technologically and engineering literate.

Question 9: How does technology impact our lives, society, and the environment?

Question 10: Why is it important to learn how technological products are made/manufactured?

Appendix K

PARTICIPANT INTERVIEW RESPONSES

Participant Name: Carl Date: February 20, 2023

Major: Industrial Technology Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☒No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: In your own words: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experienced from previous classes and this current class.

First, I will brainstorm with colleagues and develop a list of materials for what machines we need to fabricate the product. We would get together to delegate the work based on who performed specific tasks well. If we ran into problems, we would go to the teaching assistant or the instructor to help us progress with the project.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes and this current class.

Yes, we would ask each student what experience they had, such as braising, woodworking, and things of that nature—familiarity with aspects of the given project. Whoever was the strongest with experience in engineering would be paired with someone who was less hands-on but had more experience designing the drawings. We kind of did it that way, touching on individual experiences.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

When we started working, it was hard, let us say, making a box. We would have to skip around the project due to a machine not being available. If we needed a saw, we might have to go to a router instead to keep things going. We had to use our time wisely. Based on machine availability, we would come together to decide what to work on. Sometimes, it would get overwhelming, especially when we had part-time students in the group. People have jobs and may not be available all the time.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

I am a pipefitter by trade, and I was a brazer. I learned new techniques, like how to get the metal, like a refresher. We did metal casting. It was just exploring new ways of performing work. I enjoyed the work. When you think you have a good grasp of things, I am a pipefitter by trade, but you never knew everything. I got some new tools for my toolbelt and learned new skills to make me more essential in the workforce.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

I learned how to; I am more of a hands-on guy. I feel like this program uses AutoCAD, design drawings, measuring tools to see how long things are, and different types of materials based on the outside elements they will be exposed to. The longevity of a product. Things of that nature. Being more innovative, designing and building every day, because of my job, this program made me think outside the box, not just think this is how we have always done it. This program gave me new ways to get the job done.

Question 9: How does technology impact our lives, society, and the environment?

Technology is pretty much the foundation of our world. The buildings we live or work in, bridges, and roads that get paved. This program is to keep the world moving forward and make it better for everybody to have a more comfortable life. Regarding the environment, we are trying to move away from oil and use more electric products to keep the environment clean and green. This happens in the shipping environment, as they are trying to move forward with electricity to reduce oil consumption and waste associated with fossil fuels. That is the big thing being pushed right now.

Question 10: Why is it important to learn how technological products are made/manufactured?

I believe people take what goes into design and talent for granted—just learning how a car gets built or flipping on a light switch and stuff like that. It makes people aware of how important this is, and we need as many people as possible to fulfill the mission of keeping technology vital.

Appendix K (cont'd)

PARTICIPANT INTERVIEW RESPONSES

Participant Name David　　　　　　　　　　　　　　Date: February 20, 2023

Major: Industrial Technology　　　　　　　　　　　　Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☒No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☐Yes

☒No

☐Unsure

Question 4: In your own words: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experienced from previous classes, as well as this current class.

Through research, I would take what I was given, using the list of design ideas the instructor gave. To finish my project, I would try to design a product based on the rubric. Technical points, drawings, things relating to history, patents, and things of that nature. Hands-on, finding materials, where and how to cut and utilize them, and how to change designs when needed. In the case of my current project, I have to use dowels instead of hinges, which will make it sound.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes and this current class.

I think that has a lot to do with the group. Sometimes, you have all-go-getters, and sometimes, you get no-go-getters. You have the go-getter in some groups, and everyone else goes along. I feel like the last one is the main one, and in the groups I have been in, I try to be the go-getter, and every once in a while, I will get some help. Some team members are just hanging on and going along for the ride. If you get paired up with a good group, things go well, but if you do not feel like doing the work, which happens often, it does not end well for the group.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

The best strategy I use is not procrastinating and getting ahead of it with your group. Please do not wait until the week it is due. Start making roles right away. As long as everyone in the group participates, you should be good.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

The STEM class where you had to build a robot—understanding the computer side of things- was new for me. I am a hands-on person who would put the robot together, so having to do the programming and coding was an eye-opener for me. I can make the dowel pins and holes; I can do all that, but the programming side was new.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

I think it has helped me. I have always tried to be environmentally friendly. It has helped me with more of the technical side of things. I am familiar with some of the terminology, even though I may not know all the words associated with technological and engineering literacy. It helps me understand more of the engineering side of things. I am more of a brawn kind of guy, but I have learned more about the brain side of technology. For example, he is making something, and the guys on the floor think eight bolts are better than twelve. I have thought, why do we need these twelve bolts? Looking at it from the engineering side/brain side, you understand why they need more bolts. There may be more of a technical side that I did not initially see.

Question 9: How does technology impact our lives, society, and the environment?

I think technology impacts us significantly; we cannot live without it. For example, people cannot even read a road map since they rely on GPS, phones, or even something as easy as MapQuest back in the day. The environment can be good or bad. You hear about it on the news and read about how going green is not necessarily good as we are depleting natural resources to go green. I think it has the potential to help; it does reduce emissions and all that other stuff. I know there are doubts, but we tend not to pay attention as it does not directly affect us here and now unless you live in the areas where they are stripping the resources from.

Question 10: Why is it important to learn how technological products are made/manufactured?

Because you cannot go anywhere without them, everything is manufactured one way or another. From my side of it, I just come from the work side; I have a different brain than many students. Everything has technology in it. Whether it is used to make a drawing, make a product, or teach things. Technology is a part of everything we do.

Appendix K (cont'd)

Participant Name**:** Diego Date: February 28, 2023

Major: Industrial Technology Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: In your own words: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experienced from previous classes and this current class.

So my experience would be that we introduce each other and then discuss whatever the topic may be. Typically, we would start and see if anybody knows where to begin. And then, we go from there and expand on that together. And my experiences. Moreover, mainly I have had good experiences with group assignments. There is very rarely an occasion where somebody does not participate. However, for the most part, I start by asking if anybody has any ideas or concepts. Then, we build on top of that and expand on each other's ideas. So I guess when you put it like that, we would then assign roles, I guess, for the group, and then we would draw a blank. I am sorry.

Usually, after you have come up with a concept, you have to figure out things like materials. What materials are going to be used to build? Yes. Materials, the processes, how we are going to build it. What is the cost going to be? Is this going to work? Is this idea going to solve the issue we are trying to solve?

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes and this current class.

So, from my experience, at least one person usually comes out as the group leader when I am placed in a group. Moreover, they say, hey guys, I think we should do this. Are you guys okay with the plan? And then I have never really had the experience, I guess, of asking people what their strong suits are. We kind of usually break it up evenly. Then, we learn to do our part of the group. Then, we just become our little experts on the selected pieces.

Now that you say that, yes, I have had that. However, I guess you are saying it has happened where people say, "Oh, I do not know how to do this. And then somebody comes forward and says, "Oh yes, I have done that before. Maybe I should do this part instead of view.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

I want to say it boils down to communication. Because if you earn a group and you do not communicate until you are at the very end, you will have problems no matter what. However, if you have a group and you guys say, okay, it is three steps, 12345. Suppose you communicate and share what you are doing the whole time. In that case, I feel like those problems you come to at the end do not exist because you are constantly; everybody knows what is going on as long as you communicate well. I want to say yes, communication is critical during these projects. Again, to the aforementioned, people do not know what they are doing. That is certainly going to slow things down and impede progress.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

So, I think the first thing that comes to my head is the different types of analysis that we have to do in classes. The first thing that comes to mind is a fishbone diagram I did recently. I had never heard of those before or even what they did, but after I did it, I understood. Okay, you start with one main topic and then remove these branches. Moreover, I thought that was pretty useful. However, I have never experienced any other place besides that one class that I had. Okay. Yes, they are not very. They are unused, but you often see things like mind maps and diagrams. However, it does help with the distribution of work and things like that. So, I am just giving you the overall concept of what is being done for the project.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

Yes. So, if I understand correctly, I can relate to this, but the project we are doing right now in our 3D class, how we have to make it constrained to specific requirements, I guess how it has to be entirely made of wood. I designed the whole project, and I 3D printed it. Then we had our meeting and our sit-down. He is like, oh, was it the constraint? It means it has to be at a wood. Do you have to be, you know, conform to what your customer wants? If this was real life. Moreover, if the customer comes to you and says, oh, I need a box made out of wood, You cannot give them a box made out of metal. So I think that was a good lesson for me. I need to pay more attention to the requirements, I guess. Moreover, that was a real-life scenario when he said you must pay attention to what the customer wants. Moreover, I feel like that was pretty important. Sure. Moreover, I guess as far as you want to look at it from humans, from the environmental perspective. That ties into this technological engineering literacy using Word, a natural material. It does not have to go through many different heating firings or a giant crucible. All the fuels must be generated to create steel, aluminum, or things of that nature. By using wood, I am being more environmentally friendly. So that could be another way to think of it, too.

Question 9: How does technology impact our lives, society, and the environment?

As you said, technology impacts every second of our lives because it is all around us, especially the environment. Again, the first thing that comes to my mind when I think of technology and the environment is that I think of people ruining the environment. It is like big mills and everything, just dumping waste into rivers. Moreover, I feel like a lot of the tech; I guess the technology that has happened has affected the environment. Because people do not care about the environment, I think there are definitely people who are suitable for the environment, but there are also rotten eggs. Moreover, they produce all this new technology but have all these harmful wastes they do not care about. Moreover, I think it is enormous that they throw it away and write the environment.

Question 10: Why is it important to learn how technological products are made/manufactured?

That is huge because it teaches you how to design products better. After all, you learn from your mistakes, but I think the more you understand how something is made and manufactured, the better of a designer you will be. Because then you can, while designing a product, think, oh hey, you know, maybe I cannot manufacture this because of a particular feature, or I could do this, but I cannot do this. I think it helps to understand how to manufacture something, especially when you will be the one designing products in the future.

Appendix K (cont'd)

Participant Name: Harold Date: February 20, 2023

Major: Industrial Technology Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☒No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☐Yes

☒No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

Do you want me to include steps relating to the group or just what I did? The first thing is to get the group on the same page, decide how we will approach the project, or decide what we will work on if we are given a choice. First, research, discuss, and share notes on what we found. We would then begin to model a prototype.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class.

I cannot recall anybody being selected to be the team leader. We typically delegated or let people do the work they wanted to do based on their experiences. We would devise a set of outlines of what needed to be done. Some people may have been seen as leaders as they are the ones who receive the information and compile it. It is more of a collaborative effort, not so much someone taking the lead.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

I guess things went well; I think the research went well initially. Regarding things that do not go well, some people do not do as much as others. There have been times when different opinions occur regarding how much work each person was to do to help the group—more often than not, the group will work out those issues with little to no effort.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

I believe many projects I have completed in the past have had a learning curve; I mean, I have never had to do some of them. This is especially true with the engineering side of things. I do a lot of electrical/mechanical work, which is more physical, but the design side of things was very different for me. So, that has been a learning curve.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

I think the more we are exposed to the literature when doing research, the more we learn a lot of technical terms and things associated with engineering. Also, the exposure we get from the textbooks and lectures provides additional information.

Question 9: How does technology impact our lives, society, and the environment?

I am not sure how it does not impact our lives. Technology is everywhere. I think communication, and even things since high school, such as collaborating with other students, is much more accessible than it used to be. That has changed people's lives. Regarding the environment, we are using more energy with these innovations. We are generating more energy, which certainly impacts the environment.

Question 10: Why is it important to learn how technological products are made/manufactured?

I believe it is essential to know all that, especially with our project in this class. We are using much different wood and need to know what types of wood to use, what is light or stiff, and how durable they are to ensure a better result. As I am going into the industrial engineering field, I think knowing the properties of materials is essential when designing. We need to know the strengths of the products we intend to use and whether they are durable or long-lasting.

Appendix K (cont'd)

Participant Name: Jonathan Date: February 20, 2023

Major: Industrial Technology Grade: Junior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☒No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

First, with our teams, we devised ideas for the project. From ideas, you create the actual concept; you do not move to that step but come up with the functions, sometimes drawing potential solutions so you have a visual of the product. We would then move on to adjusting or editing that before moving on to the hands-on step. We usually come up with a conclusion; in other words, we select the best solution for the project from all our ideas. We usually move on to getting the materials and stating the ideas of how we are going to proceed through the project. Then we get to the hands-on and move on from there.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with less experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes and this current class.

The instructor made our group, but we branched off. We would let people with specific skills or experiences in a particular field or have experience with machinery or materials perform specific tasks.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

I am going to start with the, so, at the end of a project, mainly, everything went well, but it is not until the end that you discover close details; you discover the more minor details. We made a mold, and our final result looked good, but we looked closely, had little scratches, and discovered rough edges. Overall, we did well, but the finer details went terribly. As far as things we needed to fix, we did not think about that while we were working on the project; once you are completed, you notice maybe we should have done this better or that better. We should have done things slower. There was little feedback when working as a team; people worked on their work. We may have had a better result if we paused and looked at each other's work.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

This was not my first major. I moved from computer science to the IT major, so I was brand new to all the machines and techniques. At first, I was confused by the machines and everything, but I slowly moved into it, got more comfortable, and enjoyed the work. It is almost like a love/hate relationship, I guess.

I felt like I was struggling with some of the projects and did not understand what I should be doing, or maybe I should try doing something else. Especially with the lamp project, I had this excellent foundation, but I realized as I was moving on that I may not have the skills to do this project. I was changing up all of my projects and ideas, and I realized that if I had more experience, my project would have been better, but overall I enjoyed it.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

Could you reread the first part? I was learning hands-on through the projects and liked learning as I went. As I said before, I came from computer science, and I did not know anything, as I was learning about the tools, the functions, how to use this, how to use that. Once you get the hands-on experience, you understand the concepts, ideas, etc. Hands-on experience and teaching helped me improve my skills.

Question 9: How does technology impact our lives, society, and the environment?

I would say, for the most part, I think it is mainly just focused on how to improve our lives. Also, in the lab right now, we are trying to find ways to improve things, using reverse engineering to discover the function of products and improve people's lives.

Question 10: Why is it important to learn how technological products are made/manufactured?

I would say learning about it is important because knowing the whole process of everything makes life smoother and safer, but knowing how everything functions and what it is supposed to do makes things sense. I do not know how to put it into words; I am struggling with that, but just knowing the functions is essential, as they put things into perspective regarding how individual components are made and assembled to create a product.

Appendix K (cont'd)

Participant Name: Mary Date: February 20, 2023

Primary: Industrial Technologies Grade/Year: Junior/Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

First, you have to figure out who will lead the project and who will make sure the project is finished. There are specific criteria you have to meet. You have to write three pages on what happened during the project. You have to structure the paper, so it has enough fluff to make three pages and include enough information on the project to make it three pages.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes and this current class.

Depending on what group you have, the work is divided among the group, except for the class I am currently taking, where I am expected to do all the work. If you have a good group, everyone will take a page and work on it.

Follow-up: What about the actual physical part of the project, the work? What about other classes?

I do most of the work for my Tuesday class while everyone else sits there. Last semester, most of the projects were individual work. Regarding project work, I have more experience with mechanical engineering in that field. We had group projects and divided up the work. We did horizontal rockets. We had to do a 20-page write-up, which we divided into five pages of writing for each team member. We took graphs and did things like that. People would take care of specific tasks based on what they were good at. If someone were good at math, they would take the math section. I was good at English, so I would take that section, pretty it, and focus more on the technical part of the paper.

Question 6: When completing projects, explain what went well during the project, what did not, Moreover, what strategies did you use to overcome obstacles to project progress?

Just any project? Individual? Individually, when doing a project, I need someone to tell me it is a good idea, and I go for it. Moreover, whatever happens, happens, and if it does not work, make it work.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

I would say the woodshop lab when we made the jewelry box. I asked my dad, and he just said, try and see what happens. I had to make three different boxes because I kept messing up. I would get to the end, and when I tried to make the faceplate, I made a mistake and would have to redo it. I tried to make another face plate, and it just shredded. I had to find a solid wood to make the faceplate, and the poplar was not strong enough. Learning new skills, I had used saws before, but not as intimately as we did during class. That was a lot. I was challenged to learn and stretched. You tend to want to stay in your bubble.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

That is a hard one. By doing the project firsthand, you can advise people who might want to do the same project. Like I did, you can tell them what to do. Instead of making the faceplate at the end, maybe make it at the beginning and see if it will work. Based on your faceplate, then make the bottom.

Question 9: How does technology impact our lives, society, and the environment?

Technology in general, phones, digital technologies? It impacts our society in ways people do not expect. You are way behind if you do not have social media, a smartphone, or another device. We have tiny computers on our phones; if you have questions, you can take out your phone, Google it, and find the answer. No one knows about you if you are not on social media and not promoting or putting your product on Instagram. We are in a digital maximus because everyone has technology. Regarding the environment, it seems like we do not care about the environment as a whole. People do not recycle this day because it is too hard. People will not do it if you do not simplify it. People are lazy. If it does not work for their agenda, they will not go out of their way to do it.

Question 10: Why is it important to learn how technological products are made/manufactured?

You have a newfound sense of curiosity about projects. You are like, oh, that much work goes into it. Maybe I should be more congenial to the project, understanding and hands-on with it. This is so cool. That is so cool, like the ceramics I had not done since 4th grade art class. You are doing things with your hands. You are not theorizing math problems; if you do this and this, you will get the answer; it is just there to work with. No, you see it visually and say, I did this with my hands.

Follow-up: Is there anything else you would like to add?

Pick your group correctly!

Appendix K (cont'd)

Participant Name Neil Date: March 20, 2023

Major: Industrial Technology Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

So initially, I felt like it always started with the team gathering and trying to analyze the problem. Moreover, so that we can try to add a clear solution, I think they usually start with everyone, sort of like a brainstorm. After that, it goes like a brainstorming or phase of everyone going through different ideas and things that we may have and just trying out different solutions and say, whether we are, I guess, how we all, because everyone understands it differently or whatever.

So I guess just the different views we will go into shape the solutions we give. And then, after that, I think it just goes through as a group. Which one do we think may be the best solution for the problem? So after we determine which one we believe will be the best, where there is a vote, or we may agree. I think then it goes towards delegating the role that we will all have as far as being able to create that. We will finish that project and go forward with it. And then once I am thinking, once all of our rows are determined, we start working around individual parts, but also assisting each other if we meet much help or just constantly briefly each other, allow me to know where we are at and if there is any problems or any other questions or things that we do not understand. Moreover, I am going to say. Next, that is where everything comes together, and we try to ensure that the solution we have picked is entirely correct, that it solves our problem, and that it works the correct way where the width is supposed to work.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with less experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class.

Well, I have been in both groups. I have been in a group where I have had to take control. Moreover, I have also been in a group where it seems effortless, and everyone is like, okay, well, I am showing in this area. So I do not know how it would be best in this, or you are strong in this area. So this would be best for you. So, I mean, it just depends on the group's personnel. More often than not, someone usually steps up and, I guess, assumes, given those rows, or are they just going through the group and asking, okay, well, what do you think you would be? Your most vital area would be the best you perform in this project. As I said, sometimes it is people's autonomy. It usually becomes more accessible because it breaks the ice and allows everyone to be comfortable like I never had. I have never had any team issues with someone, like stepping up and accepting that row. However, as I have said, my best overall team experience has been when someone has stepped up and gone through and tried to assess people's strengths. Even if a person may get a topic that they are weaker in,

As you said, we usually pair them up with someone more robust or chip in and help out. I have never had any bad experiences with my teams, like do my whole experience at all. So everyone has been great in helping each other out on certain parts of projects or just finishing projects. Alternatively, if it is something that, let us say, I am, e.g., stuck on, and I cannot do it. Someone either chipping or maybe taking that test over and providing me with another test. That way, I can still contribute to the project's overall success and do it efficiently.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

So what usually always goes well is they piggyback off with the last question, which is the distribution of the work like it is always pretty, even though we tried to make sure it is equal. Everyone can contribute equally. The biggest problem I could have is that it was not a big problem, but it is when someone gets stuck in a specific part of their project. Moreover, they wait too late or allow the group to know later rather than earlier. So now, we may have to work extra hours maybe. Alternatively, someone may have to do some extra work, or we have to switch up our proportions later in the assignment. We could have figured that out earlier, but they switched it and did not have more time to work on it. I have not been in a situation where it has affected the end, like the, I guess, the overall project. However, time constraints put some stress on those sections.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Initially, when I started, I was in exercise science. So, halfway through, I switched my major. So, coming into this program, everything was new to me. As it was, it was an immersive experience. As far as learning AutoCAD and doing 3D modeling and stuff like that. So when you go, like we were talking about the woodshop, and I am using different, like the jig or other, I guess what do they call it? The equipment and machines and things of that nature. It was all pretty new to me. Moreover, as I said, I had much help from the professor with my team because I think he was the professor for both classes. However, yes, and it was not necessarily problematic. It is just getting over that hurdle of, like you said, asking and being vulnerable, say, hey, I am not sure what I am doing here. No. Can you help me out? It is slightly different with AutoCAD if things are similar because you can look it up online.

I think the most significant task was probably the project. I think it was in the industrial materials class. We had to make work; whatever the woodshop class, we had to make our project. Moreover, my final project will be like a custom shoe box. I wanted to make sure because I think she was on the side, and it was just an exciting way for me to do it. I do not know; many people have made their custom shoe boxes. So, that pretty much motivated me. Just be able to go out there and add what you learned.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

I want to say that they helped me see the causes we were using versus knowing the book's definition of it. Like you think of an example. You said more technologically literate, correct? Technological and engineering literate. In other words, the definition or elements in areas that are considered. The foundation for technological and engineering literacy is like systems designed, human capabilities, and the impact on society, the environment, and things of that nature. Yes. So I am not. I feel like it is one thing, like you said, to read it, maybe like in a dictionary or a textbook, or even to write down the definition when you can apply that when creating a project or even just doing the work for it. It just helps me understand it better, like so.

Question 9: How does technology impact our lives, society, and the environment?

I think technology helps to make our lives simpler. It helps us to be able to understand certain things about the environment. Moreover, it will also help us hopefully work on more sustainable products to improve our environment and the practices that were, I guess, creative things or like with big factories and things of that nature.

Question 10: Why is it important to learn how technological products are made/manufactured?

I think it is essential because it is one for the environment. So we can understand how to improve some of those practices so that we do not use up all our natural resources. Also, I think it is essential. So you go on to say cost, and if it is going to be beneficial to make sure products, are making maybe changes of these specific products. Because everything is not, I guess it is cost-beneficial. Moreover, yes, I think those are the biggest, too, other than probably the safety of a product.

Appendix K (cont’d)

Participant Name: Mike Date: February 24, 2023

Major: Technology Education Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☐Yes

☒No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

I do not know. I had to guess I had started with the constraints, the things I had to meet to develop the project. Then, I did some research to try to decide what I would make my project about. Yes. And then I think that is where I am right now, the search part.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes and this current class.

I have done some of the types of projects, but not as a group yet. We usually meet in person. We plan during class. We meet in person at least once a week outside of class. And then we hash it out right there. The tasks that need to be done at that meeting will be like, I am going to take this. Will you take this or wherever? So, I think we have not met any tasks requiring specific prior knowledge or anything like that. We are all at the crawling stage ourselves. I think we are all at their level. So he says when completing the project, who will not be there yet?

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

I would not say there are obstacles, just a lack of direction or specific instruction. So we kind of just come to a consensus on what to do. Then, we will deal with the consequences, if there are any.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Note: This question was not asked, as the participant had not completed a problem-solving project during this interview.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

So, in the class for our re-experiencing news, I am experiencing new things I have never dealt with before. So then that led me to ask him questions, and neither my classmates nor I had to research. And then it made me think of things I would have never considered. So, trying to look at, instead of just dealing with something that does the job, I can think about, well, what would not do the entire job? So, it is a whole new way of thinking for me.

Question 9: How does technology impact our lives, society, and the environment?

I think all of them had significant impacts. Good and bad. The first thing that comes to mind is that technology is just what you know and how communication we can communicate across the world in nearly real-time. And then, it is the responsible use of that because much of this information is out there. However, I mean COVID, they came up with a vaccine. As long as there are problems out there, there will be continuous answers to address those problems. Then, with the environment, I think they are getting more where there has always been a growing conscience. We should look out for the environment, and I think it is still starting to ramp up even more. So, I think that we are on track for doing better.

Question 10: Why is it important to learn how technological products are made/manufactured?

I am just now beginning to think that that is important. Moreover, I would say that is because I am learning about the different processes. Moreover, again, whenever you get a product, it may be like your 90% solution—moreover, knowing that and the process helps me think about how to get that 100% for a solution. Of course, that is a custom product for me. Who says that? There are other people out there who do not eat the same thing, so okay. Yes, because when you start, especially if you come up with an actual design, what are you creating this semester? I created the design, but the professor poked holes through it. So, I know the historical progression is due on Sunday, but I am at the point where I may be selecting a new design before Sunday instead of giving up the one. I had chosen paper foldable, paper-to-go containers, and food-could-go containers. Moreover, his question was, they got me, like, what makes this unique? Why do I want to buy yours or somebody else's? Moreover, it absorbs moisture if I was thinking of practical things, but those are the things that are already like. It is lightweight. It has all these other things that take up less space whenever shipping, and then you fold it as needed. However, that does things that products out there already have.

Appendix K (cont'd)

Participant Name Burl Date: March 13, 2023

Major: Industrial Technology Grade: Junior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

All right, so in projects, we usually start with brainstorming, finalizing our ideas, and narrowing them down to one idea. Then, once we have that down, we would start some drafts of a paper or prototypes of a product. From there, we will try to create a final product. Moreover, usually, something is written about that.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class.

In my experience, leadership is usually established sort of informally and can change on a day-to-day basis. The groups would distribute the workload evenly, usually based on a person's preference or skills.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

My team collaborated well and worked through problems—however, things we found challenging. We are getting started. It is not easy to get people to start working at this age, but once they are working, they are excellent. Moreover, some obstacles we have faced have been like a project failure and having to restart, but we would usually be recuperating; we use a little extra time. However, a ceramic thing might break on you while pulling it out of the forming. Moreover, that is always a bummer.

Follow-up: Have you had any experiences with creating things? Some classes, like STEM 221 and STEM 331, require teams to design and build prototypes.

We did a wood project. We did a wooden box project for that. Regarding things not going well, depending on the product's image, we might try to repair it, especially if we are low on time. It may lose some quality, but it should still work. However, if we have enough time to redo a part entirely, we would probably do that quickly by splitting the work into that part for everybody so we can do it as quickly as possible.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Yeah, I have learned a whole bunch of new methods. I had not had any ceramic experience before coming into the class. I have minimal mental experience. So, using a vertical mill for a project in 231 was neat to have fun with that machine. It would be daunting. We will first look at it, but once you get the hang of it, yes. It is a pretty funny machine. So it is delightful.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

Yes, so for most of these projects, we have to do some write-up to describe the work we have done in the processes we have gone about. Moreover, I took a class on engineering research, which was a literature glass about writing in a research—like orientation. Moreover, I have learned how to use a whole bunch of tools, and I have had to write detailed engineering reports and make more detailed lists and lists and dimensions than in high school.

Question 9: How does technology impact our lives, society, and the environment?

From the second we wake up to the second we go to sleep. The way we travel, the way we eat, and the way we indicate have all changed because of technology. Moreover, the environment has suffered due to less than favorable power sources for climate change. However, as technology improves, it gets better and better, and it is pretty exponential in how fast it is; it is just better every year; in two years, everything will be outdated. We are certainly seeing a rapid advancement in many technological products in the industry and things like that.

Question 10: Why is it important to learn how technological products are made/manufactured?

I think it is essential for the future of production, in general, and manufacturing. Many people do not understand many of the basic principles behind injection molding. So, learning about a more long-term process, like filling that box project, is essential. It was like a long project. So, it is vital to have a complete design and understand how things will go together in the design process without worrying about it in the actual production process.

Appendix K (cont’d)

Participant Name: Reed Date: March 13, 2023
Primary: Electrical Engineering Grade: Senior

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4: When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class.

The first step was to self-evaluate and discuss people's strengths, experiences, and whatnot with the team and the project's needs or requirements. Then, we would assign tasks to group members that best suited the students' abilities collectively.

Question 5: How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class.

I guess, in my experience, there is not any formal leadership generally. I guess it is human nature that, generally, somebody kind of steps up and starts to dominate the situation for lack of better terms and is willing to accept the responsibility of decision-making. Moreover, it is my experience that somebody rises to that occasion based on their leadership ability and experience. Moreover, in my case, it is my age.

Question 6: When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

What went well? I guess I am piggybacking on my last comment. Generally, some team members do not either do not or cannot or choose not to fully participate at the level that other people in the group do. So, I generally check in with these folks in particular. Moreover, sometimes they, you know, somehow express their unwillingness or their laissez-faire, let us say, attitudes in terms of getting things accomplished. So, I think my experience has been to check in regularly and see if that particular team member or sub-team is not struggling or not keeping up. With the requirements, there is a shift in responsibility sometimes, and somebody comes in and helps. So it is a matter of meeting someone who has to manage the team. In my experience working on teams, it is good to have a team leader, but sometimes that does not work out unless that is part of the assignment.

Question 7: What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

So, people have different backgrounds and capabilities, and working with somebody you may be able to learn from is something physical for more of a personal relationship. Working with people, you generally tend to grow and become better at working in teams. So, in terms of completion, as I mentioned earlier, if there are four people on a team, nobody ever puts in

25%. Moreover, the grade for the class is generally spread about so, so there is no weight per student. So if the team is flourishing and you put in, you feel as if you put in 100%, you feel good. However, if you feel you put 100% in, the project did not work out, and you did not get a good grade. It is not very pleasant.

Question 8: Describe how these projects helped you become more technologically and engineering literate.

Account the processes and things like that or exposures to new technologies, seizures, and whatnot? Yes, I can recall working on electrical engineering, like a breadboard experiment, where somebody on the team was powerful with calculus and could take up that part of the report. He expressed that he disliked writing and could not collect his thoughts for technical writing. He wrote as he spoke, which can be confusing at times. So, I was able to learn quite a bit about the way he presented some figures and some illustrations. I think he learned from my writing more succinctly and not going off on tangents, keeping the writing very technical and high level instead of explaining unnecessary things for the project.

Question 9: How does technology impact our lives, society, and the environment?

Well, our lives in society. I think the one word is productivity. Productivity since the 50s and 1950s has grown tremendously regarding the environment. I am unsure about the relationship or productivity—specifically productivity and the environment. I think we will figure that out. We will have better answers, or somebody can answer better than me. However, no doubt technology improves productivity. When people are producing more. We have more to sell to other countries, so we no longer do business in Virginia. We are expanding nationwide to Europe and other countries that need our products. I guess economically, that would be the trade and world economics.

Question 10: Why is it important to learn how technological products are made/manufactured?

Because it allows people to participate firsthand in something that will sustain societies for years.

Appendix L

PARTICIPANT REFLECTIVE WRITING ASSESSMENT QUESTIONNAIRE ONE

You will be administered a different reflective writing assessment three times during the semester. These assessment instruments will gauge your progress in articulating your experiences through the technological and engineering design processes. It will also serve as a tool to determine if the instructor observes further development of technological and engineering literacy skills. A scoring rubric is attached below for you to use to assist you with your writing assessment.

When completed, please post to Canvas in the Questionnaire One folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: ________________________________

Please answer the following questions by providing a minimum of two paragraphs for each question, as applicable.

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☐Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☐Yes

☐No

☐Unsure

Question 4 (50 points): In your own words:

When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project.

Answer:

Question 5 (50 points): How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)?

Answer:

Total score: 100 points

Rater 1: ___/100 Rater 2: ___/100

Appendix M

Reflection/Essay Rubric

Total for Reflection/Essay 100 Points	Capstone 76 – 100	Milestones 51 - 75	 26 - 50	Benchmark 0 - 25
Define Problem	Demonstrates the ability to construct a clear and insightful problem statement with evidence of all relevant contextual factors.	Demonstrates the ability to construct a problem statement with evidence of the most relevant contextual factors, and the problem statement is adequately detailed.	It demonstrates the ability to construct a problem statement with evidence of the most relevant contextual factors, but the problem statement is superficial.	Demonstrates a limited ability to identify a problem statement or related contextual factors.
Identify Strategies	Identifies multiple approaches for solving the problem that apply within a specific context.	Identifies multiple approaches for solving the problem, only some of which apply within a specific context.	Identifies only a single approach for solving the problem that does apply within a specific context.	Identifies one or more approaches for solving the problem that do not apply within a specific context.
Propose Solutions/Hypotheses	Proposes one or more solutions/hypotheses that indicate a deep comprehension of the problem. Solution/hypotheses are sensitive to contextual factors as well as all of the following: ethical, logical, and cultural dimensions of the problem.	Proposes one or more solutions/hypotheses that indicate comprehension of the problem. Solutions/hypotheses are sensitive to contextual factors and the ethical, logical, or cultural dimensions of the problem.	Proposes one solution/hypothesis that is “off the shelf” rather than individually designed to address the specific contextual factors of the problem.	Proposes a solution/hypothesis that is difficult to evaluate because it is vague or only indirectly addresses the problem statement.

Evaluate Potential Solutions	Evaluation of solutions is deep and elegant (for example, contains thorough and insightful explanation) and includes, deeply and thoroughly, all of the following: considers history of problem, reviews logic/reasoning, examines feasibility of solution, and weighs impacts of solution.	Evaluation of solutions is adequate (for example, contains thorough explanation) and includes the following: considers the history of the problem, reviews logic/reasoning, examines the feasibility of the solution, and weighs impacts of solution.	Evaluation of solutions is brief (for example, explanation lacks depth) and includes the following: considers the history of the problem, reviews logic/reasoning, examines the feasibility of the solution, and weighs impacts of solution.	Evaluation of solutions is superficial (for example, contains cursory, surface-level explanation) and includes the following: considers the history of the problem, reviews logic/reasoning, examines the feasibility of the solution, and weighs impacts of solution.
Implement Solution	Implements the solution in a manner that thoroughly and deeply addresses multiple contextual factors of the problem.	Implements the solution in a manner that addresses multiple contextual factors of the problem in a surface manner.	Implements the solution in a manner that addresses the problem statement but ignores relevant contextual factors.	Implements the solution in a manner that does not directly address the problem statement.
Evaluate Outcomes	Review results relative to the problem defined with thorough, specific considerations for further work.	Review results relative to the problem defined with some consideration of the need for further work.	Review results in terms of the problem defined with little consideration of the need for further work.	Reviews result superficially in terms of the problem defined without considering the need for further work.

APPENDIX N

PARTICIPANT REFLECTIVE WRITING ASSESSMENT ONE RESPONSES

You will be administered a different reflective writing assessment three times during the semester. These assessment instruments will gauge your progress in articulating your experiences through the technological and engineering design processes. It will also serve as a tool to determine if the instructor observes further development of technology and engineering literacy skills. A scoring rubric is attached below for you to use to assist you with your writing assessment.

When completed, please post to Canvas in the Questionnaire One folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Charles

Please answer the following questions by providing a minimum of two paragraphs for each question, as applicable.

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☒No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4 (.5 points): In your own words:

When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experienced from previous classes, as well as this current class. (Two paragraphs minimum, please).

Answer: When assigned a group project like our current class. First, we must devise a plan to lay out and understand what needs to be completed. Alongside this, group members will have to design each part to be made to fit. After this base is set, we need to go over with the group which project we will go with and have the smoothest operation time. Once the group agrees on how the project should run, we must break into some assembly lines to make the parts quickly.

Many inconvenient problems will come along, like not having the right size drill bit or the dimensions on the designs being off. Therefore, the people making the projects will have on-site job repair by reworking numbers to make the project work. Resizing the design is problem-solving when it comes down to the numbers being off. The workaround is knowing how to redesign the project and notifying your group that you have done so. Making sure everyone in the group is on the same page is the most essential part of a group project.

Question 5 (.5 points): How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experienced from previous classes, as well as this current class. (Two paragraphs minimum, please).

Answer: Through collaboration with the team with multiple ideas for the project, we all must come to some selection. The selection process depends on cost, safety, and time spent on each task. Students should understand each part of the project and know how to do each step and task. Students should do the tasks that they are most qualified to do to save time and make it more efficient. During the prototype stage, everyone can see each part made and the adjustments to fit the project.

With an informal leader, everyone must be on the same page and in the same loop, which means that everything in the project and the designs online must be the same thing to have the best success rating. Once the prototype is finished and everyone knows how to do each task, tasks can be suited for the students individually for the best time efficiency.

Total score: 100 points

Rater 1: 80/100 Rater 2: 80/100

Appendix N (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT ONE RESPONSES

You will be administered a different reflective writing assessment three times during the semester. These assessment instruments will gauge your progress in articulating your experiences through the technological and engineering design processes. It will also serve as a tool to determine if the instructor observes further development of technological and engineering literacy skills. A scoring rubric is attached below for you to use to assist you with your writing assessment.

When completed, please post to Canvas in the Questionnaire One folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Noah

Please answer the following questions by providing a minimum of two paragraphs for each question, as applicable.

Question 1: Have you heard of the term technological and engineering literacy?

Yes

Question 2: Have you performed project/problem-based learning activities while attending ODU?

Yes

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

Not sure

Question 4 (.5 points): In your own words:

When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: During high school and my early years of college as an engineering student, I remember learning about the Engineering problem-solving steps. We were expected to use these processes in order to complete our project. For my engineering class, we had to define the problem, list possible solutions, evaluate the possible solutions, develop a plan, re-evaluate and check the plan, conduct the plan, and finally investigate the results. To implement these steps, our groups gathered to discuss our action plan. For that specific class, our goal was to take the design of an everyday product and try to improve upon it and make it better. When we were gathered, we discussed each step as a group, eventually made it through each process, and had a finished result for the project.

Question 5 (.5 points): How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: The easiest thing to do is figure out the strengths and weaknesses of each person within the group, depending on the type of work or project we are trying to complete. If one person is better than the others at a specific task, assigning that person to that task is only fitting. As for team leadership, most of the time, at least in my experience, whoever steps up and starts laying out what we should be doing becomes the team leader. That is, if no one else says anything about it. Going back to the workload, in my experience, it is typically split up based on how many group members are working on the assignment or project. This is only the case if each person agrees that the amount of work assigned to them was fair, and if nobody has complaints or concerns, then it is expected that each person has their fair share of the workload finished by the deadline.

Total score: 100 points

Rater 1: 80/100 Rater 2: 80/100

APPENDIX N (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT ONE RESPONSES

You will be administered a different reflective writing assessment three times during the semester. These assessment instruments will gauge your progress in articulating your experiences through the technological and engineering design processes. It will also serve as a tool to determine if the instructor observes further development of technological and engineering literacy skills. A scoring rubric is attached below for you to use to assist you with your writing assessment.

When completed, please post to Canvas in the Questionnaire One folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Bob

Please answer the following questions by providing a minimum of two paragraphs for each question, as applicable.

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4 (.5 points): In your own words:

When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: First, we were given a brief overview of how to write and understand technological and engineering problem-solving processes. Once that was explained, we had to choose five topics to write about and ensure we could find substantial information. The information criteria were not just "Google." It had to be journals, approved articles, newspapers, etc. Next, we had to narrow our topics down to our top 3 choices. Once we decided on our top 3 choices, we had to come up with three questions about the topics that would be our papers' primary driver. After answering all three questions surrounding all three topics, we narrowed our choices down to our final topic.

After the final topic was chosen, we started to process deep dive analysis and research to support and prove our topic and to answer the questions we had come up with in the earlier process. During the class, we had to write five separate papers. While writing the five papers, we could not use the same information or supporting sources. Basically, through the first four papers, you got a lot of data and information, and the fifth and final paper was to make your case on your topic and answer all three questions you had created in the beginning.

Question 5 (.5 points): How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: It was a little nerve-racking to realize we had a group project, especially as an online student. Many thoughts were running through my head: How would we all communicate? We are all different ages and have different responsibilities; some of the students work full-time jobs, and many live in all different parts of Va. However, after we got closer to the project, the professor assigned us to groups. The group was fine but was done without real strategy-based experience or knowledge. Once our group was established, we started a group text to stay informed on our responsibilities and how we were managing them.

Our next step was determining who would do the project's different parts. We were talking among our group about distributing the workload when we were met with a surprise. The surprise was that the professor distributed the workload, and in some parts of the work, you needed strong skills in different trades and experiences in computer technology. However, we did not get to choose any of this. It was all distributed by the professor, and we just had to accept it and do our best to get it done promptly. We did not appoint an authentic Team Lead because our group went from five students down to two quickly. The other students had some family issues, and two dropped the class. So, we did the best we could with the two remaining students.

Total score: 100 points

Rater 1: 70/100 Rater 2: 70/100

Appendix N (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT ONE RESPONSES

You will be administered a different reflective writing assessment three times during the semester. These assessment instruments will gauge your progress in articulating your experiences through the technological and engineering design processes. It will also serve as a tool to determine if the instructor observes further development of technological and engineering literacy skills. A scoring rubric is attached below for you to use to assist you with your writing assessment.

<u>When completed, please post to Canvas in the Questionnaire One folder by the due date.</u>

Note: Please <u>do not search the internet to answer these questions</u>, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Don

Please answer the following questions by providing a minimum of two paragraphs for each question, as applicable.

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☒Yes

☐No

☐Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☒Yes

☐No

☐Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4 (.5 points): In your own words:

When given a group assignment, describe the steps relating to the technological and engineering problem-solving processes you were expected to use during the project. This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: Throughout my time as a student in the STEM department, I have been required to solve problems as a group. I have been expected to gather information before starting a project. For example, one project required that we examine the physical characteristics of different types of clay to choose the proper material for our project. I was also expected to think of solutions and implement those solutions. It seems as though all STEM class problems require this. For example, my group made the divot sizes too large on our final project. My group evaluated our options and decided it would be best to decrease the divot size by using adhesive.

For the majority of my group assignments at ODU, I have been expected to evaluate my results. Typically, this involves a lab report. When assessing my results, I examine what I did well and could have improved. I have been expected to know what I would do differently if I were to repeat the project.

Question 5 (.5 points): How did you strategize/collaborate to distribute the workload (were experienced students grouped with lesser experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: STEM classes 221 and 231 are some of the classes that come to mind when I think of my group work assignments. Both of these classes involve hands-on labs. These classes require efficient teamwork to complete and submit the labs on time. We distributed the workload into groups of two. For instance, two group members would work on one part while another pair worked on a separate component. This helped us get projects done more quickly. If a groupmate were less familiar with a machine or method, they would be paired up with knowledgeable people who could explain the process. If the group did not complete projects during class, we would arrange to meet in the lab during lab hours. Luckily, I have yet to experience any group projects in which a group member failed to complete their part.

The first step when giving a group assignment is to find out what skills we each have to divide the work properly. Hopefully, the tasks are easily divisible so that a sense of fairness can be retained. Then, we find any points where we need to work together or where an individual is having trouble so that another part of the group can help. Then, we go a step further and refine what we are working on by spreading it throughout the group so that we can share feedback and find any solutions to any sticking points. If we find something, we share it and get more feedback, and so forth, until we have something that the group is satisfied with.

From personal experience, I have had group members slow their work process down so they do not have time to help others. This makes it more challenging to work together and creates blockages and stoppages, which restrict other parts of the group. As long as someone stayed on track and worked with a partner, they moved through the material much faster.

Total score: 100 points

Rater 1: 90/100 Rater 2: 85/100

Appendix N (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT ONE RESPONSES

You will be administered a different reflective writing assessment three times during the semester. These assessment instruments will gauge your progress in articulating your experiences through the technological and engineering design processes. It will also serve as a tool to determine if the instructor observes further development of technological and engineering literacy skills. A scoring rubric is attached below for you to use to assist you with your writing assessment.

When completed, please post to Canvas in the Questionnaire One folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Lenny

Please answer the following questions by providing a minimum of two paragraphs for each question, as applicable.

Question 1: Have you heard of the term technological and engineering literacy?

Please check one:

☐Yes

☐No

☒Unsure

Question 2: Have you performed project/problem-based learning activities while attending ODU?

☐Yes

☐No

☒Unsure

Question 3: Have you done reflective writing as part of your classwork in industrial materials classes at ODU?

☒Yes

☐No

☐Unsure

Question 4 (.5 points): In your own words:

When given a group assignment, describe the steps relating to the technological and
You were expected to use engineering problem-solving processes during the project. This can be experiences from previous classes, as well as this current class. (Two paragraph minimum please).

Answer: The first step when giving a group assignment is to find out what skills we each have to divide the work properly. Hopefully, the tasks are easily divisible so that a sense of fairness can be retained. Then, we find any points where we need to work together or where an individual is having trouble so that another part of the group can help. Then, we go a step further and refine what we are working on by spreading it throughout the group so that we can share feedback and find any solutions to any sticking points. If we find something, we share it and get more feedback, and so forth, until we have something that the group is satisfied with. From personal experience, I have had group members slow their work process down so they do not have time to help others. This makes it more challenging to work together and creates blockages and stoppages, which restrict other parts of the group. As long as someone stayed on track and worked with a partner, they moved through the material much faster.

Question 5 (.5 points):

How did you strategize/collaborate to distribute the workload (were experienced students grouped with less experienced students, was an informal team leader selected by the group, etc.)? This can be experiences from previous classes and this current class. (Two paragraphs minimum, please).

Answer: Talking from last semester, I had group members delay and refuse to participate as much as possible, making other group members take control; it swapped from member to member with informal leadership as the specialties required for the task changed. The most we could do was give them something to study, which had them look over it and find one or two points they learned instead of the whole project. As long as someone took the lead for most of the conversation, we usually align ourselves with them, giving informal leadership. If other group members refused to contribute, we would divide the work between ourselves and find something a level or two away from essential so that we could track their progress and respond from there. If the member decided to put in the effort, we could move on with little fuss, but if little feedback was coming, we had to go to the professor in most cases.

Total score: 100 points

Rater 1: 85/100 Rater 2: 80/100

Appendix O

PARTICIPANT REFLECTIVE WRITING ASSESSMENT QUESTIONNAIRE TWO

This is the second of three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Two folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: ________________________________

Please answer the following questions by providing a paragraph or two for each, as applicable.

Question 1 (33 points): Explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

Answer:

Question 2 (33 points): What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Answer:

Question 3 (34 points): Describe how these projects helped you become more technologically and engineering literate.

Answer:

Total score: 100 points

Rater 1: ___/100 Rater 2: ___/100

Appendix P

PARTICIPANT REFLECTIVE WRITING ASSESSMENT QUESTIONNAIRE TWO RESPONSES

This is the second of three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Two folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Charles

Please answer the following questions by providing a paragraph or two for each, as applicable.

Question 1 (.33 points): When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

Answer: What goes well throughout projects is what works, meaning go with what works, then fine-tune and make it even better the next time. Strategies mainly involve troubleshooting the whole project to find out what went wrong and how you can fix it. Examples like this could be making a particular circuit work or figuring out new dimensions for the wood so the dowel can fit. Reworking numbers or relooking at everything before you are done makes it a piece of art and a final project.

Question 2 (.33 points): What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Answer: Building my last circuit required three integrated circuits, which was tricky because I had some experience in the past but only used one. My main problem working on this circuit was getting the current information relayed to the LED that would perform a blinking light pattern. The overall experience was double-checking and making the correct connections, such as troubleshooting.

Question 3 (.34 points): Describe how these projects helped you become more technologically and engineering literate.

Answer: These projects have made me more aware of double-checking and ensuring things are proper before committing to any idea.

Total score: 100 points

Rater 1: 70/100 Rater 2: 60/100

Appendix P (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT QUESTIONNAIRE TWO RESPONSES

This is the second of three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Two folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Bob

Please answer the following questions by providing a paragraph or two for each, as applicable.

Question 1 (.33 points): When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

Answer: One project that sticks out to me was a STEM class project. We had to work with plaster of Paris and make a mold of an object. The idea of the project was great, and even watching the informational videos leading up to it was very helpful and informative. However, I was nervous when it came time to do the project myself. As far as buying all the materials for the project and getting my working area set up, everything went well. However, mixing the Plaster of Paris was not something I had any experience with, and getting the consistency right was difficult. It cannot be too thick or too thin because it will not set up properly in the mold. So, by trial and error, I got the consistency to where I thought I would make a good mold and began to pour my mold. After pouring the mold, I allowed the mold to set up for four days. After the fourth day, I took the mold out of the bucket. It did not have smooth edges and was still moist at the bottom. The next step was to remove the Styrofoam cup I had made the mold of. This was difficult; I cracked some molds off while removing the cup.

The project's next step was to make a short video of the Plaster of Paris mold and describe our issues. That part went well. I later learned I was not the only one with issues with my mold; but several other students did. However, I learned something new and could work with some materials I had never worked with.

Question 2 (.33 points): What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Answer: One of my most feared projects was the vacuum forming project. When I saw this on the schedule, I was freaking out. I had heard of it but had no experience or idea of how to make a forming machine. I started this project as early as possible because I did not know how to create prints or build this machine. However, with some informational videos and much trial and error, I somehow devised a plan and prints for the build. This project forced you to use a lot of woodworking machines and power tools. I had to develop a heating source for PETG plastic and a vacuum source and order PETG plastic for the forming machine.

Once the machine was built and assembled into a production line, it was time to run some trial runs. This was very interesting because I had no idea how much heat to expose the PETG to or how long. However, with a lot of trial and error, I made several attempts to form and figure out where I would get my best results. I learned many technological and engineering skills that I would have never known about without this project.

Question 3 (.34 points): Describe how these projects helped you become more technologically and engineering literate.

Answer: With the many projects that I have had the experience doing while at ODU, I feel that I have been exposed to a wide variety of topics, materials, processes, technology, and industries. Although I am not an expert on all of them, at least I have been exposed to them and have a better understanding of some of the world's most popular technologies. The projects get you out of your comfort zone and help you gain more knowledge in many fields you may not know much about. They help broaden your horizons and knowledge in many different ways.

I feel better prepared as an OTS student because I have had the opportunity to experience new skills and technology while performing many of these projects. I have discussed this with my boss at work, and he shares similar stories with me about the projects he did while attending ODU. That makes me appreciate it even more because I know I can take some of the knowledge I gained back into my workplace and put it to use.

Total score: 100 points

Rater 1: 100/100 Rater 2: 100/100

Appendix P (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT QUESTIONNAIRE TWO RESPONSES

This is the second of three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Two folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Lenny

Please answer the following questions by providing a paragraph or two for each, as applicable.

Question 1 (.33 points): When completing projects, explain what went well during the project, what did not, and what strategies you used to overcome obstacles to project progress.

Answer: Using the last two engineering projects as an example, we have the task of completing a drone a semester ago and the job of making a catapult this semester. For the first project with the drone, the division of labor for the first portion went well. We could divide responsibilities as necessary, allowing us to spread out completely different portions of the work as we went. The things that did not go well were the complexity and how some teams were dividing labor by leaving people unused, which would have been of help. Our last project was making a catapult that fit a few specifications. I would have to say that the overall design and production went well as we practiced throughout making a few different catapults. We found suitable methods of fixing any flaws, like the project being a tad too light, and found methods to speed up a finisher drying.

Question 2 (.33 points): What was your overall experience while working through the problem you were solving (new learning that occurred, performing a task you have never done before, etc.)?

Answer: My overall experience working through my issues with the first project would have to be broken down into learning something I had little experience in, like a new programming code. Even being able to find portions of it online, we had to bridge it together into something workable. Getting the different groups to coordinate was also a point that required working around and with different people. Each had different solutions, ranging from working harder to splitting up some of the work to harassing a few people until they contributed. With the second project, I would have to say that everything went pretty well, and any issues that popped up could be promptly solved. Working between the catapult and prototype and finding methods to fix issues as they popped up ranged from just different sizing issues, which helped us understand the physics/mechanics of a catapult firing. There was a small quantity of stress at a few different points, but nothing that was not easily fixed.

Question 3 (.34 points): Describe how these projects helped you become more technologically and engineering literate.

Answer: These projects have allowed me to gain hands-on experience with a few separate machine/workplace tools with which I had fallen out of practice. I knew many individual pieces, from using the Cad program to making designs. However, using them all in a single project has given me better perspectives on finding and fixing potential design defects. By becoming more engineering literate, I can see how I have become more able to understand the logic behind the projects quickly, why I am using this wood, what to use as support, and so forth. As a technologically literate person, I have seen myself being able to use the various tools around the workshop more easily from practice.

Total score: 100 points

Rater 1: 90/100 Rater 2: 84/100

Appendix Q

PARTICIPANT REFLECTIVE WRITING ASSESSMENT QUESTIONNAIRE THREE

This is the last of the three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Three folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: ________________________________

Please answer the following questions by providing at least one to two paragraphs for each question, as applicable.

Question 1 (33 points): How does technology impact our lives, society, and the environment?

Answer:

Question 2 (33 points): Why is learning how technological products are made/manufactured necessary?

Answer:

Question 3 (34 points): Please provide your thoughts on the assessment process and your overall experiences relating to the questions posed to you over the semester.

Answer:

Question 4 (Follow-up): Do you believe performing these written reflections helped you to understand better what it means to be technologically and engineering literate (please be detailed)?

Answer:

Total score: 100 points

Rater 1: ___/100 Rater 2: ___/100

Appendix R

PARTICIPANT REFLECTIVE WRITING ASSESSMENT THREE RESPONSES

This is the last of the three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Three folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Charles

Please answer the following questions by providing at least one to two paragraphs for each question, as applicable.

Question 1 (.33 points): How does technology impact our lives, society, and the environment?

Answer: Technology has made society's lives easier and more compatible; a phone call away or even a flight to Europe is in our grasp. These things make society's lives easier, but at what cost? On the other hand, these industries that manufacture and produce gas motor cars or other gas-powered devices simultaneously hurt and destroy the environment.

Technology brings an awkward divide between products over the earth's health due to things we need daily to live versus things that make life easier. It has been like this for a while, and it could continue, but newer electric vehicle companies are trying to change that course, which is a start. In a way, technology is both good and bad. It is up to more giant corporations to get a grip on the output of the environment.

Question 2 (.33 points): Why is learning how technology products are made/manufactured necessary?

Answer: It is essential to learn about these things to see how you can affect the process and either cut costs or figure out a way to produce less waste. Another reason to learn about it is to understand how a product is made, from design to putting it together and then the finishing details to see what steps are involved in building a particular product.

Question 3 (.34 points): Please provide your thoughts on the assessment process and your overall experiences relating to the questions posed to you over the semester.

Answer: Over the semester, the questions helped me learn something new and understand the topic while writing it out. Questionnaire two made me realize that projects are mainly designing and troubleshooting the project, and when working with others, sharing ideas is very fast-paced and quicker than if you did it alone.

Question 4 (Follow-up): Do you believe performing these written reflections helped you to understand better what it means to be technologically and engineering literate? (Please be detailed)

Answer: These reflections have made me aware of writing down what transpires during a project, which makes me understand the overall project better. Figuring out what you have to achieve is crucial, and getting those goals completed is crucial, so writing them down will genuinely make you understand. I have a better understanding of what it means to be technologically literate.

Total score: 100 points

Rater 1: 96/100 Rater 2: 90/100

Appendix R (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT THREE RESPONSES

This is the last of the three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Three folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Bob

Please answer the following questions by providing at least one to two paragraphs for each question, as applicable.

Question 1 (.33 points): How does technology impact our lives, society, and the environment?

Answer: If we take a step back and think of our everyday lives, technology plays a huge factor in every one of our lives. Whether you are a CEO, businessman, instructor, student, or construction worker does not matter. Technology is involved in all of our day-to-day lives. We do not give technology much thought until it breaks or works incorrectly. Then, we tend to get uptight and talk about how bad technology is nowadays. A simple power outage will bring us to a screeching halt. We would be without lights, cell phone chargers, and laptop chargers, our food might spoil, and most women these days could not get ready for work in the morning without all of their beauty technology!

Our society today is entirely of technology. Everywhere we go, you are expected to be able to figure out new technology daily. For example, if you go to the grocery store and you do not want to stand in line, you will have to scan your groceries, use the touch screen to complete your order, and you will have to pay by using a credit card machine. You always hear people say that "technology is great when it is working," but when it is not working correctly, it can throw a monkey wrench in almost anything you try to do! Driving down the road, you will experience stop lights at every intersection. If you have never thought about this, take a moment to think about how those stoplights work. You will typically see a large silver box on one of the intersection's four corners. You will have electrical parts such as PLCs, relays, terminal points, junctions, and connections. That box houses the brain that operates the stop light system at that intersection. How many stoplights do you see in one day? Millions of these are everywhere; if a tiny part goes wrong in the system, the whole intersection is not working correctly. It could cause wrecks, confusion, and frustration among the drivers. So yes, technology drives our society daily; without it, we would not know how to function.

When you think of the environment, you may not think of technology. However, technology also plays a significant role in our environment. A few examples are emissions from our vehicles, electric hydro dams, emissions in our factories, and refrigerant recovery in our a/c units. This is just the tip of the iceberg; there are many other ways our environment is affected by technology.

Question 2 (.33 points): Why is learning how technological products are made/manufactured necessary?

Answer: Learning how technological products are made is important because it gives you a better understanding of the part and its uses. Knowing how something is made and put together will help you to understand its uses and the use of the part in the overall process that it is being utilized. It also helps to know what materials are used to make the parts or products you are using because they may have to meet certain factory specifications. If they do not, they may fail and disrupt your process downstream more significantly.

Question 3 (.34 points): Please provide your thoughts on the assessment process and your overall experiences relating to the questions posed to you over the semester.

Answer: This assessment process has been neat because it has allowed me to take a step back and even a breath to reflect on not only this semester but also previous semesters. The questions have motivated me to think in different ways and have allowed me to understand what I have learned, why I have learned them, and how they will help me in the future. We often get so caught up in learning the material that we can get through the class and forget why we are learning it and how it can impact our lives and jobs! The questions also allowed me to think critically about previous situations and roadblocks or barriers that I could overcome and did not think about when we were struggling with specific projects.

Question 4 (Follow-up): Do you believe performing these written reflections helped you to understand better what it means to be technologically and engineering literate (please be detailed)?

Answer: I must admit that, at first, I was skeptical about these reflections. I thought this might be busy work we would have to write about. However, I can say that this has not been bad at all; it has even been enjoyable to reflect on all of my previous STEM classes. I have gained more knowledge about technology and engineering than I imagined. I would not consider myself an expert in all the material we have covered and learned. However, I have been exposed to many different manufacturing technologies, construction engineering, 3-D technology, and engineering. For some detailed experiences of learning: We covered the glass and plastic bottle making, we covered the engineering and technology involved in 3D printing, we also covered a lot of different woodworking designs and machines, and finally, we had the opportunity to learn about how a house is built from the ground up to a structure. It is neat to learn that all of these examples are affected by technology and how they are engineered. Because it seems you cannot have one without the other. No matter what application you are covering, there has to be engineering involved to design the part or structure, and there also has to be technology to manufacture or build the part. So, these two terms go hand in hand with each other, not only in this class or this writing but in everyday life as well.

Total score: 100 points

Rater 1: 100/100 Rater 2: 100/100

Appendix R (cont'd)

PARTICIPANT REFLECTIVE WRITING ASSESSMENT THREE RESPONSES

This is the last of the three assessments relating to your development of technological and engineering literacy.

When completed, please post to Canvas in the Questionnaire Three folder by the due date.

Note: Please do not search the internet to answer these questions, as doing so will negatively impact the data collected from these responses. Thank you.

Participant name: Lenny

Please answer the following questions by providing at least one to two paragraphs for each question, as applicable.

Question 1 (.33 points): How does technology impact our lives, society, and the environment?

Answer: Technology's impact on our lives allows for a higher quality of life. By allowing us to expand the work one man can do, we allowed for a rise in most aspects of society. Our society has changed from technology by creating a few changes in how we interact. By allowing for improvement in communication speed, we have allowed our society's economics and structure to change by allowing us to make decisions for larger pieces of land.

Our significant changes for the environment have been the targeted usage of natural resources as they are used on a larger scale to support that quality of life at the optimal cost for our current population. That has changed with pollution and different standards.

Question 2 (.33 points): Why is learning how technological products are made/manufactured necessary?

Answer: By learning how technological products are made, we learn the costs they put on society. By understanding the costs, we understand the process that allows us to develop technological products to raise the quality of life. By learning about the processes, we learn about those resources needed to sustain our quality of life. This is the chain of thought I see when I look for importance in the technological process. By following it, we have one viewpoint on why technology is essential. I know that it is not the only viewpoint, but I see it as the largest from my perspective.

Question 3 (.34 points): Please provide your thoughts on the assessment process and your overall experiences relating to the questions posed to you over the semester.

Answer: My views on the assessment process are that it has helped put things in perspective and highlight some of the differences between this semester and the last. This semester has had people able to give me about ninety percent compared to a few previous semesters where people felt like they were giving ten percent. Working in engineering classes these last few semesters has allowed me to gain experience and understand more about what goes into an engineering process, whether metal or woodworking or the prototype/design/ process.

Question 4 (Follow-up): Do you believe performing these written reflections helped you to understand better what it means to be technologically and engineering literate (please be detailed)?

Answer: I believe these writing reflections have helped me understand what being more technologically and engineering literate means. It reminded me of the costs that go into our quality of life that engineering is working towards. Doing things better, cheaper, more efficient, and so forth have all been things I have understood, but they have never been the focus of my assignments. I feel that the viewpoint on groups has allowed me to see more of what goes into a good group compared to a bad one. I feel that this is a narrow view, but it is what I focused on in the last few questions, which has allowed me to understand the engineering perspective better.

Total score: 100 points

Rater 1: 88/100 Rater 2: 73/100

VITA

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Publications

Euefueno, W. D. (2021). Book Review: Maintaining strategic relevance (Career and Technical Education Program Discontinuance in Community and Technical Colleges*). ITEEA, STEM Connections, February, 2021.*

Muljana, P.S., Luo, T., Watson, S., Euefueno, W. D., Wright-Jutsi, K. N. (2020). Promoting Instructional designers' participation in free, asynchronous professional development: A formative evaluation. *Journal of Formative Design in Learning* https://doi.org /10.1007 /s41686-020-00044-4

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