Investigating the Impact of Reflexive Practices on College Students in a Science Laboratory Course

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INVESTIGATING THE IMPACT OF REFLEXIVE PRACTICES ON
COLLEGE STUDENTS IN A SCIENCE LABORATORY COURSE

by

Chandrani Mishra

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

December 2015
ABSTRACT

INVESTIGATING THE IMPACT OF REFLEXIVE PRACTICES ON COLLEGE STUDENTS IN A SCIENCE LABORATORY COURSE

by Chandrani Mishra

December 2015

Emphasis on professional practices to develop students’ professionalism is currently a major focus of higher education. Studies have shown the benefits of reflexive practices in classroom to facilitate the development of students’ professional attitude or identity in some fields. Reflexive practices involve students in self-reflection where he/she reflects on his/her own actions. Little investigation about the benefits of reflexive practices in the development of students’ scientific identity in a science class led to my investigation. Development of a scientific identity of students and their overall interest and motivation in science is deemed essential for retaining students in STEM fields.

My dissertation is a mixed-methods study investigating the impact of reflexive practices on college students’ development of scientific identity, interest, and motivation in a science laboratory course. The concept of reflexivity facilitating the development of students’ professional identity guides my study. Engaging students in reflexive practices in an authentic course leads to the development of their reflexivity which is composed of three components, namely awareness of oneself, inquiry attitude, and collaborative attitude. For my investigation, I collected data from students in three different institutions enrolled in courses, each featuring a different learning environments which are authentic environment with reflexive practices (n=46), authentic environment without reflexive practices (n=23), and traditional environment with reflexive practices (n=17). Students in
the reflexive setting were asked to respond to weekly reflection prompts throughout the semester. I collected data from multiple sources which included a pre/post interest and motivation questionnaire, a self-awareness questionnaire, students’ responses to reflection prompts, teaching assistants’ observations, students peer evaluations, and student interviews.

I found that although authentic learning environment is crucial for the development of students’ scientific identity, interest, and motivation, reflexive practices in an authentic setting further augments these developments by enhancing students’ reflexivity. Students’ awareness about themselves, inquiry attitude, and collaborative attitude influenced one or more of the above mentioned students’ outcomes. Most of the students in the authentic-reflexive course perceived reflections to be useful in several ways such as development of their awareness, thinking ability, and communication skills which further emphasizes the benefits of reflexive practices.
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COLLEGE STUDENTS IN A SCIENCE LABORATORY COURSE

by

Chandrani Mishra

A Dissertation
Submitted to the Graduate School
and the Department of Biological Sciences
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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DEDICATION

I dedicate my dissertation to my parents, Biswarup Mishra and Ranjana Mishra, for their endless sacrifices, prayers, and continued support for my studies. I would like to express my gratitude to my husband Dhritiman Samanta for his constant support throughout my dissertation.
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CHAPTER I
INTRODUCTION

Problem Statement and Rationale

Developing a professional attitude towards classwork is one of the current major focuses of universities around the world because the higher education guidelines emphasize prioritizing employability and engaging students in professional practices (European Consortium for Accreditation in Higher Education, 2004; Gilardi & Lozza, 2009; Spellings, 2006). Such emphasis on students’ professional practices is to prepare them for their future career. However, very little has been done in this regard at the institutional level (Crosier, Purser, & Smidt, 2007). To execute professionalism, it is important to initially identify effective classroom practices that promote the development of a professional attitude towards work and/or students’ professional identity (Gilardi & Lozza, 2009). The identity of an individual is considered a “tool” to present oneself to the surrounding world (Owens, 2003). Therefore, development of the professional identity of students at the undergraduate level prepares them to present themselves professionally in current and future endeavors. Such benefits of the development of professional identity acknowledge the need for prioritizing professional practices at institutions.

Educational practices, like inquiry-based learning strategies and developing an authentic learning environment, do have some benefits like engaging students in self-directed learning and enhancing their problem-solving skills (Hu, Kuh, & Li, 2008; Pascarella & Terenzini, 2005). However, organizing these practices in a way to promote the development of the professional identity of students is still lacking (Seymour, Hunter, Laursen, & DeAntoni, 2004). Recently, incorporation of reflexive practices as an
effective classroom practice to facilitate the development of a professional attitude towards work has been made in different fields such as health, teaching, and psychology (Gilardi & Lozza, 2009; Sutherland & Markauskaite, 2012). Reflexive practices involve reflecting on one’s own actions that facilitate the development of an individual’s professional identity (Gilardi & Lozza, 2009). For example, for students to develop a scientific identity, that is, an identity in which a student thinks and behaves like a scientist, he/she must learn to reflect back on his/her own actions, and think critically as a scientist. Therefore, development of a scientific identity can be facilitated by engaging them in reflexive practices in an interactive science learning environment.

Over the last few years, decline in STEM retention rate among college students has been of prime concern. According to Augustine (2007), there has been a 40% decline in the number of students entering STEM fields. In this regard, development of a scientific identity in students is shown to positively influence students’ retention in STEM fields (Mraz, Mishra, Daniel, Boyce, Ali, & Clase, under review). In addition to that, if a student is motivated, or develops an interest in learning science and in science careers, they are also likely to remain in STEM fields in the future (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Romine, Sadler, Presley, & Klosterman, 2013). Therefore, it is essential to develop a learning environment that facilitates this retention. My study provides a rationale for educators to incorporate effective reflexive practices within their course curriculum in order to facilitate students’ retention in STEM fields. Specifically, the purpose of my study is to investigate how reflexive practices in an authentic laboratory course influence the development of students’ scientific identity, their science and science-related career interest, and motivation.
Research Questions

My study is guided by the following research questions:

1. What are the differences in students’ identities, interest, and motivation in relation to different learning environments (authentic–reflexive, authentic–non-reflexive and traditional–reflexive laboratory)?

2. How do components of reflexivity relate to students’ identities in a laboratory course involving reflexive practices?

3. How do components of reflexivity relate to students’ interest in a laboratory course involving reflexive practices?

4. How do components of reflexivity relate to students’ motivation in a laboratory course involving reflexive practices?

5. What are students’ overall views about engaging in self-reflection in an authentic–reflexive laboratory environment?

Limitations

To identify the role of reflexive practices on the development of students’ scientific identity, I only focused on students enrolled in a biotechnology course. Therefore, the results of my study may not be generalizable to other science courses. Because of the basic epistemological (an instructor’s perception of the nature of knowledge) and pedagogical (an instructor’s opinion about including something in the curriculum) differences between the science disciplines (Redish & Cooke, 2013), the extent of the impact of reflexive practices may be different for different science subjects.

The three courses that I included in my study were taught by different instructors at three institutions. Instructors play a vital role in engaging students both cognitively and
emotionally, which influences students’ interest in the subject (Mazer, 2013). So, it is possible that the varied guidance students’ received due to different instructors may have influenced my results.

Moreover, students in the three courses chosen for this study were in different grade levels, for example, majority of students in the authentic-non-reflexive course were freshmen, whereas majority of students in the traditional-reflexive course were seniors. Therefore, the varied experience level of students may have influenced the findings to some extent.

Lastly, I did not investigate the differences in students’ outcomes between gender or ethnic groups within my target population. Therefore, the results of my study may not be generalizable to any particular gender or ethnic group.

Definitions

1. **Authentic research environment** - Authentic research is characterized by engaging students in real research, which involves working in a laboratory environment guided by a mentor for hands-on research experience (Laursen, Hunter, Seymour, Thiry, & Melton, 2010; Lopatto, 2008).

2. **Cognition** - It refers to the mental processes that are essential for the acquisition of knowledge. It involves mental activities like learning, understanding, thinking and remembering (Merriam-Webster, 2014).

3. **Collaboration** - It is a type of interaction between people with a common goal and which involves shared participation and decision making (Friend & Cook, 1990).

4. **Critical thinking** - Critical thinking, also referred to as reflective thinking, is a type of mental activity in which an individual interprets and evaluates
observations and experiences to decide future actions (Ennis, 1992; Fisher & Scriven, 1997).

5. **Deductive approach to coding** - A type of coding used to analyze qualitative data where a researcher codes the data into predetermined categories/groups based on a theoretical framework or any previous research (Patton, 2002).

6. **Descriptive coding** – A type of coding used to summarize the ideas emerging from the data in a word or short phrase. It is appropriate to code data from interviews, journals, documents, videos etc. (Saldana, 2013).

7. **Identity** - Identity of an individual is the recognition that he/she receives as a particular “kind of person” in a specific context. An individual can hold multiple identities at a time and they are changeable in nature (Gee, 2000).

8. **Inductive approach to coding** – A type of coding used to analyze qualitative data where a researcher codes the data without any predetermined categories or groups and relies more on the ideas emerging from the data (Patton, 2002).

9. **Inquiry attitude** - It is a type of attitude in which a student questions his/her observations or experiences and which guides their future actions. Such attitudes are very essential for the development of a professional identity (Schon, 1983).

10. **Intrinsic motivation** – It is defined as a drive for learning that comes from within an individual (Simpkins, Davis-Kean, & Eccles, 2006).

11. **Metacognition** - It is commonly known as “thinking about thinking,” which is the awareness of an individual about one’s own cognitive processes (Flavell, 1979).

12. **Professional identity** - It is referred to as one of the identities that an individual can possess which is associated with their current or future profession, such as a
teacher identity. A professional identity develops by interaction with others in the society and interpretation of those experiences (Gee, 2000; Geijsel & Meijers, 2005).

13. **Reflection** - Reflection is a type of mental activity in which an individual engages in the process of thinking about a particular experience which involves both the environment and how everyone acted in that particular situation. It can occur both during an experience and after the experience (Schon, 1983).

14. **Reflective journals** - Reflective journals are a form of a written document that captures an individual’s thoughts, concerns, and experiences by engaging them in an internal conversation with their own mind (Spalding, Wilson, & Mewborn, 2002).

15. **Reflective practices** - An individual who engages in the process of reflection is referred to as being reflective and such practices are referred to as reflective practices (Korthagen & Vasalos, 2005).

16. **Reflective prompts** - The reflective prompts act as a support to help individuals in the process of reflection. It helps in the externalization of mental activities (Scardamalia & Bereiter, 1985).

17. **Reflexive capacity** - The ability of an individual to reflect on one’s own actions to develop self-awareness is referred to as reflexive capacity. It can be improved by engaging individuals in reflexive practices (Gilardi & Lozza, 2009).

18. **Reflexive practices** - An individual who engages in self-reflection, i.e., reflecting on one’s own actions, is referred to as being reflexive and such practices are referred to as reflexive practices. It is a component of reflective practice and not
an entirely different concept (Hertz, 1997; Warin, Maddock, Pell, & Hargreaves, 2006).

19. Reflexivity - Reflecting on one’s own actions leads to the development of reflexivity which is awareness of an individual about oneself, their values and beliefs that impacts their future actions (Warin et al., 2006).

20. Scientific identity - An identity in which an individual thinks critically as a scientist and behaves like a scientist.

21. Scientific inquiry - It is a type of activity used by students to develop knowledge and understanding about science and how scientists work. The activities include making observations, collecting information by reading books and from other sources, asking questions, and using scientific tools (NRC, 1996).

22. Self-directed learning - It is a type of learning in which students take the initiative to learn on their own by developing learning goals and learning strategies and evaluation of learning outcomes at the end of the process (Knowles, 1975).

23. Self-determination – It is defined as students’ belief of having control over their own perceptions and leaning (Black & Deci, 2000).

24. Self-efficacy – It is defined as students’ confidence that they can perform well in their field. (Lawson, Banks, & Logvin, 2007).

25. Traditional laboratory environment – A laboratory environment in which students come to a lab, strictly follow the set protocols to obtain a known or expected result without exploring much on their own.
CHAPTER II
REVIEW OF RELEVANT LITERATURE

Conceptual Framework

Reflection is considered as an inquiry attitude where an individual thinks about a particular context and has a sort of conversation with that context in his/her own mind (Schon, 1983). Reflective practices help to engage individuals in the process of reflection in which an individual can reflect on the environment in which a particular event occurred, or how did everyone behave in that particular context (Korthagen & Vasalos, 2005). During such reflections, when an individual focuses on his or her own actions, that is, how they particularly behaved in a situation or what they could have done differently in that situation, it is referred to as a reflexive practice (Antonacopoulou, 2004; Warin et al., 2006). Reflexive practice is considered to be a part of a bigger concept, the reflective practice, and not a completely distinct element. Reflexive practices involve self-reflection which is interpretation of self-actions in a particular environment for one’s own improvement and development of knowledge (Elliot, 1993; Hertz, 1997; MacLure, 1993; Nagata, 2004). Such practices lead to the development of reflexivity, which is awareness about one’s self, one’s values and beliefs that impacts how a person will act in a particular context (Schon, 1983; Warin et al., 2006). Moreover, reflexivity is an essential component for the development of one’s professional identity (Guichard, 2005), like a scientific identity, an identity that prepares an individual to think and behave like a scientist. The concept of reflexivity facilitating the construction of one’s professional identity guides this study.
There are three principal components of reflexivity (Gilardi & Lozza, 2009). First, being aware of one’s self as a professional (Warin et al., 2006), which means reflecting on one’s own perceptions, strengths and weaknesses that impact his/her work. This component of reflexivity leads to questions like “What am I learning in this class? How am I going to use this knowledge in the future?” The second component is having an inquiry attitude, which is a “reflective conversation with the situation” (Schon, 1983). This attitude involves a constant questioning of self-actions and learning from previous experiences. The third component of reflexivity is having an ability to work and negotiate with others (Cunliffe, 2004). This social element of reflexivity implies that individuals should be able to work with others to solve a problem (Reynolds & Vince, 2004).

![Diagram of components of reflexivity]

*Figure 2.1. The components of reflexivity.*

The development of these components of reflexivity can be facilitated by engaging individuals in reflexive practices such as journaling or responding to reflective prompts while working in an authentic learning environment (Gilardi & Lozza, 2009). Therefore, these components of reflexivity are specific to an authentic learning environment. A student who is reflexive, is likely to develop a professional identity.
(Guichard, 2005). The development of a professional identity such as a scientific identity helps students to value science, be motivated towards it and develop characteristics of a scientist (Hunter, Laursen, & Seymour, 2007). Therefore, such students are likely to perform better in their science class and retain their interest and motivation in science (Berzonsky & Kuk, 2005; Hejazi, Shahraray, Farsinejad, & Asgary, 2009). Development of students’ interest and motivation is critical from an educator’s perspective in order to promote reflexive practices within their classroom. So, the development of reflexivity facilitated by the engagement of students in reflexive practices in an authentic learning environment leads to the development of students’ identity and potentially influence their interest and motivation (Figure 2.2). The purpose of my study is to investigate how reflexive practices in an authentic laboratory course influence the development of students’ scientific identity, their science and science-related career interest, and motivation.
Figure 2.2. Logic model showing how reflexive practices relate to the development of students’ identity and potentially relate to their interest and motivation.
Reflection

A commonsense view of reflection is that it is an activity that involves some form of thinking (Moon, 2006). This is also how people talk about reflection in everyday language. However, there is a lot more to add to it. People are more likely to reflect in situations that involve critical decision making (Moon, 2006). For example, decisions a player has to make on the field during a game effects the team’s performance. So, players often reflect during and after the game in making critical decisions. Therefore, reflection can be better described as a form of thinking applied to complex situations or decisions that might result in different consequences. It is a process that links one’s thoughts to their actions. Reflections facilitate using one’s beliefs and experiences to make decisions or lead to conclusions (Mezirow, 1990; Roberts, 2008). It can occur both during and after an experience as described by Schon (1983) as reflection in action and reflection on action. Moreover, reflections can take place in any environment and can be either individual or in group.

It was not until late 1990’s, when the role of reflection was significantly studied in an academic context. What is unique in an educational context is that the reflection is more structured, has specific learning outcomes and is often assessed at the end. According to Salisbury (1994), students might view this aspect of reflection positively and be more inclined to do it, as they think their reflective writing might be assessed favorably by their educator. Therefore, Moon (2006) describes reflection in the academic context as a represented form involving a purpose and specific outcomes in terms of learning, and which is seen and assessed by others. It acts as a bridge to connect students’ experiences and their learning.
Reflexivity

What adds to the complexity of reflection is its quality and depth. Studies have focused on how reflections can be done at different levels varying quantitatively and qualitatively. Superficial reflections are often assumed to be descriptive in nature, which involves description of context and events. For example, a person describing his/her experience in a social get-together does not involve any in-depth description of what he/she felt, good or bad, about something happening at the social event, but just an overall description of the event. On the other hand, in-depth reflections or deep reflections are often characterized as those that involve transformative learning, which is change in one’s understanding, behavior, and belief as a result of an experience (Hatton & Smith, 1995; Kember, 1999; Kember et al., 2000; Mezirow, 1998; Moon, 1999a, 2006; Sparkes-Langer & Colton, 1991). Deep self-reflections involve critical considerations of one’s own understanding and are also known as “critical reflection” or “reflexivity” (Antonacopoulou, 2004; Hatton & Smith, 1995; Kim, 1999; Warin et al., 2006). For example, when an individual reflects on how he/she would behave differently the next time in a particular situation, he/she is thinking of changing his/her behavior as a result of some experience, which is an example of critical reflection or reflexivity.

Role of Reflexive Practices

Reflexive practices such as engaging an individual in critical self-reflection, makes an individual aware of themselves, their strengths and weaknesses (Gilardi & Lozza, 2009; Warin et al., 2006). Such practice prepares an individual to deal with complex situations and facilitates learning from one’s own experiences (Gilardi & Lozza, 2009; Mann, Gordon, & MacLeod, 2009). Additionally, reflexivity, which helps to build
a professional identity, is a socially constructed process (Cunliffe, 2004; Gilardi & Lozza, 2009; Reynolds & Vince, 2004). Therefore, students should be provided with a collaborative learning environment to think upon their interactions within a specific context, and interactions with the students working together in order to develop reflexivity (Gee, 2000; Geijsel & Meijers, 2005; Gilardi & Lozza, 2009; Olesen, 2001; Renninger, 2009). When students work in groups, they experience a real professional set up, which facilitates the development of their social communication skills (Gilardi & Lozza, 2009). All professions have a social aspect in which professionals should be able to communicate and work with others (Renninger, 2009; Reynolds & Vince, 2004; Sutherland & Markauskaite, 2012), so acquisition of these social skills as a student, is essential for the development of their reflexivity and in turn their professional identity.

Educational practitioners prefer different ways of engaging students in reflexive practices. For example, the use of journals facilitate students’ development of self-awareness and development of their thinking and writing skills (Cunliffe, 2004; Locke & Brazelton, 1997). However, some other practitioners prefer online reflections (Sutherland, Howard, & Markauskaite, 2010). According to them, technology facilitates the process of reflection by engaging students to think more deeply and provide a more in-depth reflection (Lin, Hmelo, Kinzer, & Secules, 1999; Sutherland et al., 2010; Sutherland & Markauskaite, 2012). Students are found to spend more time reflecting in an online setting, and such reflections are also associated with better learning gains (Morgan, Rawlinson, & Weaver, 2006). But, there are some limitations associated with online reflections, such as students not always completing the reflections and at times not considering them to be essential enough and just reflecting superficially (Johnson, 2001).
However, proper design and organization of online reflections usually overcome these disadvantages (Rovai, 2007). Additionally, not all students are capable of reflecting efficiently. Therefore, guidance and support help to engage all students in the process of reflection. Supports, such as prompts, help to externalize students’ thinking and express it in words (Bereiter’s & Scardamalia’s, 1998; Lin et al., 1999). They act as a reminder to engage students in the process of reflection (Lin et al., 1999; Sutherland et al., 2010; Sutherland & Markauskaite, 2012). Moreover, students’ reflections can also be strengthened by incorporating peer responses and feedback as a part of the course activity (Levin, He, & Robbins, 2006; Maher & Jacobs, 2006; Sutherland et al., 2010; Sutherland & Markauskaite, 2012). Peer interactions allow students to learn the different perspectives of their peers and improve their individual reflections (Lin et al., 1999). Therefore, providing students with such extra support could facilitate their process of self-reflection.

As reflexive practices in higher education continue to gain in popularity, it is very important to evaluate the role of reflection and reflexive practices on college students for better implementation of such practices. Primarily, it is observed that reflexive practices, like journaling, force students to think which results in significant learning (Moon, 2006; Walker 1985; Wildman & Niles, 1987). Silence that students experience while thinking, helps them to be more attentive to themselves and to others and develop a better sense of their learning (Alerby & Elidottir, 2003; Dawson, 2003). Therefore, students are likely to experience enhanced learning when they engage themselves in reflexive practices. Reflexive practices also facilitate transformative learning as students can relate their new knowledge to their previous knowledge through reflection (Mezirow, 1998; Moon,
1999a; Moon, 2006). Students learn to derive a meaning from their experience as they are engaged in reflective thinking, facilitating their learning from experience as described in Kolb’s experiential learning theory and Schon’s reflection on action theory (Gillis, 2001; Kolb, 1984; Moon, 2006; Orem, 2001; Schon, 1983; Shepherd, 2004).

Reflexive practices benefit students at different learning situations. For example, for students, finding a solution to a simple problem may not always require thoughtful reflections. However, there is often a certain level of difficulty to deal with ill-structured material as there is not a best solution to those even according to the experts. Reflexive practices help students to deal with such problems by facilitating the process of finding a possible solution by engaging them in a thought process (King & Kitchener, 1994; Moon, 2006). Reflexive practices which involve self-reflections, promote metacognitive thinking, which are commonly defined as thinking about one’s own thinking (Flavell, 1987). While reflecting, an individual is also encouraged to think about his/her own process of learning which is key to effective learning (Ertmer & Newby, 1996; McCrindle & Christensen, 1995; Moon, 2006; Gillis, 2001; Hadwin & Winne, 1996). Self-reflections encourage students to become independent thinkers and active learners (Fuhler, 1994; Hiemstra, 2001). Therefore, reflexive practices not only guide students’ thinking but also their process of learning. In addition to the development of students’ thinking and reflecting skills, reflexive practices facilitate the development of a questioning attitude of students and different skills like problem-solving and critical thinking (Grumbacher, 1987; Jensen, 1987; Korthagan, 1988; Moon, 2006). Moreover, journaling or other forms of writing reflections are also critical for the development of
writing skills (Gardner, 1999). These skills are essential for personal and professional development of students.

Besides facilitating the development of personal and professional skills, reflective practices also foster collaborative learning and interaction with others. Reflective writing helps students to interact better with others in classroom situations (Hickman, 1987; Moon, 2006; Walker, 1985). Educators often engage students to work in groups on projects to promote learning through interaction. Reflective writing helps students to plan and monitor their progress on group activities which strengthens the interactions among them in the classroom (Glaze, 2002; Holly 1989; Shepherd, 2004). It acts as a bridge of communication among learners as well as between a learner and a tutor (Moon, 2006; Wetherell & Mullins, 1996). Reflections act as a more structured way of communication and help to develop a better professional relationship.

Reflexive practices in general also have some psychological benefits on students (Brady & Sky, 2003; Haraway, 2003; Salem, 2007). If students are trained to solve a course problem through reflections or discussions, it might as well help them in managing their life problems in the future, as they will master the skill of engaging in reflective thinking. Students experience the joy of finding a solution through self-reflections. Also, not all students are comfortable speaking in public, and writing reflections helps these students to develop confidence and a voice to express in public. Lastly, it is noted that reflective practices help reduce students’ anxiety in general and also anger to some extent (Salem, 2007). These personal benefits of reflexive practices last throughout one’s life.
Professionalism or developing a professional approach to work is highlighted to be a necessary aspect in the guidelines of higher education (European Consortium for Accreditation in Higher Education, 2004; Spellings, 2006). To be a professional in a particular field, an individual needs to learn to behave in a professional manner along with the acquisition of necessary skills and knowledge (Dall’ Alba & Barnacle 2007; Rodger & Scott, 2008; Sutherland & Markauskaite, 2012). Formal education is one of the best times for students to acquire such type of professionalism (Walkington, 2005). For example, as a part of authentic undergraduate research activities, undergraduates engaged in research get the opportunity to interact with their classmates in a real laboratory setting, which helps to build a scientific identity. Authentic Undergraduate Research Experiences (AUREs) provide undergraduates with an authentic, i.e., hands-on research experience, where a student works like a researcher, guided by a faculty member, to get real world research experience (Laursen et al., 2010; Lopatto, 2008). There are several benefits associated with such AUREs, some of which include: (a) development of research skills, (b) improved ability of communicating and working with others, (c) improved perseverance and ability to tolerate obstacles, and (d) improved understanding of a scientist (Kardash, Wallace, & Blockus, 2008; Lopatto, 2004; Seymour et al., 2004). Such benefits of authentic research experiences are also essential for the development of a professional identity (Hunter et al., 2007). Thus, there is a direct relationship between students’ exposure to authentic research experiences and the development of their professional identity (Carlone & Johnson, 2007; Gilardi & Lozza, 2009; Hunter et al., 2007). Development of a professional identity also influences students’ academic
performance by enhancing their self-efficacy (Bandura, 1997; Berzonsky, 2004a; Hejazi et al., 2009).

However, development of a professional identity cannot be solely achieved through an authentic learning environment. Instead, implementation of classroom practices like engaging students in reflexive practices facilitates the development of their professionalism or professional identity (Gilardi & Lozza, 2009). Reflexive practices are not solely an independent entity but rather a component of reflective practices. Reflexive practices focus more on critical self-reflection, which is how an individual behaved in a particular social context (Antonacopoulou, 2004; Warin et al., 2006). This self-reflection helps an individual to grow as a person and develop one’s own identity.

For many students, transition from high school to University is very challenging. They find it difficult to meet higher academic expectations and establish social connections (Berzonsky & Kuk, 2005). However, it is found that a professional identity of students may facilitate this transition as students with such an identity are likely to deal with everyday problems efficiently and be able to make critical decisions (Adams, Ryan, & Keating, 2000; Berzonsky & Kuk, 2005; Pratt, 2000). College education is also regarded as the best time for professional identity development (Hamrick, Evans, & Schuh, 2002; Lounsbury, Huffstetler, Leong, & Gibson, 2005; Nakkula, 2003). In college, students are provided with a platform to develop new skills and build professional social relationships every day, which facilitates the development of their professional identity (Lounsbury et al., 2005; Nakkula, 2003).

Additionally, previous studies have noted a positive association of identity development and students’ performance in class (Berzonsky & Kuk, 2005; Cross &
Allen, 1970; Hejazi et al., 2009; Lounsbury et al., 2005). Identity, being reflexive in nature, provides students with an outlook or viewpoint to interpret their social and individual behaviors and plan their future actions which regulate their performance in class (Burke & Reitzes, 1981; Rosenberg, 1979; Wells, 1978). Students’ academic performance, most commonly represented by their grade-point average (GPA) is positively related to the development of skills like self-regulation, persistence and critical thinking (Lounsbury, Fisher, Levy, & Welsh, 2009). These skills are also some of the essential components of a professional identity. So, the development of professional identity may indirectly impact positively on students’ academic performance. Therefore, it is very important to promote activities in undergraduate courses that help in the construction of students’ professional identity.

Educators are also often found to be curious about their students’ interest and motivation because that influences their overall performance in class. Development of students’ interest and motivation to learn science and engage in scientific careers will not only influence their overall academic performance but help them retain in STEM fields (Augustine, 2007). Students’ interest and motivation are found to be dependent on external factors like teaching strategies and classroom environment and also development of those are considered to be an important goal for all instructors at college level (Glynn et al., 2011; Nieswandt, 2007; Romine et al., 2013). It is reported in previous literature that engaging students in research activities does positively influence their motivation and self-determination (Hu et al., 2008; Pascarella & Terenzini, 2005, Gilardi & Lozza, 2009). However, the role of reflexive practices in a classroom environment to influence students’ interest and motivations has not been studied extensively.
Challenges of Student Reflections

Despite the ample benefits of the students’ reflections in a classroom environment, there are some challenges in incorporating them within a course curriculum. One of the major concerns of educators is that reflection activities are time consuming (Peyton, 1993; Salem, 2007). Moreover, different students prefer to reflect differently. For example, some might prefer individual journaling whereas others might prefer group reflections. So, a particular reflection method implemented by the teacher might not be the best for all students (Roberts, 2008; White, 2014). Another common challenge faced by the instructors is that students may not be honest in their reflections when they are aware of their work being graded (Eyler & Giles, 1999; Fernsten & Fernsten, 2005; O’Connell & Dyment, 2011a; Walmsley & Birkbeck, 2006). Students may feel pressure to not be accurate in their reflections for fear of a bad grade. Moreover, students may not share sensitive information if they are aware of being judged. Therefore, creating a reflective assignment while making sure students are encouraged to provide honest reflections is challenging for instructors. Such challenges associated with student reflections may hold back instructors from implementing reflexive practices in their classrooms.

Literature Gaps

Many studies have acknowledged the role of reflexive practices in an authentic learning environment in different fields. Reflexive practices lead to the development of a professional identity in teachers, health professionals, and professionals in the field of psychology by offering an opportunity to identify their strengths and weaknesses, helping them connect their new understanding to the existing knowledge, and encouraging them to find evidences and feedback to reinforce their opinions (Barnett & O’Mahony, 2006;
Cunliffe, 2004; Kreber, 2005; Mann et al., 2009; Mayo, 2004; Sax, 2006). However, the impact of reflexive practices within an authentic scientific learning environment on the development of a scientific identity has not been explored in previous literature.

Additionally, the impact of reflexive practices on students’ interest and motivation in a science classroom still remains untested. Beneficial influence of reflexive practices on students’ scientific identity and other student outcomes will motivate educators to engage students in reflexive practices within their classroom. Therefore, these gaps in previous literature have led to my study to investigate how reflexive practices in an authentic laboratory course influence the development of students’ scientific identity, their science and science-related career interest and motivation. Through this study, I aim to provide a rationale for educators to incorporate such practices within their course curriculum and add to the existing literature by addressing the gaps.
CHAPTER III

METHODOLOGY

Procedure

I conducted a mixed methods study to investigate how reflexive practices in an authentic laboratory course influence the development of students’ scientific identity, their science and science-related career interest and motivation. For this investigation, I collected data from three universities each featuring a specific learning environment: University A, a Midwestern research university, offering an authentic laboratory course and engaging students in reflexive practices (authentic-reflexive); University B, a Midwestern research university, also offering an authentic laboratory course but not engaging students in reflexive practices (authentic-non-reflexive); and University C, a Southern research university, offering a traditional laboratory course but engaging students in reflexive practices (traditional-reflexive). The research questions that guided this study required both qualitative and quantitative methodologies to obtain extensive data from the target population. For example, I used qualitative data sources such as students’ interviews and their responses to reflection prompts to determine students’ identity and their inquiry attitude respectively whereas I used quantitative data sources such as pre/post interest and motivation questionnaires to determine students’ change in interest and motivation due to a specific learning environment and to compare that across three different institutions. Measuring interest and motivation through qualitative methodology is very challenging because they are not directly observable variables, commonly referred to as latent variables (Glynn et al., 2011). Using both qualitative and quantitative methodologies therefore helped me provide a detailed overview of the
impact of reflexive practices on college students in a science laboratory course (Patton, 2002).

I used a quasi-experimental design to determine the differences in students’ identities, interest and motivation in relation to different learning environments (Table 3.1).

Table 3.1
*Quasi-Experimental Design Groups*

<table>
<thead>
<tr>
<th>University A (authentic-reflexive)</th>
<th>University B (authentic-non-reflexive)</th>
<th>University C (traditional-reflexive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Authentic laboratory environment</td>
<td>• Authentic laboratory environment</td>
<td>• Traditional laboratory environment</td>
</tr>
<tr>
<td>• Students engaged in reflexive practices</td>
<td>• Students not engaged in reflexive practices</td>
<td>• Students engaged in reflexive practices</td>
</tr>
</tbody>
</table>

To answer my specific research questions, I collected data from multiple sources which included: a pre/post interest and motivation questionnaire, a self-awareness questionnaire, students’ responses to reflection prompts, teaching assistants’ observations, students peer evaluations, and interviews or open-ended questionnaires.

Table 3.2 displayed below shows how each data sources were used to explore the specific research questions. A data source could be either primary or secondary, depending upon the nature of information obtained from them. Primary data sources provided more critical information that were used for analysis and the secondary data sources rather acted as a support to the primary data sources to answer a particular research question.
Table 3.2

*Data Matrix: Purpose of the study and research questions by data sources*

The purpose of this study is to investigate how reflexive practices in an authentic laboratory course influence the development of students’ scientific identity, their science and science-related career interest and motivation.

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interviews/</td>
</tr>
<tr>
<td></td>
<td>Open-ended</td>
</tr>
<tr>
<td>1. What are the differences in students’ identities, interest and motivation in relation to different learning environments (authentic–reflexive, authentic–non-reflexive and traditional–reflexive laboratory)?</td>
<td>P</td>
</tr>
<tr>
<td>2. How do components of reflexivity relate to students’ identities in a laboratory course involving reflexive practices?</td>
<td>P</td>
</tr>
<tr>
<td>3. How do components of reflexivity relate to students’ interest in a laboratory course involving reflexive practices?</td>
<td>P</td>
</tr>
<tr>
<td>5. What are students’ overall views about engaging in self-reflection in an authentic–reflexive laboratory environment?</td>
<td>P</td>
</tr>
</tbody>
</table>

P = Primary data source, S = Secondary data source
Setting

Among the courses at the three different universities, the course content of authentic-reflexive and authentic-non-reflexive lab were similar and were designed according to Science Education Alliance Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES) project supported by the Howard Hughes Medical Institute (HHMI). Apart from being taught by different instructors, the two courses differed from each other in engaging students in reflexive practices or not. Students in the authentic reflexive course were asked to respond to weekly reflection prompts throughout the semester. A set of same reflections prompts were provided to students each week online via a learning management system and students had to respond to all of them.

The SEA-PHAGES project aims to provide undergraduates with a platform to experience the process of scientific discovery by discovering new bacteriophages as a part of their course. Students are provided with a laboratory manual with detailed protocols designed by HHMI, but receive minimal instructions from the instructor regarding the use of lab equipment and the procedures. If anything does not work in their project, students are expected to figure out what went wrong by themselves and plan future steps accordingly. Students usually work with partners unless they prefer to work individually and they work at their own pace throughout the semester. The SEA-PHAGES project is distributed across two semesters, the first of which being the wet lab and second, the genomics lab. Data for my investigation were collected from the first semester of this course series. During the first semester, in the wet lab, students isolate and characterize bacteriophages from the environment. After isolation, students use aseptic microbiological techniques provided in their laboratory manual to purify the phages. The genomes of these purified phages are then sequenced from a facility. In the
genomics lab in the second semester, students work to annotate the sequenced genome from the previous semester using different bioinformatics software like Phamerator and DNA Master. At the end, students are provided with an opportunity to name their own phages before the sequenced genomes are submitted to the HHMI database which is accessible by the public. This new information of sequenced genomes is thought to be beneficial to other scientists for applications in various fields. For example, a modern approach to treat bacterial infections is phage therapy, where scientists look for phages to kill specific antibiotic-resistant bacteria. The HHMI database may serve as a rich resource for such phage therapists. Students in both the authentic courses document their progress in a lab notebook throughout the semester. Thus, the entire course is designed to provide students with an authentic research-based experience of science. A snapshot of the SEA-PHAGES project can be found in Appendix A.

The traditional-reflexive laboratory course covered similar biology content about bacteriophages but did not involve any real research experience. Students in this lab had to follow a protocol set by the instructor and obtained expected results at the end of the day. However, students in this course were engaged in reflexive practices. Students were asked to respond to weekly reflection prompts throughout the semester. A set of same reflections prompts were provided to students each week and students had to respond to all of them. The weekly reflections in this course were paper-based due to limited use of a learning management system in the course. Students submitted a hard copy of their responses in lab every week. A snapshot of the course description can be found in Appendix B.
**Quasi-Experimental Design Groups.** I designated the participants of my study from the three laboratory courses as three treatment groups (Table 3.1). Treatment Group I, authentic-reflexive, where students were enrolled in an authentic research-based laboratory course and responded to weekly reflection prompts throughout the semester; Treatment Group II, authentic-non-reflexive, where students were enrolled in an authentic research-based laboratory course but did not respond to any reflection prompts; and Treatment Group III, traditional-reflexive, where students were enrolled in a traditional laboratory course and responded to weekly reflection prompts throughout the semester.

**Target population**

Participants in this study included all students enrolled in the above mentioned courses in Fall 2014 (Table 3.3). The students enrolled in these courses came from different science and engineering majors and from varied racial and ethnic backgrounds.

**Table 3.3**

**Demographics of students in three different courses in Fall 2014**

<table>
<thead>
<tr>
<th></th>
<th>University A (authentic-reflexive)</th>
<th>University B (authentic-non-reflexive)</th>
<th>University C (traditional-reflexive)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=46)</td>
<td>(n=23)</td>
<td>(n=17)</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>50%</td>
<td>26.08%</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>50%</td>
<td>73.9%</td>
</tr>
<tr>
<td>Race</td>
<td>Caucasian</td>
<td>73.9%</td>
<td>95.6%</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>2.1%</td>
<td>4.3%</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>21.7%</td>
<td>0%</td>
</tr>
<tr>
<td>Grade level</td>
<td>Freshman</td>
<td>0%</td>
<td>86.9%</td>
</tr>
<tr>
<td></td>
<td>Sophomore</td>
<td>39.1%</td>
<td>4.3%</td>
</tr>
<tr>
<td></td>
<td>Junior</td>
<td>28.2%</td>
<td>8.69%</td>
</tr>
<tr>
<td></td>
<td>Senior</td>
<td>32.6%</td>
<td>0%</td>
</tr>
</tbody>
</table>
The distribution of grade level of students also varied between the institutions. The table shows a detailed description of demographics which helps to improve the transferability of my study.

Data Sources

The data sources of this study include pre/post interest and motivation questionnaires, a self-awareness questionnaire, students’ responses to reflection prompts, teaching assistants’ observations, students’ peer evaluations, and interviews or open-ended questionnaires. All data are securely stored in a locked cabinet or as password protected files and no identifiers have been or will be used in dissemination as in accordance with the Institutional Review Board (IRB) (Appendix C).

Semi-structured Interviews/ Open-ended questionnaire. Students were interviewed at the end of each semester with a semi-structured interview protocol to determine the identity of students and their overall views about engaging in self-reflections (Appendix D). I prepared the semi-structured interview protocol using an interview guide approach where the questions were pre-determined but the order of the questions depended upon the flow of the interview and I prompted students during the interviews as needed (Patton, 2002). I also audio recorded these interviews for transcription and future analyses, and they lasted approximately 30 – 45 minutes. I provided the students with an option to complete an open-ended questionnaire in case they did not prefer to be interviewed. The questions on the open-ended questionnaire included the same questions asked during interviews. I administered the open-ended questionnaire during the last week of the classes in parallel to my interview schedule.
Interest Questionnaire. I administered the Student Interest in Technology and Science (SITS) questionnaire (Romine et al., 2013) at the beginning and end of the semester. I used students’ responses on this questionnaire to assess change in interest of students in all three treatment groups. Romine et al. (2013) used an exploratory factor analysis of the SITS questionnaire to establish five factors each consisting of five items which are labelled as: F1, interest in learning science (Item numbers 1, 2, 4, 6, 8); F2, interest in using technology (Item numbers 3, 5, 7, 9, 10); F3, interest in science careers (Item numbers 13, 15, 16, 19, 20); F4, interest in technology careers (Item numbers 11, 12, 14, 17, 18); and F5, attitude towards biotechnology (Item numbers 21, 22, 23, 24, 25). Romine et al. (2013) also established the face validity and content validity with the help of 16 experts from various fields. They also evaluated the structural validity of the questionnaire using the CFA panel model and revealed an RMSEA of 0.037 indicating that the questionnaire has a well-defined structure and unidimensionality. In addition to that, reliability measure of the questionnaire had Chronbach’s alpha of above 0.8 for the 25 item questionnaire.

The 25 item SITS questionnaire is rated on a four option scale ranging from ‘strongly disagree’ to ‘strongly agree’ to determine students’ interest in science and technology (Appendix E). For statistical analysis, I coded ‘strongly disagree’ as 1 and ‘strongly agree’ as 4. For my study, I focused on factors F1, F3, and F5 because interest in using technology (F2) and interest in technology career (F4) were not relevant to my study. I used the change in students’ pre and post scores to assess change in interest at the end of the course.
Motivation Questionnaire. I administered the Biology Motivation Questionnaire (BMQ) (Glynn et al., 2011) as pre and post at the beginning and end of the semester respectively. I used the BMQ questionnaire to assess change in motivation of students in all three treatment groups. Exploratory factor analysis of this questionnaire by Glynn et al. (2011) revealed five factors each consisting of five items labelled as: F1, intrinsic motivation (Item numbers 1, 3, 12, 17, 19); F2, career motivation (Item numbers 7, 10, 13, 23, 25); F3, self-determination (Item numbers 5, 6, 11, 16, 22); F4, self-efficacy (Item numbers 9, 14, 15, 18, 21); and F5, grade motivation (Item numbers 2, 4, 8, 20, 24). Glynn, Taasoobshirazi, and Brickman (2007, 2009) reported the questionnaire to have good content and criterion-related validity. To evaluate the construct validity of the questionnaire, authors (Glynn et al., 2011) used confirmatory factor analysis and revealed that all the items in the questionnaire met the loading criteria of at least 0.35 on their respective factor and had a Chronbach’s alpha of 0.92.

The 25 item BMQ questionnaire is rated on a four option scale ranging from ‘never’ to ‘always’ to determine students’ motivation to learn science in college (Appendix F). For statistical analysis, I coded ‘never’ as 0 and ‘always’ as 4. For my study, I focused on factors F1, F2, F3, and F4 because grade motivation (F5) was not relevant to my study. I used the change in students’ pre and post scores to assess their change in motivation at the end of the course.

Self-Awareness Questionnaire. I administered the Self-Reflection and Insight Scale (SRIS) questionnaire (Grant, Franklin, & Langford, 2002) to assess students’ self-awareness, a component of reflexivity, at the end of the semester in authentic-reflexive learning environment. Exploratory factor analysis of this questionnaire by the authors
(Grant et al., 2002) revealed a two-factor scale labelled as: F1, self-reflection (SR) scale, which was further subdivided into ‘engagement in self-reflection’ and ‘need for self-reflection’ consisting a total of 12 items (Item numbers 1, 2, 5, 7, 8, 10, 12, 13, 15, 16, 18, 19); F2, insight (IN) scale, consisting of eight items (Item numbers 3, 4, 6, 9, 11, 14, 17, 20). While evaluating the test-retest reliability, Grant et al. (2002) reported a test-retest correlation of .77 ($p < 0.001$) and .78 ($p < 0.001$) for SR and IN scales respectively and established the content validity of this questionnaire with the help of three content experts. Both SR and IN scales have good internal consistency with Cronbach alpha values ranging from 0.71 to 0.91 and 0.82 to 0.87 respectively (Grant et al., 2002). Roberts and Stark (2008) reported the factorial and construct validity of this questionnaire. Factorial validity analysis by Roberts and Stark (2008) showed that all items of the questionnaire loaded significantly on the expected factors, indicating a good fit. Internal reliability of each subscale was reported to be $> 0.8$. Construct validity analysis of this questionnaire reported a strong correlation between the need for reflection and engagement in reflection within the SR scale ($r = 0.77$). IN scale was related to the need for reflection ($r = 0.22$) but not to the process of engaging in reflection ($r = 0.06$).

The 20 item SRIS questionnaire is rated on a six option scale ranging from ‘disagree strongly’ to ‘agree strongly’ to determine students’ knowledge about themselves (Appendix G). For statistical analysis, I coded ‘disagree strongly’ as 1 and ‘agree strongly’ as 6. After entering the data into SPSS, I reverse coded students’ responses to the nine negatively worded questions. I then computed the total score of each participant in order to categorize them as having ‘low awareness’ or ‘high awareness.’
Reflection Prompts. I asked students to respond to weekly reflection prompts/questions (Appendix H). Because all students are not capable of reflecting or willing to reflect on their own, the use of reflective prompts helps to externalize their mental activities, thus facilitating the process of reflection (Scardamalia & Bereiter, 1985). The reflective prompts were based on the Mezirow’s (1991) transformative learning theory which provides a template to engage individuals in self-reflection. It includes cognitive (content), conative (process), and emotional (assumptions) components. The reflection of students on these three components about their actions helps them think critically as a scientist (Gilardi & Lozza, 2009). I gave a set of reflection prompts to students every week except the weeks in which classes did not meet, or when a test was scheduled, either online (in authentic-reflexive environment) or in paper (in traditional-reflexive environment) based on the convenience of the instructors. Students were required to respond to all the prompts every week and their responses were analyzed to determine their inquiry attitude, a component of reflexivity.

Teaching Assistants’ Observations. I asked the teaching assistants assigned for the course (authentic-reflexive) to observe students in the lab on how they interact and communicate with their partners and note his/her observations. I provided them with an observation rubric to help them with the process (Appendix I). I used these observations to evaluate students’ ability to work and communicate with their partners which is an element of reflexivity. There were total nine Yes/No items in the rubric. I then computed the total score of each student in order to categorize them as having ‘low collaborative attitude’ or ‘high collaborative attitude.’
Students’ Peer Evaluations. I asked the students to evaluate their partners at the end of the semester to understand how they thought they worked as a group. I provided them with a peer evaluation rubric to guide them through the process (Appendix J). I used this data as a secondary source to support the findings from the teaching assistants’ observations. There are 12 items in the rubric rated on a four option scale ranging from ‘strongly disagree’ to ‘strongly agree.’ For statistical analysis, I coded ‘strongly disagree’ as 1 and ‘strongly agree’ as 4. I then computed the total score of each participant in order to categorize them as having ‘low collaborative attitude’ or ‘high collaborative attitude.’

Data Collection Timeline

I collected data from students enrolled in three courses at the three institutions in Fall 2014 with the help of the instructors (Table 3.4). I took consent from all students prior to any data collection (Appendix K). During week 1, I administered the interest (SITS) and motivation (BMQ) questionnaires in all three courses as a pre-assessment of their level of interest and motivation. I administered the SITS and BMQ questionnaires again during week 12 as a post-assessment of students’ level of interest and motivation. I asked the students in authentic-reflexive environment (University A) and students in traditional-reflexive environment (University C) to respond to reflection prompts every week throughout the semester online and on paper respectively to engage them in reflexive practices. I conducted semi-structured interviews with students during week 10 and week 11. I asked the students who did not prefer to be interviewed to complete an open-ended questionnaire that included the same questions as in the interviews during week 12. Also, during week 12, I administered the self-awareness questionnaire (SRIS) to determine students’ level of self-awareness in the authentic-reflexive learning
environment. Likewise in week 12, I asked the teaching assistants in the authentic-reflexive course to make observations about students’ interactions with their partners within the laboratory. I also asked the students in the authentic-reflexive course to evaluate their peers during week 12.

Table 3.4

_Data Collection Timeline_

<table>
<thead>
<tr>
<th>Fall 2014</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Administer interest questionnaire (SITS)</td>
<td>Week 1(Pre), Week 12 (Post)</td>
</tr>
<tr>
<td>Administer motivation questionnaire (BMQ)</td>
<td>Week 1(Pre), Week 12 (Post)</td>
</tr>
<tr>
<td>Students asked to respond to reflection prompts</td>
<td>Week 1 – Week 12</td>
</tr>
<tr>
<td>Conduct semi-structured interviews</td>
<td>Week 10, Week 11</td>
</tr>
<tr>
<td>Administer self-awareness questionnaire (SRIS)</td>
<td>Week 12</td>
</tr>
<tr>
<td>Students asked to evaluate their peers</td>
<td>Week 12</td>
</tr>
<tr>
<td>Teaching assistants observed students</td>
<td>Week 12</td>
</tr>
<tr>
<td>Administer open-ended questionnaire to students not interviewed</td>
<td>Week 12</td>
</tr>
</tbody>
</table>

_Researcher Qualifications_

I received a Bachelor’s degree in Science Education and a Master’s degree in Zoology. I am currently working on my Ph.D. in Biological Sciences. As a part of my doctoral program, I have participated in three different research projects, namely, 1) Student Outcomes from Participating in an International STEM Service-Learning Course (Mishra & Daniel, under review) 2) Getting Students OUTSIDE: Using Technology as a Way to Stimulate Engagement (Boyce, Mishra, Halverson, & Thomas, 2014); and 3). Student Identities in Authentic Undergraduate Research Experience Laboratory Courses (Mraz et al., under review). In all these projects, I have helped with data collection, data
analysis, review of literature, and writing of findings. Also, as a part of my Ph.D. coursework, I have taken several courses that include biology content, research methodology courses in education, and courses in statistics to enrich my content knowledge and to learn the techniques of doing research. All these experiences as a part of my doctoral program made me qualified to collect and analyze data to investigate how reflexive practices in an authentic laboratory course influence the development of students’ scientific identity, their science and science-related career interest and motivation.

Trustworthiness and Ethical Considerations

Like any good qualitative investigation, I have taken certain steps to enhance the rigor of my study by ensuring its trustworthiness. For this, I tried to ensure credibility, transferability, dependability and confirmability in my findings, the four essential criteria outlined by Lincoln and Guba (1985) to establish trustworthiness. Data sources in my study included pre/post interest and motivation questionnaires, a self-awareness questionnaire, students’ responses to reflection prompts, teaching assistants’ observations, students’ peer evaluations, and interviews or open-ended questionnaires. Using these multiple data sources for data triangulation, I enhanced the credibility of my study (Patton, 2002). For example, I analyzed teaching assistants’ observations and students’ peer evaluations to determine how students actually interact with their partners and see if the findings from the two different data sources are consistent. Moreover, during data analysis, I asked two of my colleagues to analyze at least a part of my data individually for inter-rater reliability and to further improve the credibility and dependability of my study (Patton, 2002). I observed a 100% interrater-reliability without any discrepancies for the data analyzed individually by the three researchers.
To ensure transferability of my findings, I provided rich descriptions of my findings supported by enough evidence. I have also used a purposeful sampling to select my participants from three different learning environments for this study to further enhance transferability (Patton, 2002). I listed any limitations involved with the study to improve the trustworthiness of my findings.

To ensure confirmability, I verified with my faculty advisor, Dr. Kristy Daniel, at regular intervals to ensure that I was coding appropriately without involving any personal bias. In the end, I compared my results to the findings of similar studies and addressed how my findings filled the gap in the literature which adds to the confirmability of my research (Patton, 2002).

In addition to all the above steps taken to maintain the quality of my study, I worked with my advisor and my committee members to make sure I am using proper methods in collecting, analyzing, and interpreting data to further improve the dependability and confirmability of my study.
CHAPTER IV
ANALYSIS OF DATA

I have organized this section in the order of my research questions. I have provided a detailed description of the quantitative and qualitative analyses for each research question and the subsequent results. Among the total pool of participants, two students from University B and four students from University C did not complete either a part of a questionnaire or did not volunteer to be interviewed. I did not consider the partial data from these students for analysis. Therefore, the final participant list included a total of 86 students (Table 4.1).

Table 4.1

*Participant counts by quasi-experimental design groups*

<table>
<thead>
<tr>
<th>University A (authentic-reflexive)</th>
<th>University B (authentic-non-reflexive)</th>
<th>University C (traditional-reflexive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 46</td>
<td>n = 23</td>
<td>n = 17</td>
</tr>
<tr>
<td>• Authentic laboratory environment</td>
<td>• Authentic laboratory environment</td>
<td>• Traditional laboratory environment</td>
</tr>
<tr>
<td>• Reflexive practices</td>
<td>• No reflexive practices</td>
<td>• Reflexive practices</td>
</tr>
</tbody>
</table>

Research Question 1

What are the differences in students’ identities, interest, and motivation in relation to different learning environments (authentic–reflexive, authentic–non-reflexive and traditional–reflexive)?
I divided this research question into three sections for the ease of analysis.

Section 1. Aims to Analyze the Differences in Students’ Identities in Three Different Learning Environments

To determine students’ identities, I used semi-structured interviews with students/open ended questionnaire in three different learning environments (authentic-reflexive, authentic-non-reflexive and traditional-reflexive). I transcribed students’ responses to the interview questions which were relevant to this research question and then coded them manually using a deductive approach to coding (Patton, 2002). I coded the relevant student responses on the open ended questionnaire using the same approach. The coding was based on a rubric developed from a study by Mraz et al. (under review) (Appendix L). The three main categories of students’ identities in a college science laboratory course identified in the rubric are: ‘scientific’ identity, ‘student’ identity, and ‘detached’ identity.

After determining the identities for all the participants, I coded students with a scientific identity as 1, with student identity as 2, and with detached identity as 3. Likewise, I coded three different learning environments as 1, 2, & 3 respectively for analysis. Following that, I performed a Chi-square test of independence of students’ identities between three learning environments. There was a significant association between the students’ identities and the learning environments, $\chi^2 (4) = 12.37, p = 0.01$.

Figure 4.1 shows the distribution of students’ identities across three different learning environments. Students in authentic-reflexive environment had a greater percentage of scientific identity (71.7%) compared to authentic-non-reflexive (65.2%) and traditional-reflexive (23.5%) environments. The standardized residual for scientific
identity was significantly lower for the students in traditional-laboratory environment ($z = -2.0$). Therefore, percentage of students demonstrating a scientific identity increases as the authenticity of the learning environment increases. Students in traditional-reflexive environment had a greater percentage of student identity (58.8%) compared to authentic-non-reflexive (26.1%) and authentic-reflexive (21.7%) environments. The standardized residual was significantly higher for the students in traditional-laboratory environment ($z = 2.1$). Therefore, percentage of students demonstrating a student identity decreases as the authenticity of the learning environment increases.

![Figure 4.1. Distribution of identities of students across learning environments.](image)

In the section below, I provide a detailed description of the identities of students with evidences that were used to determine their identities.

Scientific Identity. I included a student in this category if he/she acted and behaved like a scientist. Students in this category were able to solve problems on their own, had a sense of ownership over the project, could view the real world contribution of
their work, and who could work in a collaborative environment with their partner. For example, Aaron, from the authentic-reflexive course stated, “It doesn’t feel like other school courses at all. It is something about doing. It is teaching me lots of methods and techniques that I could use. In other lab courses, it is all set and we pretty much know what we are going to get, but here you have to figure out a lot on your own. Overall, the course helped me realize that I do like research and may pursue in future.” Similarly, Audrey, from the authentic-non-reflexive course stated, “…it is lot more work in this lab. You always do not get the solution in the lab manual, you have to actually think and find the best solution, but it is definitely worth it…I think coordination with my partner really worked well. You cannot always know everything. You always need that other person who looks at things differently and gives you feedback.” So it is evident that these students demonstrate a scientific identity because they did not mind working extensively on their own to handle their project and also exhibited a collaborative scientist-like attitude.

**Student Identity.** In this category, I included students who stated that they took the course just because it was required or were motivated to get a good grade. These students clearly did not view themselves as a scientist. For example, Kyle, from the authentic-reflexive course stated, “It is a lot more work. I took this class just because I needed the credit hours. It was lot about failures. You would expect something to happen and then you would get something completely different.… In this case, I liked to work with a partner because she was a Biology major, so she knew a lot. But if I had known, I don’t know how much I would appreciate that.” Similarly, Parker, from the traditional-reflexive course stated, “This was one of the required courses for my major. I had taken
similar labs before but this was about virus… Some of the techniques were new in this lab whereas most of them were common to the microbiology lab I took last semester. But the exams were little easier than the other one.” So, it is clearly evident that these students exhibited a student like identity as they took this course primarily because it was required, or for credits and did not seem to be willing to work hard in the lab.

*Detached Identity.* In this category, I included students who participated in the course without actually valuing the course experience or connecting the course experience to their personal interests and remained uninterested about everything. For example, Katelyn, from the authentic-non-reflexive course stated, “...I could never clearly understand the big picture that the TA and the instructor always talked about. Whenever we had an issue, we had to first try to figure out on our own but I did not like that aspect. I have never worked with phages before nor am I going to work in future (plans to be a physician’s assistant), so just why. It took away so much of my time. It was way more work.” Similarly, Ryan, from the traditional-reflexive course stated, “This is my last lab course ever. I have realized that I do not work very well in labs. I am probably not a lab person…I don’t want to go into research definitely in future. Planning to take some non-research jobs.” So, it is clearly evident that these students demonstrate a detached identity because they did not seem to be interested at all either in the course content or in the lab environment.

Section 2. Aims to Analyze the Differences in Students’ Interest in Three Different Learning Environments

The three factors in the interest questionnaire that I considered for this study consisted of five items each and were labelled as: F1, Interest in learning science; F3,
Interest in science careers; and F5, Attitude towards biotechnology. For each student, I summed scores for the items in each factor for both pre (Σ_{pre}) and post (Σ_{post}) assessments. Following that, I calculated change in students’ scores by subtracting the ‘pre’ score from the ‘post’ score. For example, I derived students’ change (Δ) in interest in learning science (F1) as follows:

$$\Delta_{F1} = \Sigma_{F1\text{-post}} - \Sigma_{F1\text{-pre}}$$

Similarly, I calculated students’ change in interest in science careers (F3) and attitude towards biotechnology (F5). I also calculated an overall change in interest combining all the above three factors as follows:

Overall change in interest ($\Delta_{\text{overall}}$) = $\Delta_{F1} + \Delta_{F3} + \Delta_{F5}$

I ran a one-way ANOVA comparing students’ change in interest, both overall and factor-wise, between different learning environments. I assigned statistical significance when $p \leq 0.05$. The ANOVA that compared overall students’ change in interest across three learning environments revealed a significant difference in students’ interest [F (2, 83) = 7.197, $p = 0.001$] between authentic-reflexive ($M = 3.26$, $SD = 4.09$), authentic-non-reflexive ($M = 1.91$, $SD = 6.97$), and traditional-reflexive ($M = -2.47$, $SD = 5.74$). This result indicates that students’ overall interest changed significantly with the change in the learning environment. Table 4.2 shows a Tukey’s pairwise comparison of students’ change in interest between the three learning environments. There were significant differences between authentic-reflexive and traditional-reflexive ($p = 0.001$) with the authentic-reflexive having a higher mean, and between authentic-non-reflexive and traditional-reflexive environments ($p = 0.03$) with the authentic-non-reflexive having a
higher mean. These results indicate that students’ overall interest increased significantly as the authenticity of the learning environment increased.

Table 4.2

Tukey’s post-hoc pairwise comparison table of students’ overall change in interest between learning environments

<table>
<thead>
<tr>
<th>Learning environment (I)</th>
<th>Learning environment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authentic-Reflexive</td>
<td>Authentic-Non-reflexive</td>
<td>1.347</td>
<td>1.360</td>
<td>0.58</td>
<td>0.235</td>
</tr>
<tr>
<td>Authentic-Reflexive</td>
<td>Traditional-Reflexive</td>
<td>5.731*</td>
<td>1.511</td>
<td>0.001</td>
<td>1.148</td>
</tr>
<tr>
<td>Authentic-Non-reflexive</td>
<td>Traditional-Reflexive</td>
<td>4.383*</td>
<td>1.703</td>
<td>0.03</td>
<td>0.685</td>
</tr>
</tbody>
</table>

* Indicates significant differences

Table 4.3 shows a factor wise comparison of students’ change in interest across different learning environments using one-way ANOVA. I found significant difference in students’ change in interest in learning science [$F (2, 83) = 3.101, p = 0.05$] between authentic-reflexive ($M = 1.08, SD = 2.04$), authentic-non-reflexive ($M = 1.13, SD = 3.60$), and traditional-reflexive ($M = -0.82, SD = 3.55$). This result indicates that students’ interest in learning science changed significantly with the change in the learning environment. I also found significant difference in students’ change in interest in science careers [$F (2, 83) = 3.708, p = 0.02$] between authentic-reflexive ($M = 1.26, SD = 2.29$), authentic-non-reflexive ($M = 0.78, SD = 4.35$), and traditional-reflexive ($M = -1.05, SD = 2.46$). This result indicates that students’ interest in science careers changed significantly with the change in the learning environment. However, there was no significant difference in students’ attitude towards biotechnology [$F (2, 83) = 2.164, p = 0.12$] between authentic-reflexive ($M = 0.91, SD = 2.42$), authentic-non-reflexive ($M = 0.00,
$SD = 3.04$), and traditional-reflexive $(M = -0.58, SD = 2.76)$. Therefore, students’ attitude towards biotechnology did not change significantly with the change in the learning environment.

Table 4.3

*One-way ANOVA comparing students’ interest across learning environments*

<table>
<thead>
<tr>
<th>Students’ Interest</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest in learning science (F1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>50.571</td>
<td>2</td>
<td>25.285</td>
<td>3.101</td>
<td>0.05*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>676.731</td>
<td>83</td>
<td>8.153</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>727.302</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in science careers (F3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>67.160</td>
<td>2</td>
<td>33.580</td>
<td>3.708</td>
<td>0.02*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>751.724</td>
<td>83</td>
<td>9.057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>818.884</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude towards biotechnology (F5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>32.323</td>
<td>2</td>
<td>16.162</td>
<td>2.164</td>
<td>0.12</td>
</tr>
<tr>
<td>Within Groups</td>
<td>619.770</td>
<td>83</td>
<td>7.467</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>652.093</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant differences

I performed Tukey’s pairwise comparison for the factors that showed significant differences (Table 4.4). For interest in learning science, I observed significant difference between authentic-reflexive and traditional-reflexive ($p = 0.05$) with the authentic-reflexive having a higher mean. This result indicates that students’ interest in learning science increased significantly as the authenticity of the learning environment increased.

For interest in science careers, I observed significant differences between authentic-reflexive and traditional-reflexive ($p = 0.02$), with the authentic-reflexive having a higher mean and between authentic-non-reflexive and traditional-reflexive ($p = 0.04$) with the authentic-non-reflexive having a higher mean. These results indicate that students’ interest in science careers also increased significantly as the authenticity of the learning environment increased.
Table 4.4

**Tukey’s post-hoc pairwise comparison table of students’ change in interest between learning environments**

<table>
<thead>
<tr>
<th>Interest in learning science (F1)</th>
<th>Learning environment (I)</th>
<th>Learning environment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authentic-Reflexive</td>
<td>Authentic-Reflexive</td>
<td>-0.043</td>
<td>0.729</td>
<td>0.99</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Authentic-Reflexive</td>
<td>Traditional-Reflexive</td>
<td>1.910*</td>
<td>0.810</td>
<td>0.05</td>
<td>0.545</td>
<td></td>
</tr>
<tr>
<td>Authentic-Non-reflexive</td>
<td>Traditional-Reflexive</td>
<td>1.954</td>
<td>0.913</td>
<td>0.08</td>
<td>0.659</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interest in science careers (F3)</th>
<th>Learning environment (I)</th>
<th>Learning environment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authentic-Reflexive</td>
<td>Authentic-Reflexive</td>
<td>0.478</td>
<td>0.769</td>
<td>0.80</td>
<td>0.137</td>
<td></td>
</tr>
<tr>
<td>Authentic-Reflexive</td>
<td>Traditional-Reflexive</td>
<td>2.319*</td>
<td>0.854</td>
<td>0.02</td>
<td>0.975</td>
<td></td>
</tr>
<tr>
<td>Authentic-Non-reflexive</td>
<td>Traditional-Reflexive</td>
<td>1.941*</td>
<td>0.963</td>
<td>0.04</td>
<td>0.520</td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant differences

Section 3. Aims to Analyze the Differences in Students’ Motivation in Three Different Learning Environments

The four factors in the motivation questionnaire that I considered for this study consisted of five items each and were labelled as: F1, Intrinsic motivation; F2, Career Motivation; F3, Self-determination; and F4, Self-efficacy. For each student, I summed scores for the items in each factor for both pre (Σ_pre) and post (Σ_post) assessments.

Following that, I calculated the change in their scores by subtracting the ‘pre’ score from the ‘post’ score.

For example, I calculated students’ change (Δ) in intrinsic motivation (F1) as follows:

\[ Δ_{F1} = Σ_{F1-post} - Σ_{F1-pre} \]
Similarly, I calculated students’ change in career motivation (F2), change in self-determination (F3), and change in self-efficacy (F4). I also calculated an overall change in motivation combining all the above three factors as follows:

\[
\Delta_{\text{overall}} = \Delta_{F1} + \Delta_{F2} + \Delta_{F3} + \Delta_{F4}
\]

I ran one-way ANOVA comparing students change in motivation, both overall and factor-wise between different learning environments. I assigned statistical significance when \( p \leq 0.05 \). The ANOVA that compared overall students’ change in motivation across three learning environments revealed no significant difference in students’ motivation \([F (2, 83) = 2.492, p = 0.08]\) between authentic-reflexive \((M = 5.11, SD = 7.76)\), authentic-non-reflexive \((M = 2.95, SD = 8.24)\), and traditional-reflexive \((M = 0.23, SD = 7.49)\) learning environments. This result indicates that students’ overall motivation did not change significantly with the change in the learning environment.

Table 4.5 shows a factor wise comparison of students’ change in motivation across different learning environments using one-way ANOVA. I found significant difference in students’ change in career motivation \([F (2, 83) = 4.61, p = 0.01]\) between authentic-reflexive \((M = 0.97, SD = 2.38)\), authentic-non-reflexive \((M = 0.82, SD = 2.30)\), and traditional-reflexive \((M = -1.05, SD = 2.65)\) learning environments. This result indicates that students’ career motivation changed significantly with the change in the learning environment. I also found significant differences in students’ change in self-efficacy \([F (2, 83) = 4.88, p = 0.01]\) between authentic-reflexive \((M = 1.89, SD = 2.93)\), authentic-non-reflexive \((M = -0.21, SD = 3.50)\), and traditional-reflexive \((M = -2.94, SD = 3.33)\) learning environments. This result indicates that students’ self-efficacy changed significantly with the change in the learning environment. However, there were no
significant differences in students’ intrinsic motivation $[F (2, 83) = 0.140, p = 0.87]$ between authentic-reflexive ($M = 1.30$, $SD = 2.87$), authentic-non-reflexive ($M = 1.34$, $SD = 3.65$), and traditional-reflexive ($M = 0.88$, $SD = 2.68$) learning environments. This result indicates that students’ intrinsic motivation did not change significantly with the change in the learning environment. Likewise, I did not find any significant differences in students’ self-determination $[F (2, 83) = 0.043, p = 0.95]$ between authentic-reflexive ($M = 0.93$, $SD = 3.08$), authentic-non-reflexive ($M = 1.00$, $SD = 2.76$), and traditional-reflexive ($M = 0.70$, $SD = 4.32$) learning environments. This result indicates that students’ self-determination did not change significantly with the change in the learning environment.

Table 4.5

*One-way ANOVA comparing students’ motivation across learning environments*

<table>
<thead>
<tr>
<th>Students’ Motivation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic motivation (F1)</td>
<td>Between Groups</td>
<td>2</td>
<td>1.314</td>
<td>0.140</td>
<td>0.870</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>83</td>
<td>9.406</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Career motivation (F2)</td>
<td>Between Groups</td>
<td>2</td>
<td>27.086</td>
<td>4.614</td>
<td>0.013*</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>83</td>
<td>5.870</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self –determination (F3)</td>
<td>Between Groups</td>
<td>2</td>
<td>0.461</td>
<td>0.043</td>
<td>0.958</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>83</td>
<td>10.799</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self – efficacy (F4)</td>
<td>Between Groups</td>
<td>2</td>
<td>49.080</td>
<td>4.885</td>
<td>0.010*</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>83</td>
<td>10.047</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant differences

I performed Tukey’s pairwise comparison for the factors that showed significant differences (Table 4.6). For career motivation, I found significant differences between authentic-reflexive and traditional-reflexive ($p = 0.01$) with the authentic-reflexive having
a higher mean and between authentic-non-reflexive and traditional-reflexive ($p = 0.04$) with the authentic-non-reflexive having a higher mean.

### Table 4.6

*Tukey’s post-hoc pairwise comparison table of students’ change in motivation between learning environments*

<table>
<thead>
<tr>
<th>Learning environment (I)</th>
<th>Learning environment (J)</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Career motivation (F2)</td>
<td>Authentic-Reflexive</td>
<td>Authentic-Non-reflexive</td>
<td>0.152</td>
<td>0.619</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Authentc-Reflexive</td>
<td>Traditional-Reflexive</td>
<td>2.037</td>
<td>0.688</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Authentic-Non-reflexive</td>
<td>Traditional-Reflexive</td>
<td>1.885</td>
<td>0.775</td>
<td>0.04*</td>
</tr>
<tr>
<td>Self-efficacy (F4)</td>
<td>Authentic-Reflexive</td>
<td>Authentic-Non-reflexive</td>
<td>2.108</td>
<td>0.809</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>Authentic-Reflexive</td>
<td>Traditional-Reflexive</td>
<td>2.185</td>
<td>0.899</td>
<td>0.04*</td>
</tr>
<tr>
<td></td>
<td>Authentic-Non-reflexive</td>
<td>Traditional-Reflexive</td>
<td>0.077</td>
<td>1.014</td>
<td>0.99</td>
</tr>
</tbody>
</table>

* Indicates significant differences

These results indicate that students’ career motivation increased significantly as the authenticity of the learning environment increased. In case of self-efficacy, I observed significant difference between authentic-reflexive and traditional-reflexive ($p = 0.04$) with authentic-reflexive having a higher mean, indicating that students’ self-efficacy increased significantly as the authenticity of the learning environment increased. I also found a significant difference in students’ self-efficacy between authentic-reflexive and
authentic-non-reflexive ($p = 0.02$) with authentic-reflexive having a higher mean which indicates that students’ self-efficacy increased as they got engaged in reflexive practices.

**Research Question 2**

How do components of reflexivity relate to students’ identities in a laboratory course involving reflexive practices?

To answer this research question, I first analyzed the students’ reflexivity in the authentic-reflexive and traditional-reflexive learning environments. As mentioned before, there are three main components of reflexivity: awareness of one’s self; inquiry attitude; and ability to work with others and I have determined each of them individually as follows.

*Awareness of One’s Self*

To determine students’ awareness about themselves, I used the 20 item awareness questionnaire (SRIS) as data source. The questionnaire is rated on a six option scale ranging from ‘disagree strongly’ to ‘agree strongly.’ For statistical analysis, I coded from ‘disagree strongly’ as 1 to ‘agree strongly’ as 6. After entering the data into SPSS, I reverse coded students’ responses to the nine negatively worded questions. The total score of each participant on the questionnaire could range from a minimum of 20 to a maximum of 120. I grouped the students into two categories by dividing the range into two equal segments. I grouped the students who scored between 20 and 70 as having ‘low awareness’ and students who scored between 71 and 120 as having ‘high awareness’ in the authentic-reflexive and traditional-reflexive courses. This is based on a study by Romine et al. (2013) which reported that students who tend to pick low scoring options on a particular questionnaire like strongly disagree or disagree, are usually low on the construct that the questionnaires aims to measure. Similarly, students who tend to pick
high scoring options like agree or agree strongly, are usually high on that construct. Therefore, in this study, I categorized students who scored in the lower half as having low awareness and students who scored in the upper half as having high awareness.

**Inquiry Attitude**

To determine students’ inquiry attitude in the authentic-reflexive and traditional-reflexive courses, I analyzed their responses to the reflection prompts using the rubric designed by Kember et al. (2008) (Appendix M). I used deductive approach to code students’ reflections into one of the four categories identified in the rubric: No-reflection/Habitual Action; Understanding; Reflection; and Critical Reflection. I used students’ reflections from Week 1 through Week 12 as the data source. For each week, I coded individual students’ reflections and categorized them into one of the four above mentioned categories. After that, I determined a student’s overall reflection to be in a category that appeared in most weeks throughout the semester, calculated as statistical mode. For example, Anna’s reflections throughout the semester were categorized as follows:

| Week 1 – Understanding | Week 2 – Reflection | Week 3 – Understanding | Week 4 – Understanding | Week 5 – Understanding | Week 6 – Understanding | Week 7 – Reflection | Week 8 – Understanding | Week 9 – Did not turn in | Week 10 – Reflection | Week 11 – Understanding | Week 12 – Understanding |

As evident from the above example, Anna’s reflections fell in the ‘Understanding’ category in most number of weeks (8 out of 12). Therefore, I identified her overall reflections in the course to belong to the ‘Understanding’ category.

I have provided below a detailed description of the four categories with some examples of students’ reflections of each category. The ‘$n$’ number associated with each
category are the number of students’ reflections identified to belong to that particular category.

*No-reflection/Habitual Action* (n=2). In this category, I grouped students whose responses showed no evidence of them attempting to understand the concept or forming an individual opinion about it. For example, Evan in his reflections in week 9, in response to the question whether he thought what he did last week was research, stated, “Yes, we tested to see how a phage would react at room temperature.” Similarly, Michael in his reflections in week 5, in response to the question what he accomplished in the previous week, stated, “We were finally able to isolate a plaque.” So, these students did not seem to engage in reflections and rather just preferred to report their daily laboratory activities without any evidence of their understanding.

*Understanding* (n=20). In this category, I grouped students whose responses revealed understanding of the concept but were found to rely more on textbook information rather than relating to their personal experiences. For example, Sydney in her reflections in week 6, in response to the question what she accomplished in the previous week, stated, “This past week we continued to streak plates to isolate our phage. With one more streak we should be ready for serial dilutions.” Similarly, Joshua in his reflections in week 3, in response to the question where they are compared to the overall goal for the project and if they are ahead or behind their schedule, stated, “So far we have been iterating the process described in the lab notebook entries in order to isolate a phage. We have seen some possible phage, so we are going to continue the process in order to purify it. We are on schedule.” Therefore, it is clearly evident from these responses that
students relied more on textbook information and did not attempt to relate to their personal insights.

**Reflection (n=24).** In this category, I grouped students whose responses revealed their personal insights about the context and who attempted to relate their personal experiences to the textbook knowledge. For example, Joanne in her reflections in week 9, in response to the question what she accomplished in the previous week, stated, “On Tuesday this week we analyzed our results from the empirical test. There seemed to be contamination on many of the plates and some of the plaques weren’t looking like our original plaques that we isolated. The contamination from the plaques could be from many different things, included contaminated agar, contaminated MTL, or contaminated phage buffer. The different plaque morphology could have been caused by plaque contamination. To try and determine the source of error, we did the phage-titer assay again using a plaque from our last streak plate, and we filtered the MTL and did two of the plaques from the empirical test again (the ones that could have been web plates). We also changed our phage buffer and top agar. On Thursday we analyzed the results. The re-filtered MTL still yielded plaques with different morphologies than usual. The 100 plate from the phage titer assay turned out good, but there was not enough phage for a web plate, so we plated two new dishes with higher concentrations to see if that will give us a web plate.” Similarly, Eric, in his reflections in week 8, in response to the question whether he thought what he did last week was research, stated, “Yes, everything we do in this class is research. It is all a part of the greater research project, but the small steps that are contained within the research process tend not to feel like research—but it is. We are handling phages that are so diverse that their genetic code is unique. Nobody has studied
our particular phage before. Each one has different characteristics. Sometimes some experimentation in the lab is necessary in order to determine some of these traits. Sort of like research within research.” Therefore, it is clearly evident that these students not only relied on text book information but were also putting their own insights in their reflections.

*Critical Reflection (n=0).* Students’ whose responses revealed change in their perspective about a particular concept as a result of their personal experience were supposed to be grouped in this category. However, I did not find any student in this category in any of the courses.

I then divided students into two groups; one having ‘low inquiry attitude’ if their reflections were categorized as ‘No-reflection/Habitual Action’ or ‘Understanding’; and the other group having ‘High inquiry attitude’ if their responses were categorized as ‘Reflection’ or ‘Critical Reflection’ as suggested in the rubric by Kember et al. (2008).

*Ability to Work with Others (Collaborative attitude)*

I used two data sources for analyzing students’ collaborative attitude in the authentic-reflexive and traditional-reflexive courses. First, the teaching assistants’ observations, which I primarily used for the quantitative analysis; and second, the students’ peer evaluations which acted as a secondary source to add to the confirmability of the findings. I have reported if there were any discrepancy between the findings from the two data sources.

The total score of each student in the teaching assistants’ observations could range from 0 to 9 and I grouped them into two categories by dividing the range into two equal segments. I empirically grouped students who scored between 0 and 4 as having ‘low
collaborative attitude’ and the students who scored between 5 and 9 as having ‘high collaborative attitude.’ Similarly, the total score of each student in the students’ peer evaluations which could range from 12 to 48. I also empirically grouped them into two categories by dividing the range into two equal segments. I grouped the students who scored between 12 and 30 as having ‘low collaborative attitude’ and who scored between 31 and 48 as having ‘high collaborative attitude.’ Since the questionnaires included qualities of students with high collaborative attitude, I assumed that students possessing more of those qualities would have higher collaborative attitude than the students possessing only a few of them.

I found that the students who showed high collaborative attitude on teaching assistants’ observation, also showed high collaborative attitude in peer evaluations. Therefore, the data from the two sources were consistent for all students except in one case where I identified a student to have ‘low collaborative attitude’ from the teaching assistants’ observation but he revealed to have ‘high collaborative attitude’ in peer evaluation.

Reflexivity, being developmental in nature, it is unlikely for a student to have no reflexivity. Results indicate that 54.3% of students exhibited high self-awareness level, 52.2% of students exhibited high inquiry attitude, and 78.3% of students exhibited high collaborative attitude in the authentic-reflexive course (Figure 4.2). In the traditional-reflexive course 35.3% of students exhibited high self-awareness level, 58.8% of students exhibited high inquiry attitude, and 76.5% of students exhibited high collaborative attitude (Figure 4.3).
Figure 4.2. Frequency distribution of component-wise students’ level of reflexivity in an authentic-reflexive learning environment.

Figure 4.3. Frequency distribution of component-wise students’ level of reflexivity in a traditional-reflexive learning environment.
**Relationship between the components of reflexivity and students’ identities**

I identified students’ identities during the analysis of first research question. Figure 4.4 depicts the percentage of students possessing each type of identity in the authentic-reflexive and traditional-reflexive courses.

![Figure 4.4](image)

*Figure 4.4. Distribution of students’ identities in authentic-reflexive (A) and traditional-reflexive (B) learning environments.*

For statistical analysis, I coded students with ‘low awareness’ as 1 and with ‘high awareness’ as 2. Similarly, I coded students with ‘low inquiry’ as 1 and with ‘high inquiry’ as 2; students with ‘low collaborative attitude’ as 1 and with ‘high collaborative attitude’ as 2. I also coded students’ identities as 1, 2 and 3 for scientific, student and detached identities respectively.

Next, I performed a Chi-square test of independence of students’ identities between their levels of reflexivity. Table 4.7 shows the frequency distribution of students’ identities for low and high self-awareness level. Among the students who showed high self-awareness level, 39.7% of them had a scientific identity whereas among the students who showed low self-awareness level, only 19.0% showed scientific identity. There was a significant association between the students’ identities and their level of
awareness, $\chi^2(2) = 13.755, p = 0.001$. This result indicates that students are more likely to demonstrate a scientific identity when their level of self-awareness increases.

Table 4.7

*Cross tabulation analysis between students’ identities and their level of self-awareness*

<table>
<thead>
<tr>
<th>Component of reflexivity</th>
<th>Types of students’ identity</th>
<th>Total (N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scientific</td>
<td>Student</td>
</tr>
<tr>
<td>Awareness of one’s self</td>
<td>Low</td>
<td>19.0%</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>39.7%</td>
</tr>
</tbody>
</table>

Table 4.8 shows the frequency distribution of students’ identities for low and high level of inquiry attitude. Among the students who showed high inquiry attitude, 41.3% of them had a scientific identity whereas among the students who showed low inquiry attitude, only 17.5% showed scientific identity. There was a significant association between the students’ identities and their level of inquiry attitude, $\chi^2(2) = 10.215, p = 0.006$. This result indicates that students are more likely to demonstrate a scientific identity when they have high inquiry attitude.

Table 4.8

*Cross tabulation analysis between students’ identities and their level of inquiry attitude*

<table>
<thead>
<tr>
<th>Component of reflexivity</th>
<th>Types of students’ identity</th>
<th>Total (N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scientific</td>
<td>Student</td>
</tr>
<tr>
<td>Inquiry attitude</td>
<td>Low</td>
<td>17.5%</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>41.3%</td>
</tr>
</tbody>
</table>

Table 4.9 shows the frequency distribution of students’ identities for low and high level of collaborative attitude. Among the students who showed high collaborative attitude, 52.4% of them had a scientific identity whereas among the students who showed...
low collaborative attitude, only 6.3% showed scientific identity. There was a significant association between the students’ identities and their level of collaborative attitude, $\chi^2(2) = 15.84, p < 0.001$. This result indicates that students are more likely to demonstrate a scientific identity when they have high collaborative attitude.

Table 4.9

*Cross tabulation analysis between students’ identities and their level of collaborative attitude*

<table>
<thead>
<tr>
<th>Component of reflexivity</th>
<th>Types of students’ identity</th>
<th>Total (N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scientific</td>
<td>Student</td>
</tr>
<tr>
<td>Collaborative attitude</td>
<td>Low</td>
<td>6.3%</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>52.4%</td>
</tr>
</tbody>
</table>

Research Question 3

How do components of reflexivity relate to students’ interest in a laboratory course involving reflexive practices?

The three factors in the interest questionnaire that were considered for this study consisted of five items each and were labelled as: F1, Interest in learning science; F3, Interest in science careers; and F5, Attitude towards biotechnology. For this analysis, I summed students’ scores for the items in each factor for the post ($\Sigma_{\text{post}}$) assessment to determine students’ interest at the end of the course. Also, I calculated students’ overall interest as follows:

$$\Sigma_{\text{overall}} = \Sigma_{\text{F1-post}} + \Sigma_{\text{F3-post}} + \Sigma_{\text{F5-post}}$$

Then, to identify if there is any significant difference in interest between the students with high and low reflexivity, I performed independent sample t-tests. I assigned statistical significance when $p \leq 0.05$. I found a significant difference in students’ overall
interest \( t (61) = -2.338, p = 0.023 \) between students with low \((M = 49.71, SD = 6.41)\) and high \((M = 53.48, SD = 6.36)\) self-awareness level. However, I did not find significant difference in students’ overall interest \( t (61) = 0.054, p = 0.957 \) between students with low \((M = 51.62, SD = 7.07)\) and high \((M = 51.53, SD = 6.3)\) inquiry attitude. Likewise, I did not find any significant difference in students’ overall interest \( t (61) = 0.501, p = 0.618 \) between students with low \((M = 52.36, SD = 7.83)\) or high \((M = 51.35, SD = 6.29)\) collaborative attitude. These results indicate that students’ overall interest increases with the increase in their level of self-awareness, but not with their level of inquiry or collaborative attitude. Table 4.10 shows the results of independent sample t tests which I performed to determine the difference in interest (factor wise) between students with high or low reflexivity. Notably, I found significant difference in students’ interest in learning science \( t (61) = -2.628, p = 0.01 \) and interest in science careers \( t (61) = -1.886, p = 0.05 \) between students with low and high self-awareness. However, I did not find any significant difference in students’ attitude towards biotechnology between students with low and high self-awareness. I also found no significant difference in interest (factor wise) between students with low and high inquiry or collaborative attitude (Table 4.10). These results indicate that students tend to have higher interest in learning science and in science careers when their level of self-awareness increases. However, students’ attitude towards biotechnology is not influenced by their level of self-awareness. Also, students’ interest in learning science, in science careers, or their attitude towards biotechnology does not change with their level of inquiry or collaborative attitude.
Table 4.10

Independent sample t-tests to determine differences in interest (factor wise) of students’ having low or high reflexivity

<table>
<thead>
<tr>
<th>Factors of interest questionnaire</th>
<th>Low</th>
<th>High</th>
<th>95% CI of mean difference</th>
<th>t</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in learning science (F1)</td>
<td>16.31</td>
<td>3.04</td>
<td>32</td>
<td>-3.08</td>
<td>-0.41</td>
</tr>
<tr>
<td></td>
<td>18.06</td>
<td>2.16</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in science careers (F3)</td>
<td>15.75</td>
<td>3.28</td>
<td>32</td>
<td>-2.97</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>17.19</td>
<td>2.76</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude towards Biotechnology (F5)</td>
<td>17.65</td>
<td>2.28</td>
<td>32</td>
<td>-1.72</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>18.22</td>
<td>2.30</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inquiry attitude</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in learning science (F1)</td>
<td>17.07</td>
<td>3.31</td>
<td>29</td>
<td>-1.61</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>17.26</td>
<td>2.26</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in science careers (F3)</td>
<td>16.21</td>
<td>3.57</td>
<td>29</td>
<td>-2.04</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>16.67</td>
<td>2.67</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude towards Biotechnology (F5)</td>
<td>18.34</td>
<td>2.07</td>
<td>29</td>
<td>-0.39</td>
<td>1.91</td>
</tr>
<tr>
<td></td>
<td>17.58</td>
<td>2.44</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collaborative attitude</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in learning science (F1)</td>
<td>17.50</td>
<td>3.16</td>
<td>14</td>
<td>-1.26</td>
<td>2.11</td>
</tr>
<tr>
<td></td>
<td>17.08</td>
<td>2.67</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in science careers (F3)</td>
<td>16.29</td>
<td>3.83</td>
<td>14</td>
<td>-2.11</td>
<td>1.66</td>
</tr>
<tr>
<td></td>
<td>16.51</td>
<td>2.90</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude towards Biotechnology (F5)</td>
<td>18.57</td>
<td>2.06</td>
<td>14</td>
<td>-0.56</td>
<td>2.20</td>
</tr>
<tr>
<td></td>
<td>17.76</td>
<td>2.34</td>
<td>49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant differences ($p \leq 0.05$)
Research Question 4

How do components of reflexivity relate to students’ motivations in a laboratory course involving reflexive practices?

The four factors in the motivation questionnaire considered for this study consisted of five items each and were labelled as: F1, Intrinsic motivation; F2, Career motivation; F3, Self-determination; and F4, Self-efficacy. For this analysis, I summed students’ scores for the items in each factor for the post ($\Sigma_{\text{post}}$) assessment to determine students’ motivation at the end of the course. Also, I calculated the overall motivation of students as follows:

$$\Sigma_{\text{overall}} = \Sigma_{\text{F1-post}} + \Sigma_{\text{F2-post}} + \Sigma_{\text{F3-post}} + \Sigma_{\text{F4-post}}$$

Then, to identify if there is any significant difference in motivation between the students with high and low reflexivity, I performed independent sample $t$-tests. I assigned statistical significance when $p \leq 0.05$. When compared the students’ overall motivation with their self-awareness level, I found significant difference in students’ motivation [$t (61) = -2.833, p = 0.006$] between the students with low ($M = 62.84, SD = 11.03$) and high ($M = 69.94, SD = 8.66$) self-awareness level. However, I did not find any significant difference in overall motivation [$t (61) = -1.153, p = 0.25$] between students with low ($M = 64.69, SD = 11.53$) or high ($M = 67.74, SD = 9.45$) inquiry attitude. Likewise, I did not find any significant difference in overall motivation [$t (61) = -0.019, p = 0.98$] between students with low ($M = 66.29, SD = 13.47$) or high ($M = 66.35, SD = 9.63$) collaborative attitude. Therefore, these results indicate that students’ overall motivation increases with the increase in their level of self-awareness, but not with their level of inquiry or collaborative attitude.
Table 4.11 summarizes the results of independent sample t-tests which I used to
determine the difference of motivation (factor wise) between students with low and high
reflexivity. Notably, I found significant difference in students’ intrinsic motivation \([t (61)
= -1.880, p = 0.05]\), career motivation \([t (61) = -2.329, p = 0.02]\), self-determination \([t
(61) = -2.550, p = 0.01]\), and self-efficacy \([t (61) = -2.861, p = 0.006]\) between the
students with low and high self-awareness. However, I did not find any significant
difference in motivation (factor wise) between students with low and high inquiry or
collaborative attitude (Table 4.11). These results indicate that students tend to have
higher intrinsic motivation, career motivation, self-determination, and self-efficacy when
their level of self-awareness increases. However, students’ intrinsic motivation, career
motivation, self-determination, and self-efficacy are not influenced by their level of
inquiry or collaborative attitude.
Table 4.11

Independent sample t-tests to determine differences in motivation (factor wise) of students’ having low or high reflexivity

<table>
<thead>
<tr>
<th>Factors of motivation questionnaire</th>
<th>Low</th>
<th>High</th>
<th>95% CI of mean difference</th>
<th>t</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Intrinsic motivation (F1)</td>
<td>16.56</td>
<td>2.98</td>
<td>32</td>
<td>17.87</td>
<td>2.51</td>
</tr>
<tr>
<td>Career motivation (F2)</td>
<td>15.87</td>
<td>4.23</td>
<td>32</td>
<td>17.90</td>
<td>2.39</td>
</tr>
<tr>
<td>Self-determination (F3)</td>
<td>14.84</td>
<td>3.12</td>
<td>32</td>
<td>16.80</td>
<td>2.98</td>
</tr>
<tr>
<td>Self-efficacy (F4)</td>
<td>15.56</td>
<td>2.66</td>
<td>32</td>
<td>17.35</td>
<td>2.28</td>
</tr>
</tbody>
</table>

* Indicates significant differences (p ≤ 0.05)
Research Question 5

What are students’ overall views about engaging in self-reflection in an authentic–reflexive laboratory environment?

To determine students’ overall views about engaging in self-reflection, I used students’ interviews or open-ended questionnaires as my data source. For analysis of the data, I first transcribed the students’ responses to the interview questions that were relevant to this research question. Then, to provide an overview of students’ perceptions of engaging in reflections during the course, I calculated the number of students who perceived reflections as ‘not useful’, ‘less useful’, ‘neutral’, ‘useful’ or ‘very useful’ during the interviews.

When students were asked during the interviews about how they felt about completing reflections in the course, those who responded negatively and thought of them to be completely useless, I categorized them in a group of students perceiving reflections as ‘not useful.’ For example, Michael said “I did not like reflections overall. I thought they were useless, a waste of time.” Next, I categorized students as perceiving reflections ‘less useful’ when they did not see the importance of including them in the course. Such as James, who responded, “I did not hate it completely but actually could not see much relevance of having them in the course” was placed in this category. There were some students who neither supported nor were against doing reflections. I grouped them as perceiving reflection ‘neutral.’ For example, Rebecca responded, “I didn’t mind doing the reflections but not very sure if they were or weren’t helpful.” On the other hand, students who thought that reflections were helpful to some extent, I categorized them as perceiving reflections ‘useful.’ Such as, Emily stated, “I could clearly see why we were asked to do these reflections. They helped us to better understand what is
happening overall.” Finally, I grouped students in the category of perceiving reflections as ‘very useful’ when they clearly stated how they benefitted from doing reflections. Such as, Justin said, “It helped to personalize my feelings and thoughts and made me more aware of myself. It is going to help me as a scientist in future.” Descriptive statistics show that 76.09% of all students in this authentic-reflexive course considered reflections to be useful or very useful and 15.22% of all students considered reflection as less or not at all useful (Figure 4.5).

![Graph showing views about reflections](image)

**Figure 4.5.** Students’ overall views about reflections in an authentic-reflexive course.

Next, to provide a detailed description of students’ views, I coded students’ responses in the interview manually using an inductive approach to coding (Patton, 2002). I also coded relevant students’ responses on the open ended questionnaires using the same approach. First, I used a descriptive line by line coding to code students’ responses (Saldana, 2013). Following that, I condensed the small codes into sub-categories and then into broader categories based on similarities. These final categories
are reported below with the number of students that had a response belonging to that category.

Students’ Views about Engaging in Self-Reflections

Students had mixed views about engaging in self-reflections. Some of the students’ responses were positive whereas some were negative (Figure 4.6).

<table>
<thead>
<tr>
<th>Categories of positive responses</th>
<th>Categories of negative responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gained new insights</td>
<td>Questions were repetitive</td>
</tr>
<tr>
<td>Developed self-awareness</td>
<td>Could not see the relevance</td>
</tr>
<tr>
<td>Developed thinking ability</td>
<td>Time consuming</td>
</tr>
<tr>
<td>Developed communication skills</td>
<td></td>
</tr>
<tr>
<td>Helped to be on track</td>
<td></td>
</tr>
<tr>
<td>Helped to remain connected to the overall goal</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 4.6. Students’ mixed views about self-reflections in an authentic-reflexive course.*

In this section, I provide a detailed description of the type of positive and negative responses. The (n) number in each category indicates the number of students that had a response belonging to that particular category. To note, there were some students whose responses were grouped in more than one category.

*Gained new insights (n=13).* This category included students’ responses that indicated that they gained better understanding about the project and learned about future directions. For example, Lisa (who demonstrated a scientific identity) stated, “It was a way to gather my thoughts outside our lab notebook. It is always good to see what I did,
what I am doing and what I have to do in future.” Students found reflections as a way to put their thoughts in words and as well as gain new insights. For example, Eric (who demonstrated a scientific identity) said, “It is good to reflect because I think it will help you internalize what you did past week and why you did it. There was a question that always asked about the application, so it made us think about the directions of our work.” Therefore, it is evident that students could clearly see the value of reflections in developing better knowledge about their project and as well as providing a platform to think about the future directions.

*Developed self-awareness (n=9).* Some of the students’ responses highlighted the role of reflections in developing their self-awareness. For example, Emily (who demonstrated a student identity) stated, “Reflections helped me understand why I am in this class, what are the things I can do best and could possibly consider in my future job.” Similarly, Joanne (who demonstrated a scientific identity) stated, “I think you get a wider scope of understanding your research and about your strengths and weaknesses. I gained insights on my actions as a scientist.” Therefore, students did value reflections in making them aware of their own skills and knowledge to help them in their current project and also in future endeavors.

*Developed thinking ability (n=29).* This was one of the most common responses of students. They thought reflections improved their thinking ability to a great extent. It is evident in what Kevin (who demonstrated a student identity) stated, “It (reflections) just gets you thinking. They help you think about your process.” Likewise, Laura (who demonstrated a scientific identity) said, “They (reflections) made us think deep. We kept thinking all the way why we were doing this project. I think it is going to help us as a
scientist in future. Scientists do not do experiments just blindly. So, it is a good way to think on stuff.” Therefore, students not only commented on how reflections forced them to think deeply, but also how they would benefit out of them.

*Developed communication skills (n=5).* Another benefit of reflections pointed out by students included development of their communications skills. For example, Justin (who demonstrated a scientific identity) stated, “It (reflections) gives you the skill to summarize your findings and be able to communicate to others which you know is very important scientific skill.” Reflections helped them in both intrapersonal and interpersonal communications skills. For example, Carolyn (who demonstrated a scientific identity) said, “They (reflections) made me think about the course and led to important conversations between me and my partner. I can definitely see the merit in them.” Therefore, students also perceived self-reflections as to facilitate their communication with their partners.

*Helped to be on track (n=15).* A number of students saw the benefits of reflection in keeping them on track throughout the semester. This is evident in what Sarah (who demonstrated a scientific identity) stated, “Those (reflections) are things that helps you keep on track with your goals.” Similarly, Jessica (who demonstrated a scientific identity) stated, “It (reflections) always made me think if I was on track and following all aseptic techniques.” This lab being an authentic research-based lab, students often pointed out the importance of reflections in keeping them on track and help them proceed at a steady pace.

*Helped to remain connected to the overall goal (n=8).* Students also perceived reflections to help them remain connected to the big picture or the overall goal of the
project. For example, Kathleen (who demonstrated a scientific identity) stated, “It is important to look back because you can see if you doing things correctly or where is this taking you towards future. It was a good opportunity to gauge where we were in terms of our overall goal.” Similarly, Kavita (who demonstrated a scientific identity) said, “I could talk about what went wrong. It was really good. It (reflections) also made us to think how we should plan to move towards our bigger goal.” Therefore students thought the reflections helped them to connect their current work to the overall goal of the project which was beneficial.

Apart from these positive responses, there were three categories that emerged from the negative responses of students when asked about their views about engaging in self-reflection. I have listed them as follows.

*Questions were repetitive (n=34).* This was the most common response from students. Students who did not like reflections and even some students who liked reflections felt the questions were repetitive. They did not like answering the same questions every week. For example, Evan (who demonstrated a detached identity) stated, “I felt like I was answering the same question again and again. It got repetitive a lot. So, I do not think I gained anything.” Similarly, Sheila (who demonstrated a scientific identity) stated, “It got pretty redundant soon. Although they help you think about your work, I think variations in questions would help.” Therefore, although students who liked reflections overall and could see the value in it, thought the questions were repetitive and desired a change in them.

*Could not see the relevance (n=2).* There were two students who said that they could not see the relevance of reflections in the class. One among them was James who
demonstrated a student identity. As quoted before, he did not see much value in the reflections mainly because he did not think they were very relevant in this course.

Similarly, Amber (who demonstrated a detached identity) stated, “…looking back was good at times. However, I did not like reflections as a whole as I could not actually see the relevance.” According to these students, reflections were not very important to have in this course.

*Time consuming (n=2).* There were two students who did not like reflections at all because they took way too much time and were not that useful. This was evident in what Keren (who demonstrated a student identity) stated, “It was kind of time consuming and not at all worth it. If it was me, I would not have done it at all, but from an academic point of view, may be do it just once a month.” Similarly, Michael (who demonstrated a student identity) as quoted before, did not like reflections because they were useless and a waste of time. Therefore, these students did not like reflections primarily because they were very time consuming and were not worth doing at all in this particular course.
CHAPTER V
SUMMARY

My project investigated the impact of reflexive practices on college students in a science laboratory course. Through this investigation, I have developed a better understanding of how reflexive practices in a science laboratory course impact the development of students’ scientific identity, their science and science-related career interest and motivation. In previous literature, it is found that a classroom environment that incorporates reflexive practices such as engaging students in self-reflection and working in a collaborative environment, facilitates the development of students’ awareness about themselves, their strengths and weaknesses, and other social skills like inter-personal communications (Gilardi & Lozza, 2009; Renninger, 2009; Warin et al., 2006). Reflexive practices encourage students to think about their interactions with their peers and instructors in a specific context, which leads to the development of their reflexivity (Gee, 2000; Geijsel & Meijers, 2005; Gilardi & Lozza, 2009; Olesen, 2001, Renninger, 2009). Students’ reflexivity in turn influences the development of their professional identity (Gilardi & Lozza, 2009; Warin et al., 2006). Similarly, effective classroom practices are also key to the development of students’ interest and motivation (Gylnn et al., 2011; Nieswandt, 2007; Romine et al., 2013). The discussion of results of my study provides an explanation of how students’ self-reflections impact the development of their scientific identity and science and science-related career interest and motivation. I have organized this chapter in the order of my research questions.
Discussion of Results

Differences in students’ identities, interest, and motivation in relation to different learning environments (authentic–reflexive, authentic–non-reflexive and traditional–reflexive laboratory)

Students’ identities in three learning environments. Regarding the differences in students’ identities in three different learning environment, I found that a large number of students in the authentic-reflexive and authentic-non-reflexive course demonstrated a scientific identity. In contrast, a large number of students in the traditional-reflexive course demonstrated a student identity. These results indicate that an authentic learning environment (with or without reflexive practices), is more effective in development of a scientific identity than traditional laboratory environment involving reflexive practices. This is consistent with the previous literature as Carlone and Johnson (2007) and Hunter et al. (2007) showed the importance of undergraduate research experience in the development of students’ scientific identity. Hands-on research experience in an authentic laboratory enhances students’ research skills, communication and collaboration skills, perseverance and improved understanding of a scientist (Kardash et al., 2008; Lopatto, 2004; Seymour et al., 2004). Such benefits of authentic learning environment in turn is responsible for the development of students’ scientific identity (Hunter et al, 2007), and this is probably the reason why students in the traditional laboratory environment have a lower percentage of scientific identity.

It is also noteworthy that the percentage of students exhibiting a scientific identity is slightly higher in authentic-reflexive course than in the authentic-non-reflexive course, indicating that reflexive practices may have influenced positively the
development of students’ scientific identity. One reason for this could be that reflexive practices help in the development of students’ self-awareness, inquiry attitude, and collaborative attitude as noted by Gillardi and Lozza (2009). These components of reflexivity collectively help an individual to interpret his/her actions, learn about one’s abilities, learn to interact with others professionally and think about the type of person they would like to be. Therefore, I suppose that students in authentic-non-reflexive course may have been lacking in one or more of these benefits of reflexive practices which may have affected the development of their scientific identity. Also, I found that the traditional-reflexive environment had the highest percentage of students with a student or detached identity compared to authentic-reflexive and authentic-non-reflexive environments which reinforces the interpretation of the findings of this research question.

**Students’ interest in three learning environments.** Secondly, regarding the differences in students’ interest in three different learning environment, I found that students’ change in interest differs significantly between the different learning environments. Specifically, there was a significant difference between authentic-reflexive and traditional-reflexive, and between authentic-non-reflexive and traditional-reflexive. It appears that authentic learning environment positively influences students’ interest. This is consistent with the previous literature which shows that students’ interest is dependent on external factors like effective classroom environments (Nieswandt, 2007; Romine et al., 2013). Kunter, Baumert, and Koller (2007) reported that a teacher-centered, traditional classroom environment is more regulated which effects students’ feeling of autonomy, whereas a more student-centered authentic learning environment provides students with a learning experience that fosters a feelings of autonomy, success,
competence, and accomplishments. Therefore, these unique features of authentic learning environment may have boosted students’ interest compared to traditional environment. The two factors in the interest questionnaire that contributed to the significant difference between overall students’ change in interest between the authentic-reflexive and traditional-reflexive, and between authentic-non-reflexive and traditional-reflexive were interest in learning science and interest in science careers which can be again attributed to the benefits of authentic learning environment mentioned previously. However, the third factor, attitude towards biotechnology did not differ significantly between the learning environments. The possible reason could be that a student’s attitude or interest towards a particular subject area in the traditional-reflexive course could have been influenced by other factors like how the instructor delivered the content material in the associated lecture course or their exposure to other biotechnology related courses in previous semesters.

When compared between authentic-reflexive and authentic-non-reflexive environments, I found that students overall change in interest was higher in the authentic-reflexive environment than the authentic-non-reflexive, although the difference was not statistically significant. This result is not unanticipated because personal interest tends to change slowly over a long period of time (Alexander & Jetton, 1996; Romine et al., 2013). Therefore, a longitudinal study would be more appropriate to measure students’ change in interest. However, the positive mean difference of students’ interest between the authentic-reflexive and authentic- non-reflexive environment could be attributed to the benefits of self-reflections. I found that engaging in reflexive practices provides students with opportunities to reflect on their projects, encourage them to think on the
implications of their findings and help them to remain connected to the overall goal of the project. These advantages of self-reflections may have contributed to the overall gain of interest in students of authentic-reflexive course.

*Students’ motivation in three learning environments.* Lastly, regarding the differences in students’ motivation in three different learning environments, I found that students’ overall change in motivation did not differ significantly between the different learning environments. However, when I looked at the individual factors in the motivation questionnaire, that contributed to the overall students’ motivation, I found significant difference in students’ change in career motivation and self-efficacy whereas there was no significant difference in students’ intrinsic motivation and self-determination across the different learning environments. Hassandra, Goudas, and Chroni (2003) and Wehmeyer and Field (2007) reported that intrinsic motivation and self-determination are factors that are largely influenced by one’s social and cultural background, family encouragements, and out-of-school activities. Therefore these individual differences cannot be controlled or altered in a specialized classroom environment, which may be the reason why there was no significant difference in students’ intrinsic motivation and self-determination across the different learning environments.

With regard to career motivation, I observed significant differences, specifically between authentic-reflexive and traditional-reflexive and also between authentic-non-reflexive and traditional-reflexive environments. This significant difference can be attributed to the advantages of authentic research-based learning environments which is consistent with the previous observation by Hu et al. (2008) and Pascarella and Terenzini
(2005) who showed the benefits of engaging students in authentic research activities in enhancing their motivation. However, with regard to students’ self-efficacy, I observed significant differences specifically between authentic-reflexive and authentic-non-reflexive and authentic-reflexive and traditional-reflexive learning environments. This observation indicates that both authenticity of learning environment and reflexivity of students are necessary to enhance self-efficacy. Banas and York (2014) reported that authentic learning positively influences the development of self-efficacy. According to Bandura (1994), attaining success is a major factor in development of self-efficacy. If students’ experience easy success such as in a traditional laboratory environment, they get habituated to obtaining quick results and are frustrated with negative results easily. In contrast, students in authentic learning environment, working on a long term project, face and overcome obstacles and setbacks throughout the project which enhances their resilience. This enhanced resilience in turn generates a strong sense of self-efficacy (Bandura, 1994). Throughout the learning process, if students are provided with opportunities for self-monitoring and feedback from peers and instructors, it adds to their sense of self-efficacy (Bandura, 1986; 2001). Therefore, reflexive practices in combination with authentic learning environment in this study provided students with an opportunity of self-monitoring, learning about their abilities, and getting constructive feedback, which may have positively influenced students’ self-efficacy.

Relationship between reflexivity and students’ identities in a laboratory course involving reflexive practices

For the second research question, I first focused on analyzing the relationship between students’ self-awareness and identity and found that a significant number of
students with high self-awareness had a scientific identity. Warin et al. (2006) stated that when an individual engages in self-reflection, he/she interprets his/her actions and that leads to awareness of one’s self which is key to the development of one’s professional identity. When students are aware of their abilities, strengths and weaknesses, they are more likely to think about the type of person they would like to be or the type of career that is best for them (Gilardi & Lozza, 2009). Therefore, I think students in these reflexive courses, who had a higher self-awareness, may have viewed themselves as scientists working on an independent research project, in a real laboratory environment and therefore exhibited a scientific identity. However, some students with low self-awareness also had a scientific identity which may have been due to several other factors that influenced students’ professional identity such as exposure to multiple authentic courses, individual research experiences, or a particular family background.

In the analysis of the relationship between inquiry attitude and identity, a significant number of students with high inquiry attitude demonstrated a scientific identity. An individual with high inquiry attitude, always attempts to have reflective conversation with the situation according to Schon (1983), which enables him/her to constantly monitor self-actions. Inquiry attitude, which is an ability to question one’s beliefs, feelings and assumptions helps an individual to solve any problem and is greatly responsible for the development of one’s professional identity (Gilardi & Lozza, 2009). Development of this inquiry attitude is facilitated by engaging students in reflexive practices. Therefore, I think students with high inquiry attitude in these reflexive courses could question their own actions and were able to solve problems by learning from their mistakes. Benefits of high inquiry attitude may have helped them to see themselves as a
scientist and therefore demonstrate a scientific identity. However, some students with a low inquiry attitude also had a scientific identity which can be again attributed to the fact that identity can be influenced by several other external factors.

I primarily used teaching assistants’ observations to determine if a student has high or low collaborative attitude, the third component of reflexivity. Similar to the other two components, a significant number of students with high collaborative attitude exhibited a scientific identity. An individual with high collaborative attitude, is able to negotiate and work effectively with peers (Reynold’s & Vince, 2004). According to Gilardi and Lozza (2009), ability to negotiate and have a dialogue or conversation with others plays a crucial role in the development of professionalism among students, and therefore, students should be encouraged to work in groups. Therefore engaging students in reflexive practices in these courses like providing them with the opportunity to work with partners and to reflect upon their own actions facilitated the development of students’ collaborative attitude and probably led to the development of their scientific identity. However, unlike the two other components of reflexivity, very few students with low collaborative attitude demonstrated a scientific identity. Most of the students with low collaborative attitude demonstrated either a student or detached identity which reveals that the ability to work with others greatly influence the development of a scientific identity. 

Relationship between reflexivity and students’ interest in a laboratory course involving reflexive practices

When I analyzed the relationship between students’ overall interest and their self-awareness level, I found a significant difference in interest between the students with low
and high self-awareness. This difference in interest can be attributed to the benefits of a student’s high self-awareness, such as gaining knowledge about oneself and one’s strengths and weaknesses, which helps a student to develop interest in a particular area and eventually choose a path for future career (Gilardi & Lozza, 2009; Warin et al., 2006). This positive relationship between the self-awareness and students’ interest was also evident when I analyzed the factors of the interest questionnaire individually. My results show that students with high and low self-awareness differ significantly in their interest in learning science and interest in science careers. Silvia (2001) stated that if students develop interest in a particular subject area, they are likely to choose a related career. Therefore, it shows that the more the students are aware of themselves, the greater are their possibility to develop interest in the subject and enter in a career of related field.

When analyzing the relationship between students’ inquiry attitude and their interest, I did not find any significant difference in overall interest between students with high or low inquiry attitude. Likewise, I did not find any significant difference in interest between students with high or low collaborative attitude. One reason for this observation could be that students’ interest is influenced by several internal and external factors such as background knowledge, one’s awareness, cultural value, emotion, competence, social support, social interactions (Bergin, 1999; Nieswandt, 2007; Silvia, 2006), which were not considered in this study.

**Relationship between reflexivity and students’ motivation in a laboratory course involving reflexive practices**

When I compared students’ overall motivation with their self-awareness level, I found a significant difference in motivation between the students with low and high self-
awareness. This finding is consistent with the previous literature which showed how students’ awareness of themselves actually improves their motivation. According to Roeser and Peck (2009), when a person is aware of one’s self, he consciously plans for goals and puts them in action and is therefore motivated. This difference in motivation is also evident when I analyzed the factors of the motivation questionnaire individually. My results show that students with high and low self-awareness differed significantly in their intrinsic motivation, career motivation, self-determination, and self-efficacy. Therefore, if a student is provided with opportunities to develop self-awareness, he/she can be motivated to learn science and enter into science career.

When analyzing the relationship between students’ inquiry attitude and their motivation, I did not find any significant difference in overall motivation between students with high or low inquiry attitude. Likewise, I did not find any significant difference in motivation between students with high or low collaborative attitude. One reason for this observation could be that students’ motivation is influenced by several factors such as one’s social and cultural background, family encouragements, and out-of-school activities (Hassandra et al., 2003; Wehmeyer & Field, 2007) which were not considered in this study.

Students’ engagement in self-reflection

When I analyzed students’ reflections, I found that majority of students reflected at the level of ‘understanding’ or at the level of ‘reflection’ as identified in the rubric by Kember et al. (2008). It was evident from their reflections that students who reflected at the level of ‘understanding,’ did not value their own experience and rather relied on the textbook information. Moreover, these students did not prefer questioning their own
actions during reflections. Students who reflected at the level of ‘reflection’ had their own insights in the reflections and were found to question their actions and learn from their mistakes. The highest level of reflection identified in the rubric is ‘critical reflection.’ Students in this category are expected to reveal a change in perspective in their reflections. However, in my study, I did not find any student to reflect at the level of ‘critical reflection.’ One possible reason of this could be that change in perspective takes time for students and it is not always visible in the written reflections (Kember et al., 2008; Osborne & Wittrock, 1983). In addition to that, when I looked at the reflection prompts/questions, I realized that there were no questions that directly encouraged students to think about any change in their perspective. The questions were designed in a way that asked them to think upon their current actions, understanding of the project and the future directions. Therefore, I think if there were some questions to encourage students to think about their previous and current conceptions and compare them in their reflections, the results could have been different.

Regarding students’ views about engaging in self-reflections, I observed that a majority of students in the authentic-reflexive course found self-reflections ‘useful,’ and appreciated that they were included in this course. Among the student-reported benefits of self-reflection, development of self-awareness, thinking ability, and communication skills which are closely related to the components of reflexivity, awareness of oneself, inquiry attitude, and collaborative attitude respectively. Therefore, it is clearly evident that reflexive practices like engaging students’ in self-reflection indeed helped students to develop the components of reflexivity which is consistent with the previous literature
(Gillardi & Lozza, 2009). Some of the other benefits reported were gaining new insights, able to be on track, and to remain connected to the overall goal of the project.

Implications for Teaching

In different fields of education like teacher education, health and psychology, the reflexive practices in an authentic learning environment enhance the development of professional identity of students (Barnett & O’Mahony, 2006; Cunliffe, 2004; Kreber, 2005; Mann et al., 2009; Mayo, 2004; Sax, 2006). With the growing need to retain students in STEM fields, it is imperative to employ reflexive practices in authentic science classrooms to promote the development of students’ scientific identity, their interest and motivation, as these tend to positively influence students’ retention in STEM fields (Mraz et al., Under review; Glynn et al., 2011; Romine et al., 2013). Authentic science laboratory courses that already exist and is known to influence students’ development of scientist like attitude must be redesigned to engage students in reflexive practices in order to maximize the benefits.

Based on the findings of my study, reflexive practices make students aware of themselves, their strengths and weaknesses, and improve their thinking and communication abilities. It is likely that if a student is aware of one’s self, he/she will engage in more effective learning by utilizing his/her strengths. Reflexive practices also tend to help students improve their communication with peers and instructors in classroom, which facilitates the exchange of thoughts and develop better understanding of the content. Nevertheless, self-reflections enhance students thinking ability which is key to become a scientist in future. Therefore, it is important that students are provided with opportunities to engage in self-reflections within a course curriculum.
However, it is imperative to effectively engage students in self-reflection. Scardamalia and Bereiter (1985) reported that all students are not capable of reflecting on their own, therefore use of some prompts helps to externalize their mental activities, thus facilitating the process of reflection. Through my investigation, I found that students did appreciate the reflection questions (prompts) but they did not like answering to the same prompts week after week. Therefore, it is very important to change the reflection questions occasionally or engage students in different forms of reflections every week. For example, students could be occasionally asked to reflect in groups or in an online blog to make it more interactive. Moreover, Levin et al. (2006) and Sutherland and Markauskaite (2012) found that students’ reflections can also be strengthened by incorporating peer responses and feedback. Peer interactions allow students to learn different perspectives of their peers and improve their individual reflections (Lin et al., 1999). Therefore, these alternative ways of engaging students in self-reflection could potentially benefit the students in an authentic science laboratory course.

Additionally, different forms of reflexive practices might be a possible solution to one of the challenges associated with classroom reflections. It is seen that different students prefer to reflect differently (Roberts, 2008; White, 2014). For example, some might prefer individual journaling whereas others prefer group reflections. Incorporating different types of reflexive practices in classroom might cater to the need of all students and prove to be a more effective learning environment. As my study provides an overview of students’ outcomes associated with reflexive practices and students’ perceptions of engaging in self-reflection, I hope educators will find it useful in implementing effective reflexive practices in their classrooms.
Conclusions

Overall, I found that authentic learning environment is crucial for the development of students’ scientific identity, interest, and motivation. However, reflexive practices incorporated in an authentic learning environment further augments these developments by enhancing students’ reflexivity. Among the three main components of reflexivity identified in previous literature, I found that self-awareness influences students’ identity, interest, and motivation positively. The other two components of reflexivity, inquiry attitude and collaborative attitude, were found to have a greater impact on students’ identity than on the other outcomes. Through this investigation, I also explored students’ perceptions of engaging in self-reflection and found that majority of students could see the value of engaging in self-reflection as it benefited them personally and professionally. In this regard, my study provides an implication for teachers interested in engaging students in reflexive practices in an authentic classroom setting. Previous literature showed the role of reflexive practices in an authentic learning environment in the development of professional identity of students for different professions like teaching, health professionals and professionals in the field of psychology (Barnett & O’Mahony, 2006; Cunliffe, 2004; Kreber, 2005; Mann et al., 2009; Mayo, 2004; Sax, 2006). My study adds to the existing literature by investigating the impact of reflexive practices within an authentic scientific learning environment on the development of a students’ scientific identity, interest and motivation which has not been explored previously.
Future Directions

Lack of research in the area of the role of reflexive practices in science classroom demands further investigation. In this regard, my study leads to potential future directions that can be explored. Firstly, for this study, I focused on a single authentic research based course involving reflexive practices. So, one of the future works could be to explore the role of reflexive practices in different authentic courses as that might reveal some other benefits of reflexive practices which could not be found in this study.

Secondly, as I collected data from students in one semester, a longitudinal study to investigate the long term impact of reflexive practices on students’ outcomes may lead to interesting findings. For example, as I mentioned in my study that students were not found to reflect critically on their change in perspective in this course and given that the previous literature states such changes in perspective takes time, a longitudinal study would be appropriate to reveal students’ change in perspectives as a result of engaging in reflexive practices.

Lastly, in this study, students engaged in only one form of self-reflections which is writing in response to the reflection prompts. Therefore, future research investigating the role of different forms of reflections such as group reflections or reflections via online blog will be informative as it is known that different students prefer to reflect differently.

Investigations on these future directions of my study will add beneficially to the existing literature and provide a solid implication for educators to include such practices within their classroom to benefit the students professionally.
APPENDIX A
SNAPSHOT OF THE SYLLABUS OF AUTHENTIC LABORATORY COURSES

**In Situ**—Students isolate and purify novel bacteriophages from environmental samples, characterize the phages, and prepare bacteriophage genomic DNA for sequencing.

<table>
<thead>
<tr>
<th>Week</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>Students employ standard microbiological techniques to isolate and purify phages from environmental samples.</td>
</tr>
<tr>
<td>5-9</td>
<td>Students use molecular techniques to isolate DNA and perform restriction analyses of genomic samples.</td>
</tr>
<tr>
<td>8-10</td>
<td>Students prepare grids and visualize phage morphology using electron microscopy.</td>
</tr>
<tr>
<td>9-12</td>
<td>In each lab section, the students evaluate the quality of DNA samples and decide as a group which genome will be sequenced.</td>
</tr>
<tr>
<td>12-14</td>
<td>Students prepare samples for archiving and inclusion in a mycobacteriophage collection.</td>
</tr>
</tbody>
</table>

**Transition**: Genomes are sequenced and assembled during the winter recess. The finished sequences are returned to the students for the *In Silico* portion of the course.

**In Silico**—Students continue the path of inquiry by annotating the sequenced genomes.

<table>
<thead>
<tr>
<th>Week</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Genome files are finished and oriented. Faculty and students discuss post-annotation strategies.</td>
</tr>
<tr>
<td>3-7</td>
<td>Students generate draft annotations and evaluate overall genome structure. Students perform some comparative genomic analyses.</td>
</tr>
<tr>
<td>6-10</td>
<td>Students complete annotations of phage genomes.</td>
</tr>
<tr>
<td>9-14</td>
<td>Students pursue post-annotation experimentation on their phages. Post annotation research.</td>
</tr>
<tr>
<td>12-14</td>
<td>Student-annotated files are merged, finalized, and reviewed by the Hatfull Laboratory for future submission to GenBank.</td>
</tr>
</tbody>
</table>
## APPENDIX B

**SNAPSHOT OF THE SYLLABUS OF TRADITIONAL LABORATORY COURSE**

<table>
<thead>
<tr>
<th>28-Aug-14</th>
<th>Biological Safety and standard practices and how to use a pipet-aid and pipette.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Sep-14</td>
<td><em>Laboratory Section 1: Lambda bacteriophage and Escherichia coli (ER1647) viral plaque assay, background/theory.</em></td>
</tr>
<tr>
<td></td>
<td><strong>PART A:</strong> Preparation of media with calculations.</td>
</tr>
<tr>
<td>11-Sep-14</td>
<td><strong>PART B:</strong> Plating of prepared media, streaking plates with <em>E. coli</em> and amplification of <em>E. coli</em> colonies.</td>
</tr>
<tr>
<td>18-Sep-14</td>
<td><strong>PART C:</strong> Amplification of lambda bacteriophage.</td>
</tr>
<tr>
<td>25-Sep-14</td>
<td><strong>PART D:</strong> Serial dilutions of lambda bacteriophage and infection of bacteria for plaque assay.</td>
</tr>
<tr>
<td>2-Oct-14</td>
<td><strong>PART E:</strong> Counting of plaques and determination of viral titer calculations. Q&amp;A session for midterm.</td>
</tr>
<tr>
<td>9-Oct-14</td>
<td>Midterm</td>
</tr>
<tr>
<td>16-Oct-14</td>
<td>Fall Break No class</td>
</tr>
<tr>
<td>23-Oct-14</td>
<td><em>Laboratory Section 2: Baculovirus plaque assay on Sf9 insect cells, background/theory.</em></td>
</tr>
<tr>
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<td><strong>PART A:</strong> Cell culture technique and cell counting with a hemocytometer theory.</td>
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<tr>
<td>30-Oct-14</td>
<td><strong>PART B:</strong> Groups A/B (Groups C/D no class): Culturing Sf9 (hemocytometer count practice) and baculovirus plaque assay.</td>
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<tr>
<td>6-Nov-14</td>
<td><strong>PART B:</strong> Groups C/D (Groups A/B no class): Culturing Sf9 (hemocytometer count practice) and baculovirus plaque assay.</td>
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<tr>
<td>13-Nov-14</td>
<td><strong>PART C:</strong> Hemagglutination assay for viral detection and titer.</td>
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<tr>
<td>20-Nov-14</td>
<td>Presentations and Q&amp;A session for final exam.</td>
</tr>
<tr>
<td>27-Nov-14</td>
<td>Thanksgiving Holiday. No class.</td>
</tr>
<tr>
<td>3-Dec-14</td>
<td>Final Exam</td>
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</table>
NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the “Adverse Effect Report Form”.
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: CH2-13091701
PROJECT TITLE: Understanding how Student Thinking Changes when Provided Instruction in an Authentic Research Environment within a Systems Biology Project
PROJECT TYPE: Change to a Previously Approved Project
RESEARCHER(S): Kristy Daniel
COLLEGE/DIVISION: College of Science and Technology
DEPARTMENT: Biological Sciences
FUNDING AGENCY/SPONSOR: HHMI
IRB COMMITTEE ACTION: Exempt Approval
PERIOD OF APPROVAL: 08/29/2014 to 08/28/2015

Lawrence A. Hosman, Ph.D.
Institutional Review Board
APPENDIX D

SEMI-STRUCTURED INTERVIEW PROTOCOL / OPEN-ENDED QUESTIONNAIRE

Name: ___________________________________________
Institution: _______________________________________
Course Name: ______________________________________

1. What are your career aspirations?

2. How do you think this class has prepared you for the type of career you are interested in pursuing?

3. Use your own words to define what is science.

4. Describe where your ideas about science have stemmed from?

5. Explain what experiences you have had that helped you to understand the process of doing science and how they helped you come to this understanding?

6. What motivated you to enroll in this course?

7. What have you learned about science this semester that you would not have learned without participating in this research course?

8. What have you learned about the challenges of doing real research?

9. How is any of what you have learned about research in this course transferable to your other courses?

10. Describe who has helped you with your research this semester and how they have helped.

11. What is your reaction about working with others during this course?
12. What has contributed to your level of satisfaction (or dissatisfaction) with your current research experience?

13. What did you think about completing reflection prompts assignments on Blackboard?

14. What if anything did you gain from completing those reflections?

15. Please use the space below to share anything else about this course that you would like to help us understand/know. (This may include your overall feelings, specific details about any aspect, comments about course/time management, or anything else you want to share!)
APPENDIX E
STUDENTS’ INTEREST IN TECHNOLOGY AND SCIENCE (SITS) QUESTIONNAIRE

Please circle one response for each statement.

1. I enjoy learning science.  
   | Strongly | Disagree | Agree | Strongly | Agree |

2. College science has improved my decision-making.  
   | Strongly | Disagree | Agree | Strongly | Agree |

3. I enjoy using technology to solve science problems.  
   | Strongly | Disagree | Agree | Strongly | Agree |

4. I plan to take more science classes in college.  
   | Strongly | Disagree | Agree | Strongly | Agree |

5. Technology helps me learn science.  
   | Strongly | Disagree | Agree | Strongly | Agree |

6. More time in the college day should be devoted to science.  
   | Strongly | Disagree | Agree | Strongly | Agree |

7. Computers make learning science more interesting.  
   | Strongly | Disagree | Agree | Strongly | Agree |

8. Learning science is interesting.  
   | Strongly | Disagree | Agree | Strongly | Agree |

9. I enjoy using technology to learn science.  
   | Strongly | Disagree | Agree | Strongly | Agree |

10. More time in science classes should involve the use of technology.  
    | Strongly | Disagree | Agree | Strongly | Agree |

11. I would be more likely to take a job if I knew it involved working with technology.  
    | Strongly | Disagree | Agree | Strongly | Agree |

12. Working in technology would be interesting.  
    | Strongly | Disagree | Agree | Strongly | Agree |

13. I would like to become a scientist.  
    | Strongly | Disagree | Agree | Strongly | Agree |

14. I would like to get a job in technology.  
<pre><code>| Strongly | Disagree | Agree | Strongly | Agree |
</code></pre>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>15. I would like to work in a field related to biotechnology.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>16. I would like to work with people who make discoveries in biotechnology.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>17. I would enjoy a job in technology.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>18. I will probably choose a job that involves using technology.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>19. I would enjoy working in a biotechnology laboratory</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>20. I would like to work in a science laboratory</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>21. Biotechnology helps create solutions to the world’s problems.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>22. Biotechnology is important for a country’s development.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>23. Biotechnology discoveries improve our ability to treat diseases.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>24. Biotechnology is important for modern life.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>25. Biotechnology is useful for the problems of everyday life.</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
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<tr>
<td>Statement</td>
<td>Never</td>
<td>Rarely</td>
<td>Sometimes</td>
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<td>--------------------------------------------------------------------------</td>
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<tr>
<td>01. The biology I learn is relevant to my life.</td>
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<td>02. I like to do better than other students on biology tests.</td>
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<td>03. Learning biology is interesting.</td>
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<td>04. Getting a good biology grade is important to me.</td>
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<td>05. I put enough effort into learning biology.</td>
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<td>06. I use strategies to learn biology well.</td>
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<td>07. Learning biology will help me get a good job.</td>
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<td>08. It is important that I get an &quot;A&quot; in biology.</td>
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<td>09. I am confident I will do well on biology tests.</td>
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<td>10. Knowing biology will give me a career advantage.</td>
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<td>11. I spend a lot of time learning biology.</td>
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<td>12. Learning biology makes my life more meaningful.</td>
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<td>13. Understanding biology will benefit me in my career.</td>
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<td>14. I am confident I will do well on biology labs and projects.</td>
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<td>15. I believe I can master biology knowledge and skills.</td>
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<td>16. I prepare well for biology tests and labs.</td>
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<td>17. I am curious about discoveries in biology.</td>
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<td>18. I believe I can earn a grade of &quot;A&quot; in biology.</td>
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<td>20. I think about the grade I will get in biology.</td>
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<tr>
<td>21. I am sure I can understand biology.</td>
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<tr>
<td>22. I study hard to learn biology.</td>
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<td>23. My career will involve biology.</td>
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<td>24. Scoring high on biology tests and labs matters to me.</td>
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<td>25. I will use biology problem-solving skills in my career.</td>
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APPENDIX G

SELF-REFLECTION INSIGHT SCALE (SRIS) QUESTIONNAIRE

Please read the following questions and circle the response that indicates the degree to which you agree or disagree with each of the statements. Try to be accurate, but work quite quickly. Do not spend too much time on any question.

THERE ARE NO "WRONG" OR "RIGHT" ANSWERS - ONLY YOUR OWN PERSONAL PERSPECTIVE

BE SURE TO ANSWER EVERY QUESTION
ONLY CIRCLE ONE ANSWER FOR EACH QUESTION

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. I don't often think about my thoughts</td>
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<tr>
<td>2. I am not really interested in analyzing my behaviour</td>
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<td>3. I am usually aware of my thoughts</td>
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<td>4. I'm often confused about the way that I really feel about things</td>
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<td>5. It is important for me to evaluate the things that I do</td>
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<td>6. I usually have a very clear idea about why I've behaved in a certain way</td>
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<td>7. I am very interested in examining what I think about</td>
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<td>8. I rarely spend time in self-reflection</td>
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<td>9. I'm often aware that I'm having a feeling, but I often don't quite know what it is</td>
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<td>10. I frequently examine my feelings</td>
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<td>11. My behaviour often puzzles me</td>
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<td>12. It is important to me to try to understand what my feelings mean</td>
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<td>13. I don't really think about why I behave in the way that I do</td>
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<td>14. Thinking about my thoughts makes me more confused</td>
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<td>15. I have a definite need to understand the way that my mind works</td>
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<td>16. I frequently take time to reflect on my thoughts</td>
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<td>17. Often I find it difficult to make sense of the way I feel about things</td>
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<td>18. It is important to me to be able to understand how my thoughts arise</td>
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<td>19. I often think about the way I feel about things</td>
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<tr>
<td>20. I usually know why I feel the way I do</td>
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APPENDIX H

REFLECTION QUESTIONS/PROMPTS

- What did you accomplish this week? What research findings do you have for this week?
  - Reflect on the meaning and/or implications of your findings for the work that you have done in lab thus far. Refer to the data or evidence that you have to support any claims that you make.

- Relate your findings to the bigger picture of our class and how they contribute to the overall goal of the research project.

- What issues or challenges did you face this week? What did you do to overcome these challenges?

- Do you work with a partner? If yes how did you both interact/work with each other during this week? Did you have any issues working together?

- Did any of your experiment fail this week? If yes:
  - What have you learned from your failure?
  - Do you think it is important to fail sometimes? Why do you think you failed? How did you change in order to be successful?
  - Overall, what do you think could be the best strategy to overcome failure and be successful?

- Where are you compared to the overall goal for the project? Are you ahead or behind schedule?

- What are your goals and plans for the upcoming week?

- What questions do you have about the results, the activities/experiments, and/or the research project?

- State ideas you have for future work. What could you do differently in the future and what new things could you do? You should try to propose ideas that are more than simply repeating the existing activity or experiment
APPENDIX I

TEACHING ASSISTANTS' OBSERVATION RUBRIC

Teaching Assistant __________________________ Course __________ Date _________

Student A ____________________________ Student B __________________________

1. Student always communicate with his/her partner in class. Student A / Student B
2. Student always stays with his/her partner during class. Student A / Student B
3. Student is often seen to discuss with his/her partner. Student A / Student B
4. Students have a good understanding among themselves. Student A / Student B
5. Students often complain about each other. Student A / Student B
6. Students are found to respect each other’s views. Student A / Student B
7. Students often ask each other questions about the project. Student A / Student B
8. Students are actively involved in the joint project. Student A / Student B
9. Students never had any issues working together. Student A / Student B

Please add any additional observations made about the above students.

<table>
<thead>
<tr>
<th>Student A</th>
<th>Student B</th>
</tr>
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<tbody>
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</tbody>
</table>
APPENDIX J

STUDENTS’ PEER EVALUATION RUBRIC

<table>
<thead>
<tr>
<th>Your Name</th>
<th>Name of your partner</th>
<th>Date</th>
</tr>
</thead>
</table>

Course

1. I liked working with my partner.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

2. My partner was knowledgeable  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

3. My partner was understandable  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

4. My partner was cooperative throughout the class.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

5. My partner always provided valuable insights about the project.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

6. My partner always discussed with me before taking any decision.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

7. My partner always respected my opinions.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

8. My partner always worked with me to troubleshoot a problem.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

9. My partner also worked with me beyond the class time.  
   - Strongly Disagree  
   - Disagree  
   - Agree  
   - Strongly Agree

10. My partner equally contributed in making the final presentation.  
    - Strongly Disagree  
    - Disagree  
    - Agree  
    - Strongly Agree

11. I benefited working with my partner in the project.  
    - Strongly Disagree  
    - Disagree  
    - Agree  
    - Strongly Agree

12. I would like to work with him/her again in future.  
    - Strongly Disagree  
    - Disagree  
    - Agree  
    - Strongly Agree

Please feel free to share anything else about your experience working with your partner in this class:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________


APPENDIX K

PROTOCOL TO OBTAIN STUDENTS’ CONSENT FOR THE STUDY

Dear Student,

I am an Assistant Professor in Department of Biological Sciences at the University of Southern Mississippi (USM) conducting a research investigation on how college student thinking changes when provided instruction in an authentic research environment within a systems biology project. Science educators, like myself, have focused upon what to teach and how to teach it. However, not much is known about what’s going on in students’ mind when they are engaged in a research-based course focused on systems biology. Professors can teach better if they know how to help students think processing, but we need your assistance in helping us determine what is effective for students. I hope you will be interested in contributing to this project. I am asking for volunteers to provide me with your insights into how you develop your understandings and thinking skills while working through biology research-based problems.

Your participation is totally optional. However, if you are willing to participate, you can choose to do so at one of two levels:

<table>
<thead>
<tr>
<th>Type of Study Participation</th>
<th>Your Time Commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> Provide access to your answers on: (1) homework assignments and quizzes (2) basic demographic information (grade level, major, etc.) PLUS share with me your thought processes by completing an open ended questionnaire</td>
<td>ONE open ended questionnaire (~ 30 min) at the end of the semester</td>
</tr>
<tr>
<td><strong>2</strong> Provide access to your answers on: (1) homework assignment and quizzes (2) basic demographic information (grade level, major, etc.) PLUS share with me your thought processes during an interview</td>
<td>ONE interview (~30min) at the end of the semester</td>
</tr>
</tbody>
</table>

The questions used in the interview are aligned with this course. This interview may benefit you by allowing you time to reflect upon your experiences in the course and think about biology research-based problems in a new manner. The interviews will be scheduled at a time and location convenient to you towards the end of the semester. These interviews may be video and audio recorded to ensure accurate data collection and to facilitate data analysis. These data files will be
stored in a secure location at USM and will be kept on file for no more than three years after project completion.

You must be 18 years old to participate in this study and your participation is completely voluntary. If you agree to participate, you may choose not to answer any question. You may withdraw from the study at any time without consequences to you. Your confidentiality will be strictly protected. Your name will be replaced with a code. Only the researcher team at USM will have access to the master list that matches your name with the code. Video and audio files from interviews will be transcribed by the student investigator or a university transcriptionist. As soon as the transcriptions are complete, all files will be securely stored. The study is being conducted to provide a better understanding of how students apply their knowledge toward plant systematics problems. Eventually we would like to publish findings. NO results will be reported in a manner that would allow a reader to associate any responses to you. You will not be purposely deceived, nor does this project does not pose physical danger. Participating in the study will subject you to no risks greater than those you normally encounter in everyday life.

Please feel free to ask any question during or after your participation in this study. If you have questions or concerns about this study, you may contact me:

Kristy Halverson
118 College Dr. #5018
University of Southern Mississippi
Hattiesburg, MS 39406
e-mail: Kristy.Halverson@usm.edu
phone: (601) 266-5841

For questions concerning human subjects research, you may contact the USM Campus Institutional Review Board at:

The University of Southern Mississippi
118 College Drive #5147
Hattiesburg, MS 39406-0001
(601) 266-6820

You also may email the Campus IRB Compliance Office at irb@usm.edu.

Your signature on the attached consent form indicates that you have received a copy, read, and understand this letter that describes the study. The informed written consent is required by IRB for your participation.

Thank you!
Sincerely,

Kristy Halverson, Ph.D.
Informed Consent Form

Understanding how student thinking changes when provided instruction in an authentic research environment within a systems biology project

Please indicate what your decision is regarding participation in this study by checking one box indicating your choice, signing and then dating the consent form.

☐ I AGREE TO PARTICIPATE: Consent is hereby given to participate in the study titled: Understanding how student thinking changes when provided instruction in an authentic research environment within a systems biology project. I understand that my participation is voluntary and that I may withdraw at any time without consequences to me. I know that my participation has no bearing upon my course grade.

Circle a number below to indicate your level of participation:

1. I agree to grant access to my answers on (1) homework assignments and quizzes, and (2) basic demographic information (grade level, major, etc.) and share my thinking process by completing one open ended questionnaire (~30 min) at the end of the semester.

2. I agree to grant access to my answers on (1) homework assignments and quizzes, (2) basic demographic information (grade level, major, etc.) and share my thinking process during one ~30 min interview to be scheduled at my convenience during the semester.

_________________________________________  __________________________
Signature                                           Date

_________________________________________  __________________________
Name (Please Print)                                Student ID number

_________________________________________  __________________________
Email address                                    Phone number

☐ I DECLINE TO PARTICIPATE: I choose NOT TO participate in the study titled: Understanding how student thinking changes when provided instruction in an authentic research environment within a systems biology project. I know that my decision has no bearing upon my course grade.

_________________________________________  __________________________
Name (Please Print)                                       Date
## APPENDIX L

STUDENTS’ IDENTITIES IN AN AUTHENTIC RESEARCH BASED LABORATORY COURSE (Mraz et al., under review)

<table>
<thead>
<tr>
<th>Identities</th>
<th>Description of identities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Identity</strong></td>
<td>Students who act and behave like a scientist are included in this category. This category of students included students who are able to solve problems on their own, work independently by owning their own project, can view the real world contribution of the project, and who can work in a collaborative working environment with their partner.</td>
</tr>
<tr>
<td>• Problem Solver</td>
<td></td>
</tr>
<tr>
<td>• Independent Lab Member</td>
<td></td>
</tr>
<tr>
<td>• Collaborator</td>
<td></td>
</tr>
<tr>
<td>• Real World Contributor</td>
<td></td>
</tr>
<tr>
<td>• Project Owner</td>
<td></td>
</tr>
<tr>
<td><strong>Student Identity</strong></td>
<td>Students who take this course just because it was required or are just motivated by grades are included in this category. These students don’t view themselves as a scientist.</td>
</tr>
<tr>
<td><strong>Detached Identity</strong></td>
<td>Students who just participate in the course without actually valuing the course experience or connecting the course experience to their personal interests and remain uninterested about everything are included in this category.</td>
</tr>
</tbody>
</table>
**APPENDIX M**

**RUBRIC FOR THE ASSESSMENT OF STUDENTS’ RESPONSES TO REFLEXIVE PROMPTS TO DETERMINE THEIR INQUIRY ATTITUDE (Kember et al., 2008)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description of categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-reflection/ Habitual action</td>
<td>Students’ whose responses show no evidence of them attempting to understand the concept or forming an individual opinion about it will be grouped in this category</td>
</tr>
<tr>
<td>Understanding</td>
<td>Students’ whose responses reveal their understanding of the concept but who rely more on text book information rather than relating to their personal experiences will be grouped in this category</td>
</tr>
<tr>
<td>Reflection</td>
<td>Students’ whose responses reveal their personal insights about the context and who attempt to relate their personal experiences to the textbook knowledge will be grouped in this category</td>
</tr>
<tr>
<td>Critical reflection</td>
<td>Students’ whose responses reveal change in their perspective about a particular concept as a result of their personal experience will be grouped in this category</td>
</tr>
</tbody>
</table>
REFERENCES


doi:10.13140/2.1.4790.5921


http://librarysearch.cf.ac.uk/primo_library/libweb/action/dlDisplay.do?docId=CA


