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Examining Science Identity Work and Scientific Literacy in Non-STEM Majors

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Examining Science Identity Work and Scientific Literacy in Non-STEM Majors

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in Education

by

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ABSTRACT

Examining STEM Identity Work and Scientific Literacy in Non-STEM Majors

by

Krista L. Lucas

Scientific literacy is vital for 21st century citizens to have the skills to make informed decisions based on sound science, and seeing oneself as a *science person* is important for citizens to feel capable of making such decisions based on science. Science educators are in the best position to encourage these attribute in their students. In particular, undergraduate non-STEM majors make up approximately 55% of college graduates, and college and university faculty are in a particularly important position to offer opportunities for STEM identity work in this population of students to encourage the development of a *science person* identity, which is intertwined with learning the skills important for scientific literacy like evaluation of science in the news.

This mixed-methods study focused on students in a biology course developed primarily for non-STEM majors, and examined their STEM identity work along with evidence of their scientific literacy. Data collected includes surveys, focus groups, observations of group work and final presentations, and final written reflections. Using Wilcoxon Rank Sum tests to compare pre-class and post-class survey responses, student participants felt more like science people following their experiences in this non-STEM majors' biology course and that their biology professor saw them as science people at the end of the course compared to the beginning of the term. Qualitative analysis supported

these findings, with participants sharing that they felt like science people when they were successful in school science, had the opportunity to engage with science content in lab or real-life case studies, were recognized by instructors and peers as competent in science, and recognized qualities of scientists that they felt they also shared.

In terms of scientific literacy, following their experience in non-STEM majors' biology, students' beliefs and attitudes surrounding science became more positive and their self-efficacy and ability to communicate and apply science content to contexts outside of the classroom also were positively impacted. Students were also more confident of their ability to evaluate science as presented in the popular media following the course. While this identity work was taking place, the students also had opportunities to demonstrate and further develop scientific literacy skills, such as the application of content knowledge and communication of scientific ideas, along with highlighting the importance of their evolving beliefs, attitudes, and interests in science.

Non-science majors are frequently overlooked when considering research in science education, as research centered around undergraduates tends to focus on STEM major retention or interest, rather than the STEM identity work of those students who have chosen a major in a different field. Therefore, this research contributes to the body of literature with undergraduates in STEM courses, along with literature centered on identity work, which tends to focus on younger age groups (K-12 grades).

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In 1999, *The Lancet* published a now-infamous paper by Andrew Wakefield connecting autism with the measles, mumps and rubella (MMR) vaccine. Since that time, the connection between autism and the MMR vaccine has been examined and debunked in numerous studies worldwide (e.g., Chen et al., 2004; Farrington et al., 2001; Flaherty, 2011) and the Wakefield paper was retracted in 2010 due to issues with the experimental design and bias in the researchers, leading to unsupported conclusions (Eggertson, 2010). However, the effects of this paper were devastating in terms of decreased herd immunity to measles and MMR vaccination rates, of which we are still seeing the aftermath in terms of measles outbreaks and anti-vaccine campaigns (Centers for Disease Control and Prevention [CDC], 2019; Hoffman, 2019). Between the publishing and retraction of the Wakefield paper, the popular media and celebrities have used their platforms to share this paper and their views connecting autism and vaccines widely. This is one example of why scientific literacy is a necessity in the population as a whole – while the peer review process uncovers many issues with research, if the public has a higher degree of scientific literacy, it is more likely that they will make decisions and form beliefs based on sound science. This has important implications in many areas such as public health, climate change, along with personal purchasing and voting decisions.

When *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1990) was published, concern about the state of science education in the United States was high, with K-12 students ranking toward the bottom in international science and mathematics assessments and average performance lower than it was in 1969. At that point, the recommendations for reform in science education were centered around increasing scientific literacy and understanding of the nature of science along with teaching content. Nearly 30 years later, the National Academies of Sciences, Engineering, and Medicine (NASEM, 2016) continued to advocate for scientific literacy beyond just science content knowledge. Increased scientific literacy benefits the individual in terms of access to science and technology-based employment and the ability to synthesize and respond to science in daily life (Hodson, 2014b), and a societal benefit of scientific literacy is increased civic engagement (Rudolph & Horibe, 2016). Scientific literacy affords the general public the ability to face the domains of science for use or production in society, and thus one goal of science education should be to produce citizens who are involved in the community (Rudolph & Horibe, 2016). Additionally, a more scientifically literate population is important for holistic national advancement and is more supportive of scientific endeavors, and views science as important for an individual to function and make informed decisions in an increasingly scientific and technological society, be well-educated, or appreciate science (Laugksch, 2000; NASEM, 2016). With the increasing importance of scientific literacy to laypersons, we need to know how to encourage scientific literacy specifically in the population of non-STEM majors.

Approximately 45% of college graduates major in a STEM discipline, and therefore 55% have not majored in STEM (National Science Board, 2018). Scientific literacy can be viewed as a combination of scientific problem-solving, conceptual knowledge, and the communication of such knowledge (Holbrook & Rannikmae, 2007), and this attribute is important for the development of functional citizens (Roth & Lee, 2004). One important way that many people interact with science is through popular media, which contains multiple science or environmental stories each day, and it is sometimes challenging to sort through the perspectives provided (Hoffman, 2019). Because of this, it is important to encourage the development of scientific literacy in the population, and colleges and universities are in the unique position to teach this skill to their student populations. Towards this end, many colleges require non-science majors to take some science courses. However, these courses are likely to be introductory courses designed to either weed out potential majors or provide a foundation for future learning (NASEM, 2016), rather than prepare scientific literate citizens to engage with science in the very place they are most likely to encounter it, in popular media (Parkinson & Adendorff, 2004). Thus, we do not know how such intentional instruction leads to increased scientific literacy and to building non-STEM majors' identities as science people.

It is important to consider that students who choose a major outside of STEM report that they do not identify as "science people," or have high anxiety toward the subject (Partin & Haney, 2012), but this does not mean that they cannot begin to identify as science people through positive and applicable experiences with science (Garcia et al., 2015). Examining the theories of STEM identity development and identity work more closely, we find many common themes regardless of the context. These themes include recognition of self and by others as a science person (e.g., Chemers et al., 2011; Rodriguez et al., 2019), a sense of belonging and encouragement in science (e.g., Perez et al., 2013; Rainey et al., 2018; Robinson et al., 2019), and self-efficacy in learning and doing science (e.g., Chemers et al., 2011; Potvin & Hazeri, 2013). Additionally, using individual interests to engage students in science is important in their identity work (e.g., Dou et al., 2019; Kelly et al., 2017). Frequently, the importance of feeling like a science person is connected to persistence in STEM, but this idea can also be expanded upon into the non-science major context. In this context, students participate in science identity work within the context of the science classroom to successfully learn science (Brickhouse, 2001; Brickhouse et al., 2000) and to view themselves as science people so they may interact confidently with science material outside of their formal science experiences (Hazari et al., 2013). In this way, science identity work by non-STEM majors is connected to their scientific literacy.

In general, non-science majors enter a science course feeling high levels of science anxiety (Desy et al., 2009) and low perceptions of their ability to learn and do science (Baldwin et al., 1998; Cotner et al., 2017; Sorby et al., 2006). Therefore, particular considerations regarding how to best engage this group in the subject are important. This has implications for the development of scientific literacy beyond the classroom as well; specifically, engaging students in the content and how it applies to life outside of the classroom contributes to overall scientific literacy (Scharmann & Harty, 1986).

Historically, science instruction and curriculum development at the undergraduate level have been under scrutiny due to the lack of applicability of content knowledge to students' lives and their current or future needs, but scholars and science educators feel that science courses offer the best opportunities for students to develop scientific literacy (Scharmann & Harty, 1986). Even 30 years ago, there was a call for a change in undergraduate science education. In particular, the appeal was for undergraduates to learn a combination of scientific content knowledge and a context for science in students' personal lives and within society, along with more information on potential career pathways (Scharmann & Harty, 1986; DeHaan, 2005). Implementing such changes in undergraduate science education first requires an examination of which instructional methods best support these ideas. Pedagogical changes, such as adding course-based research experiences (Ballen, et al., 2017) or integration between disciplines (Bozzone & Doyle, 2017) have the potential to capture the attention of all students enrolled in an introductory science course, rather than solely a small subset of highly interested students. Additionally, designing science courses for non-STEM majors that engage students in constructivism or outside interests is also important, as it results in significant increases in students' understanding and performance on tests, confidence, engagement, critical thinking skills, and interest in teaching engineering and science (Hargrove-Leak, 2012; Partin & Haney, 2012; Rowe et al., 2015; Sorby et al., 2006; Weasel & Finkel, 2016).

A complete re-design of introductory STEM courses is not always necessary to have an effect on student learning or scientific literacy development. For instructors, reflecting on teaching methods, utilizing clickers or integrating other active learning methods to impact instruction into existing coursework is important (Jin & Bierma, 2013; Krajewski & Schwartz, 2014; Wilke, 2003). In particular, it is important to note that for non-STEM majors taking science classes, encouraging self-efficacy in terms of their ability to learn and do science successfully is important, because they frequently enter a science class feeling negatively about these abilities (Baldwin et al., 1998; Cotner et al., 2017; Desy et al., 2009; Sorby et al., 2006).

Engaging undergraduates in learning science is important, and there are multiple methods that can be employed to do so, particularly by starting with prior knowledge or interests. Teaching students to find and utilize reliable sources by leveraging their knowledge and use of technology is an important goal of science education (Halpin, 2016). Undergraduate non-science majors can also be engaged through novel curriculum or experiences (Garcia et al., 2015; Metz et al., 2014). Another way to engage non-science majors through content is to use relevant topics to organize a course, such as using diseases to teach biological themes (Garcia et al., 2015), or through analogies that are familiar to non-STEM majors (Seiler & Huggins, 2018). An additional consideration when teaching non-STEM majors science courses is the content to include (Hott et al., 2002). In particular, recommendations of genetics content as part of genetic literacy for non-STEM majors has been examined due to the increasing advancement of genetics but the corresponding low levels of understanding of genetics in society (Bowling, et al., 2008; Hott et al., 2002). This is important because "these courses serve both as 'gateways' for STEM majors, as well as a 'last exit' from science for non-STEM majors" (Weasel & Finkel, 2016, p. 44).

Previous studies work together to suggest methods to re-design courses specific to the non-STEM major population, with the goal of increasing the scientific literacy of citizens as a whole, but do not address science identity within this population, and are primarily quantitative. This study adds to previous findings and addresses a gap in the literature, because it is specifically focused around STEM identity work in populations of undergraduate non-STEM majors and the ways in which they demonstrate scientific literacy, which is a population that is not the focus of prior research. This research focuses on the beliefs of a group of non-science majors enrolled in a general education course, aiming to learn more about their perceptions of themselves as science people, the identity work they engage in during the course, and demonstrations of scientific literacy.

Research Questions

1: How did non-STEM majors' perceptions of themselves as science people change through the course of a semester?

2: How did non-science majors engage in identity work in a non-STEM majors biology course?

3: How did non-STEM majors demonstrate their scientific literacy through engagement in biology coursework (focusing on a project examining science in the news)?

Chapter II: Conceptual Framework and Literature Review

This study is framed by the theories of science identity and identity work (e.g. Calabrese Barton et al., 2013; Carlone & Johnson, 2007). For non-science majors, a focus on science identity work is important, especially as they interact with scientific material within the classroom context and beyond.

A. Conceptual Framework

This study was framed by the theory of science identity work, which is influenced by more general theories of STEM identity or identifying as a science person, along with scientific literacy. Generally, a science person is one who views science as a part of themselves (Hazari et al., 2013), and is the result of a composite of behaviors and experiences in science (Vincent-Ruz & Schunn, 2018).

1. Science Identity Work

There are several main themes throughout the theories of STEM identity and identity work, regardless of the context. These themes include recognition of self and by others as a science person (e.g., Chemers et al., 2011; Rodriguez et al., 2019), a sense of belonging, encouragement, or recognition in science (e.g., Perez et al., 2013; Rainey et al., 2018; Robinson et al., 2019), and self-efficacy in learning and doing science (e.g., Chemers et al., 2011; Potvin & Hazeri, 2013). Additionally, integrating other interests to engage students in science is important in supporting their identity work (e.g., Dou et al., 2019; Kelly et al., 2017). Therefore, a definition of science identity work combining these ideas is useful: one is engaging in identity work when they recognize themselves or are recognized as a science person, feel a sense of recognition in science, and engage in scientific performances.

Related to the social practice of learning, Carlone and Johnson (2007) asserted that science identities are enacted through performances for others who recognize the performer as competent. This idea has strong implications for how identities might be developed through membership in a learning community as well. If one is involved in such a relational learning experience, it follows that their identity would continue to evolve through learning experiences. Taking a step back from how learning occurs and looking specifically at how students develop their own identity, Erikson (1968) referred to the end of childhood and the beginning of adolescence particularly important for identity formation in general. This encompasses all of the adolescent's previous identities and more, including those regarding what the child wanted to be and was forced to become as well as what they hope to become in the future.

Specifically, a person's science (or STEM) identity can be defined as "the sense of who students are, what they believe they are capable of, and what they want to do and become in regard to science" (Aschbacher et al., 2010, p. 566; Brickhouse, 2001). A science identity can also be constructed during this time of identity development and is at least partially influenced by peers and educators (Carlone et al., 2015). Related to science identity theory, identity work specifically refers to ways in which students take on particular identities at various times through specific actions and relationships (Calabrese Barton et al., 2013). This is especially important in considering required coursework not related to students' major studies, such as general education courses at a university. How students learn material in such courses calls on them to do identity work in the subject area (Calabrese Barton et al., 2013).

In terms of how to define and study STEM identity and identity work, Carlone (2012) said that there are three important things to consider: “first, identities are formed in practice. Second, people have a say in who they become (agency), but that agency is often limited…Third, social identification occurs within and is influenced by multiple timescales” (p. 11). Previously, Eccles (2009) discussed that social factors were important in identity development along with the actions a person took. Specifically, whether a person believed they would be successful in science was partially due to actions of family, friends, and teachers. Eccles (2009) stated that identity can be modeled by a combination of three components: value of membership in a particular identity group, beliefs about the content of the identity, and self-efficacy regarding the ability to portray a specific identity. Finally, Johnson and colleagues (2011) noted that “when people author identities, they perform combinations of behavior, speech, and artifacts perceived as ‘appropriate’ as they enter new settings, drawing on their histories as resources for these performances” (p. 344). In summary, context, agency, time, and social factors are all important in STEM identity development.

Generally, the purpose of studying science identity is coupled with a study of learning. Brickhouse (2001) described the relationship between identity and learning, saying that individuals’ engagement in science is as important, if not more so, than their content knowledge. Additionally, the actions of science in the classroom that are most valued are generally those with a close match to what a practicing scientist does. Educators are important in STEM identity development, and can have either positive or negative influence over this (Aschbacher et al., 2010; Calabrese Barton et al., 2013). However, this type of science identity may or may not be valued by students, and therefore they may not see it as something they would like to take on. This is especially true for non-STEM majors who are not looking to enter science careers, because they would not value a STEM identity in this way. Thus, it is important to demonstrate other aspects of a STEM identity that would be valuable to them to succeed in science classes, their chosen careers, or as citizens. Likewise, school science often does not allow the students to "pursue different aspects of a problem or devise a variety of ways of showing what they know," (Brickhouse et al., 2000, p. 455), which suggests that a way to nurture science identity development is to allow engagement with the content in different ways. Brickhouse (2001) noted that encouragement in identity development from teachers is particularly important for all students, and that "science teachers might consider how science might play a part in the identities-in-practice of science-fiction enthusiasts, computer jocks, or writers" (p. 289).

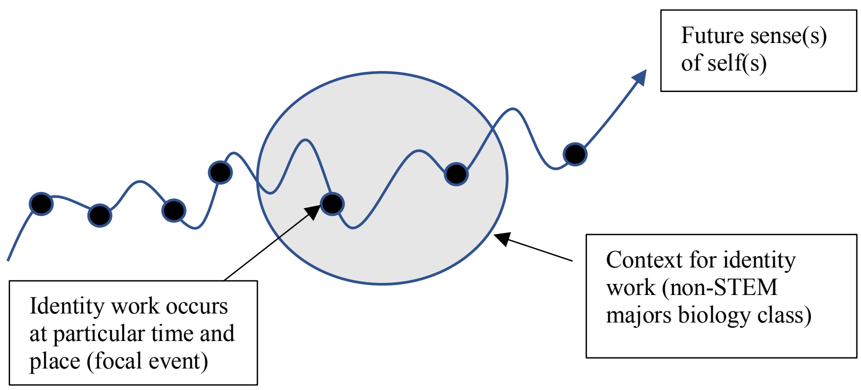
While change in identity can be measured over years, individuals engage in identity work towards these identities that can be identified in moments and within specific contexts. Calabrese Barton and colleagues (2013) did not solely study science identity, but also focused on individuals' identity work. They described identity work as follows:

> By identity work we refer to the actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment and as constrained by the historically, culturally, and socially legitimized norms, rules, and expectations that operate within the spaces in which such work takes place. (Calabrese Barton et al., 2013, p. 38)

This implies that identity work is ongoing and fluid for an individual based on a particular context or situation, and in terms of students who are non-STEM majors, this concept might be more useful to consider. Because individuals in this group do not need to identify as science people to succeed in their major program or career, they are unlikely to develop a salient STEM identity. However, to be successful in a science course they can engage in "identity work" as described above. In this case, the potential spaces the non-STEM student is operating within are the STEM class in which they are enrolled as well as opportunities outside of class when they interact with science in their lives.

Figure 1

Configuring Identity Trajectories



Note. Adapted from "Crafting a future in science: Tracing middle school girls' identity work over time and space" by Angela Calabrese Barton, Hosun Kang, Edna Tan, Tara B. O'Neill, Juanita Bautista-Guerra, and Caitlin Brecklin, 2013, *American Educational Research Journal, 50*(1), p. 66. Copyright 2012 by American Educational Research Association.

Additionally, students' relationships with classmates as well as actions they take while in class allow them to take on a science person identity. Figure 1 shows how identity work can be conceptualized as occurring in various times and places, and is not a straight trajectory. It is important to note that identity work occurs in specific contexts, and that artifacts can be examined to learn about how this work is undertaken (Calabrese Barton et al., 2013).

To study ways in which identity work takes place, Carlone et al. (2014) followed students who moved from enjoying science to disliking it within two years. In this case, important factors in studying the students' identity work included the examination of students' identities in the science classroom through "scientific performances" (p. 837) and what was valued by peers and teachers during these performances. Additionally, identity work was observable through the ways these actions either matched or conflicted with classroom norms along with the resources students utilized to "construct meanings of their experiences and themselves" (p. 837).

Discourse is also important in identity work, especially how students began to refer to themselves as engineers who are doing engineering (Kelly et al., 2017). As students participated in engineering challenges, they engaged in identity work in engineering through discussions with their peers and teacher. The teacher encouraged this identity work by "naming and addressing students as engineers, naming practices of engineering, using [an] engineering storybook as [a] mediating tool…[and] recognizing students' activities as engineering" (Kelly et al., 2017, p. 51). Students gained engineering content knowledge along with recognition as engineers by the teachers, themselves, and their peers.

Identity work may occur as part of salient identity development, but may not culminate in a student taking on a science person identity entirely. In science, identity work has been observable as students recognizing themselves or their peers as scientists or educators recognizing students as scientists (Rodriguez et al., 2019), an increase in students' self-efficacy in science (Eccles, 2009), using tools to engage in learning (Kelly et al., 2017), and talking about science (Dou et al., 2019).

Overall, understanding how students are engaging with the material in science classes and how that impacts the way in which they perceive themselves are important in order to grasp what they are learning (Brickhouse, Lowery, & Schultz, 2000). When individuals participate in novel scientific experiences, peer support is important in the development of a science identity (Carlone et al., 2015). For students to successfully learn science, they must construct "identities compatible with science identities," (Brickhouse et al., 2000, p. 443).

In the non-STEM majors biology class context, identity work refers to the ways in which students within a science class act like scientists or describe themselves as science people (Calabrese Barton et al., 2013; Carlone et al., 2014). While science identity work and its relationship to learning has been examined in children and adolescents (Carlone et al., 2014; Kelly et al., 2017), undergraduate students also engage in identity work within a science classroom while learning scientific concepts and applying them to other contexts. For elementary students learning engineering, it was important that teachers provided experiences for their students to be engineers, that collaboration was a part of their learning, and that the teacher recognized the students as engineers (Kelly et al., 2017).

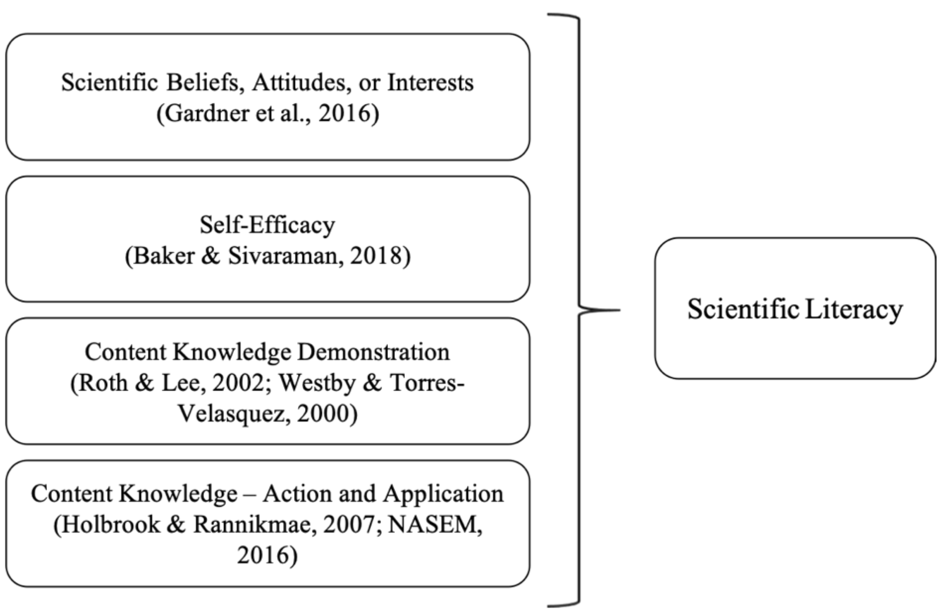
This was similar for female undergraduate STEM majors, for whom recognition was integral to their successes in STEM (Carlone & Johnson, 2007; Rodriguez et al., 2019). While there is a lack of literature on STEM identity development and identity work in undergraduate non-science majors, it is reasonable to extend ideas to this group because they also engage in courses to learn science and become more scientifically literate citizens (Roth & Lee, 2004). Along with simply learning science content, it is important for non-STEM majors to increase in their scientific literacy to encourage scientific engagement as citizens (Roth & Lee, 2004; Rudolph & Horibe, 2016). This also requires development of a science person identity, and a course and project designed to encourage such identity work for non-STEM majors is an ideal context to nurture such development.

2. Scientific Literacy

There are multiple definitions of scientific literacy found in the literature, and studies surrounding these various definitions are found in the literature review in the next section. To understand non-science majors' scientific literacy, I focused on four main facets shown in Figure 2 as guided by previous literature. These four aspects of scientific literacy were (1) scientific beliefs, attitudes, and interests (Gardner et al., 2016); (2) self-efficacy (Baker & Sivaraman, 2018); (3) demonstration of science content knowledge (AAAS, 1989; NASEM, 2016; Roth & Lee, 2002; Westby & Torres-Velasquez, 2000); and (4) application of or action surrounding science content knowledge (Holbrook & Rannikmae, 2007; NASEM, 2016), and I will describe each of these below.

Figure 2

Components of Scientific Literacy



Scientific literacy is partially informed by individuals' scientific beliefs, attitudes and interests (Gardner et al., 2016). This "affective dimension" (Gardner et al., 2016, p. 43) contributes to the ways in which people build an understanding of the natural world in terms of how they process science content in their daily lives. Therefore, the filter that individuals view science content through can both be impacted by the science content they are learning and vice versa. Some examples of beliefs, attitudes, or interests include whether science is personally helpful, frustrating, or intriguing. See Appendix A for the belief, attitude, and interest items used in this study that were adapted from Gardner et al. (2016).

The second part of scientific literacy is self-efficacy, both in terms of the knowledge students possess and the feeling that they are able to learn or do science (Baker & Sivaraman, 2018). In general, when students saw increases in grades, they reported higher self-efficacy in understanding the content delivered in science courses. In turn, when students felt confident in their content knowledge they also demonstrated further self-efficacy during laboratory exercises. Likewise, self-efficacy was evident through collaboration in the lab, where not only the top students were willing to contribute to the understanding of the group but all students provided input to further the group's knowledge as a whole (Baker & Sivaraman, 2018).

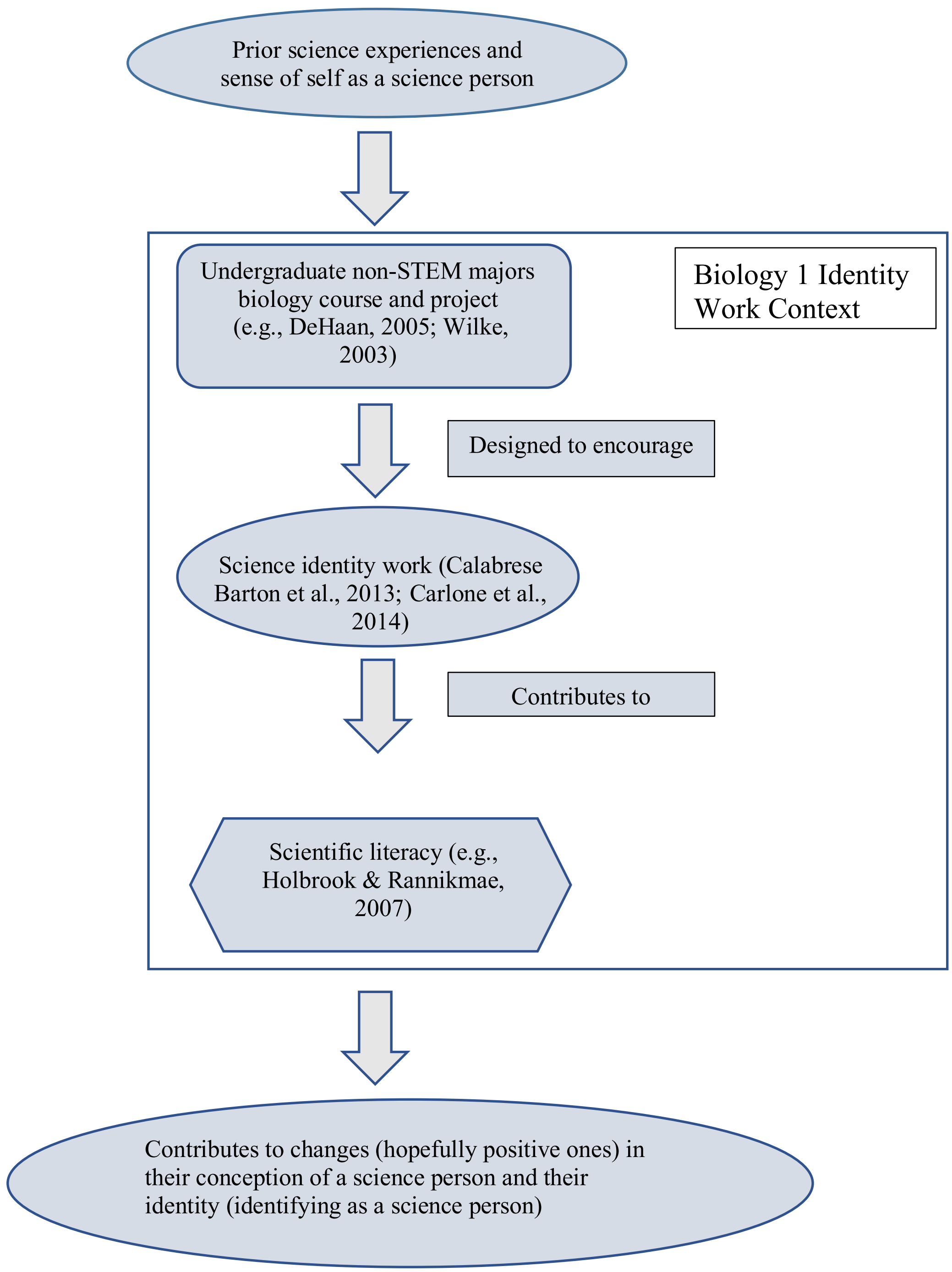
Demonstrating content knowledge is the third aspect of scientific literacy (AAAS, 1989; NASEM, 2016; Roth & Lee, 2002; Westby & Torres-Velasquez, 2000). Such demonstrations are not necessarily in exam formats (Benjamin et al., 2017), but can also be shown through presentations or discussions (Tinsley, 2016; Westby & Torres-Velasquez, 2000). Such knowledge includes more than just a recitation of definitions, but includes connection-making between topics (Rathburn, 2015), placing the scientific content knowledge in context (Roth & Lee, 2002), and forming opinions or making decisions based on science content knowledge (Tinsley, 2016).

Finally, action surrounding content knowledge is important for scientific literacy (NASEM, 2016, Laugksch, 2000; Rudolph & Horibe, 2016). In particular, applying science knowledge to civic engagement (Laugksch, 2000; Rudolph & Horibe, 2016) or socioscientific issues (Sabel et al., 2017) are important for 21st century citizens who are not in a STEM-based career. Additionally, scientific literacy has implications for how individuals engage with science in society, along with how scientific information is contextualized and utilized by the citizenry (Laugksch, 2000).

Science identity work along with scientific literacy were used to frame this study, within the context of a non-STEM majors' biology class. In particular, I examined how students engaged in identity work along with how they demonstrated scientific literacy. I was interested in learning more about the impact their engagement in identity work and resulting scientific literacy had on their ideas of what it meant to be a science person in general, along with how they felt about themselves as science people. Figure 3 on the following page shows the overall relationship between the research context, science identity work, and scientific literacy.

Figure 3

The Relationship Between the Research Context, Students' Identity Work, and Scientific Literacy



B. Literature Review

The literature below encompasses a further discussion of STEM identity in people from kindergarten through graduate school, along with a discussion of scientific literacy. This provides a basis for this research, along with demonstrating the gap this fills in terms of studying non-science majors.

1. STEM Identity and Identity Work

In general, the motivation of studies framed by science identity has been to find ways to recruit or retain students in STEM or nurture interest in STEM subjects. The purpose would be slightly different for faculty teaching non-STEM majors. In this case, contributing to their general scientific literacy is likely more important than trying to recruit this population of students into STEM majors. Within both populations of college students (STEM and non-STEM majors) there are some who are concerned with learning science primarily to succeed in class, but regardless of student motivation STEM faculty should consider the ways in which STEM identity contributes to student learning and attitudes toward science. For example, viewing and talking about science as a subject that is accessible to everyone rather than just for certain types of people is important in encouraging science identity development and identity work (Aschbacher et al., 2010). Additionally, the notion of identity work is potentially more useful for faculty teaching non-STEM majors, as it is important for all students to take on a STEM identity in specific contexts to successfully learn science (Brickhouse, 2001; Brickhouse et al., 2000) and to view themselves as science people so they may interact confidently with science material outside of their formal science experiences (Hazari et al., 2013).

In general, most college students do not think of themselves as science people, which is problematic, because the purpose of science education should be at least partially to impact the willingness and ability of society as a whole to engage with scientific issues (Hazari et al., 2013). Certain stereotypes of science and scientists can negatively affect STEM identity, belonging, and career interest for female students in particular, especially if they view science as nerdy or masculine (Starr, 2018). Additionally, explicitly supporting non-STEM majors in STEM helps mitigate a lack of belonging or self-efficacy for this population in these courses, through methods such as content help or encouragement by the professor (Robinson et al., 2019). Content help includes tutoring or office hours, while encouragement is usually informal recognition of students' improvement or successes. This is a promising way to encourage identity work throughout a curriculum for non-STEM students.

Development of curriculum for non-STEM majors taking STEM courses should include a way for students to engage in identity work. A place to begin with curriculum development is to consider how to build interest in STEM for non-STEM majors or leveraging previous interests or knowledge (Renninger, 2009). For example, nurturing early interest by providing a variety of teaching strategies like working in groups or content that is applicable to life outside of the classroom along with furthering later stages of interest by including more critical thinking or content that challenges previously held notions (Renninger, 2009). This can include teaching students to engage verbally with the science (Brown, 2004), such as through scientific discussions or sharing ideas. Engaging with science through discussions is a part of identity work, as this includes opportunities for building interest as well as recognition by self and others as a scientist.

Beginning with content that is meaningful to non-STEM majors is important and one way to do this is to use current events and relate them to scientific topics. Also related to building interest is encouraging non-STEM students to participate in science discourse in class or through informal experiences such as visits to libraries or science museums (Dou et al., 2019).

2. Scientific Literacy

There have been multiple attempts to define and describe scientific literacy over the past several decades. While the concept of scientific literacy arose prior to the work of the AAAS (1990), the publishing of *Science for All Americans* marked the beginning of current attempts to define and study its complexity. Overall, the concept of scientific literacy is moving away from a primarily content knowledge-based definition, and toward one involving actions surrounding important issues and decision-making related to science (Holbrook & Rannikmae, 2009; Vandegrift et al., 2020). Table 1 below summarizes several of these definitions from the literature, beginning with *Science for All Americans* (AAAS, 1990).

Table 1

Summary of the Definitions of Scientific Literacy from the Literature

Definition	Reference
• understanding of the natural world • awareness of the interrelatedness of scientific, mathematical, and technological disciplines • conceptual understanding • thinking like a scientist • the recognition that science is a human undertaking that is at times robust and limited, • the ability to use both content knowledge and scientific thinking in multiple contexts	*Science for All Americans* (AAAS, 1990)

• scientific literacy should be considered on the level of the community or social context and not solely the individual	Roth & Lee (2002)
• conceptual (science content understanding) • process-based (the nature of science or understanding experimental design) • situational (how science relates to everyday life) • social component in terms of the ability to interact with science along with other people	Holbrook & Rannikmae (2007, 2009)
• learning science—acquiring and developing conceptual and theoretical knowledge • learning about science—developing an understanding of the characteristics of scientific inquiry, the role and status of the knowledge it generates • doing science—engaging in and developing expertise in scientific inquiry and problem-solving • addressing socio-scientific issues (SSIs)—developing the critical skills to confront the personal, social, economic, environmental and moral-ethical aspects of SSIs	Hodson (2014a, 2014b)
• understandings of scientific processes and practices • familiarity with how science and scientists work • capacity to weigh and evaluate the products of science • ability to engage in civic decisions about the value of science	National Academies of Science, Engineering, and Medicine (2016)
• scientific literacy is viewed in terms of behaviors such as evaluation of claims, application of scientific content to decisions, curiosity and questioning the natural world, understanding scientific data, understanding socio-scientific issues	Vandegrift et al. (2020)

There is a high degree of agreement regarding development of scientific literacy as a main goal of science education. While populations of students differ in terms of major courses of study, overwhelmingly the desire of educators to develop scientific literacy for all students is fairly consistent. Differences lie between students or general citizens compared to professional scientists. For example, Holbrook and Rannikmae (2007) distinguished between the importance of teaching science in terms of professional scientists compared to everyone else. They said that in general,

> The science teaching focus is from an understanding of what is important from a scientist's perspective rather than from the viewpoint of the learner, or society. It calls upon students to act as "little scientists", even though they have yet to master the problem-solving and decision making skills that are an integral part of their science learning. (Holbrook & Rannikmae, 2007, p. 1349)

This positions educators to teach what is important and necessary in terms of science literacy in society, and specifically highlights skills central to utilizing science outside of school. Teachers' beliefs about and attitudes toward scientific literacy are therefore critical.

The common aspects of prior definitions and studies include scientific beliefs, attitudes and interests (Gardner et al., 2016; Laugksch, 2000; Ryder, 2001; Tinsley, 2016), self-efficacy in terms of learning and understanding science content (Ryder, 2001), along with content knowledge and how it translates to action in real-life situations (Holbrook & Rannikmae, 2007). These characteristics are best developed by focusing on issues in which non-STEM majors are interested because that will most likely result in higher engagement and scientific literacy (Gardner et al., 2016; Tinsley, 2016), and therefore the goal should be to produce citizens who are engaged with their communities (Roth & Lee, 2002; Rudolph & Horibe, 2016).

Undergraduate students who are not planning to pursue a major or career in STEM still require a set of knowledge, skills, and attitudes to interact with science. Specifically, their beliefs and attitudes toward along with their interest in science are important indicators of scientific literacy (Gardner et al., 2016; Ryder, 2011; Tinsley, 2016). In particular, leveraging student knowledge of and interest in technology, social networks, and other media is a way to observe scientific literacy in action (Greenhow et al., 2015; Takahashi & Tandoc, 2016; Tsai, 2018). Understanding students' confidence in media sources along with their engagement with these sources provides insights into their knowledge and perception of science (Takahashi & Tandoc, 2016). Argumentation surrounding socio-scientific issues resulted in significantly more positive attitudes toward sustainability in undergraduates who participated in six hours of argumentation-based classes compared to those who learned about the same topics via lectures or textbooks (Tsai, 2018). Similarly, utilizing a social networking site as the context for participation in discussions and argumentation surrounding scientific issues showed that students gained the skills of argument formation along with development of skepticism when confronted with new information that had not been verified (Greenhow et al., 2015). In particular, social media or other networking sites provided unique ways for students to participate in discussion surrounding socio-scientific issues, highlighting how important these issues are in leading students to form scientific literacy (Greenhow et al., 2015).

College faculty are in a unique position to foster scientific literacy in their students, whether they are STEM majors or not. This was stated clearly by Glaze (2018), who examined scientific literacy using controversial issues in STEM:

> In addition to controllable factors, such as teaching approaches and exposure to authentic experiences, there are factors such as interest and community support that also impact scientific literacy and how it translates outside of classroom experiences. For our part, university teachers of science have the opportunity to change how we

> approach science teaching in an effort to positively impact both the content elements and the perceptions, as professors are often the only practicing scientists students will encounter. (p. 4)

In this way, STEM faculty can model scientific thinking and actions, provide opportunities for their students to build self-efficacy in science, and teach the content in ways that are not separate from the practices of science, but which are authentically connected to the actions. Additionally, teaching through student-led research on controversial topics can challenge prior knowledge or understanding in STEM that contributes to scientific literacy by encouraging critical thinking surrounding issues in science (Glaze, 2018).

Finally, citizen science is a means to develop broad scientific literacy, usually in the form of content knowledge, engagement, or the ability to form a scientifically-grounded opinion. This is a potential bridge between school science and how it impacts individuals' actions outside of school. Examining undergraduates' participation in a large-scale project provided insight into a number of scientific literacy outcomes, such as increased understanding of content, science as a process, or attitudes toward science, and many scientists and science educators are looking to develop more such projects (Bonney et al., 2009). Involving non-STEM majors in a variety of citizen science projects resulted in high levels of engagement with the projects along with the desire to communicate their results (Kridelbaugh, 2016), along with increased ability to form opinions and find scientific support for them (Sabel et al., 2017). This follows Roth and Lee (2004), who highlighted that scientific literacy is developed by a community of people and not solely the individual.

There have been multiple studies examining scientific literacy in a variety of age groups, focusing on different components, and utilizing a variety of methodologies. Table 2 shows the trends throughout these studies, and also demonstrates the gap in qualitative literature at the level of undergraduate non-STEM majors and how they demonstrate scientific literacy.

In summary, for those who are not interacting professionally with science (i.e. non-STEM majors), it is important to instill what Ryder (2001) referred to as “functional scientific literacy” (p.1). This includes a set of positive set of beliefs and perspectives surrounding science, the attitude that anyone is capable of understanding and interacting with scientific material, and some amount of content knowledge. In particular, scientific literacy for the population of undergraduate non-science majors is best viewed as a combination of scientific problem-solving, conceptual knowledge, and communication of knowledge (Holbrook & Rannikmae, 2007), along with the application of these attributes to real-life situations (Gardner et al., 2016; Holbrook & Rannikmae, 2007). Examining a course and project designed to encourage students’ identity work with the goal of contributing to their overall scientific literacy is important as it fills a gap in the literature on undergraduate science education and science identity for non-STEM majors and adds to the literature on development of scientific literacy. Additionally, the overlap of the identity work and scientific literacy constructs is a novel discussion of how they influence one another, particularly in non-STEM majors.

Table 2

Trends in Studies of Scientific Literacy

Study authors	Age of Population Studied				Component of Scientific Literacy			
	K-12	Higher Ed Non-STEM majors	Higher Ed STEM majors	Grad school/ Career	Content Knowledge Demonstration	Science Beliefs, Attitudes or Interest	Self-Efficacy	Content Knowledge Action/ Application
Baker & Sivaraman, 2018[b]			X		X		X	
Benjamin et al., 2017[b]			X		X			X
Crowell & Schunn, 2016[b]				X				X
Dragos & Mih, 2015[b]				X	X	X		
Drummond & Fischhoff, 2017[b]				X	X			
Gardner et al., 2016[b]		X			X	X		
Gormally et al., 2012[b]		X	X		X			
Greenhow et al., 2015[c]	X	X	X					X
Kridelbaugh, 2016[d]		X						X
Parkinson & Adendorff, 2004[a]			X		X			X
Pelger & Nilsson, 2016[a]			X		X			X
Rathburn, 2015[a]		X	X		X			X
Sabel et al., 2017[c]		X	X		X			X
Tinsley, 2016[b]		X			X	X		
Tsai, 2018[b]	X							X
Vieira & Tenreiro-Vieira, 2016[c]	X				X			X

[a] Qualitative study. [b] Quantitative study. [c] Mixed methods study. [d] Pedagogical recommendations.

Chapter III: Methods

A. Research Context

The context of this study was a non-STEM majors biology class at Canyon University. The university was located on the west coast of the United States and had a student body of approximately 3500 undergraduates (60% female and 40% male). From the university demographic reports, 49% of students identified as white, 14% as Latinx, 11% as Asian, 5% as Black, and 20% chose to self-report as "other" (which included students who are biracial).

The Canyon University general education program included a laboratory science requirement, a common graduation requirement in four-year colleges and universities. This could be fulfilled by taking any lab science the school offers, but some options for lab science courses were specifically geared toward non-science majors. One such class was entitled "Biology 1" and was a broad overview of the subject, including topics such as cellular metabolism, genetics, ecology, evolution, and animal behavior. The course met three times per week: 150 minutes weekly in a lecture hall and 110 minutes weekly in a lab. The general structure of the lecture hall portion of the course included a small amount of direct instruction (approximately 15% of class time), and then students worked together on a variety of activities such as case studies, analyzing data, or discussing a topic. I have been the sole instructor of this course since 2015. The semester of data collection coincided with the COVID-19 pandemic, and therefore face-to-face instruction was cancelled approximately seven weeks into the semester.

Because the main goal for the course was to produce scientifically literate citizens, the final experience of this course was a group project and presentation was focused on interpreting science in the media, one way that people interact with science on a daily basis, and thus an important part of being a scientifically literate citizen. Students were instructed to search the phrase, “a new study says,” find a scientific study that had been reported on in the news, analyze the science behind the story, and connect it to topics from the course. The full assignment details are found in Appendix C. This type of skill development in investigation of science in the news is particularly important for non-science majors, who will utilize this knowledge in the future (Majetic & Pellegrino, 2014). During one in-class workday on their projects, groups of students collaborated to determine whether their chosen topic was based in science or pseudoscience, evaluate how the popular media presented the science, and how the study specifically connected to course content. Groups presented these projects to their peers and instructor for their final experience, and individually they wrote reflections on what they had learned. Peers discussed their topic with each other and this also offered the opportunity to be recognized as having scientific knowledge or as a science person by peers and the instructor.

Students who took the course were primarily junior and senior non-STEM majors who would not change their major to STEM. Most had not taken a science course in many years and their previous experience with science varied widely. The main facets of Biology 1 were case study-based lessons and labs meant to place the students in the role of scientists, and engage them in science practices such as asking questions, designing experiments, and drawing conclusions. This instructional design was purposeful and based upon previous findings that various aspects of active learning had positive results regarding learning and scientific literacy in non-STEM majors science courses (e.g. Hargrove-Leak, 2012; Weasel & Finkel, 2016; Wilke, 2003).

During the semester of data collection, the Biology 1 enrollment was 27 students, most of whom were in their third or fourth year at the university (enrollment for this course ranged over 5 years from 12-30). Of the 27 students in the class, 23 consented to participate in the research project following Institutional Review Board approval, and nine of these 23 participated in focus groups. Demographic information for all 23 participants is found in Table 3, and specific information regarding the nine focus group participants is found in Table 4.

Overall, ten students reported having at least one parent working in a STEM field, and four students were sports medicine majors enrolled in the class as a requirement for graduate school. The courses for the sports medicine major were primarily human anatomy and physiology-based and these students were not excluded from participation in this study because these topics did not overlap with any taught in Biology 1. For the remaining students, majors included advertising, music, international studies, business, public relations, marketing, political science, psychology, and sociology. All students, regardless of major, were invited to participate in the study. Table 5 provides a list of topics chosen by groups for their final presentations, along with the group members.

Table 3

Biology 1 Participant Demographics

Gender		Year in school				Race/ethnicity				
F	M	1	2	3	4	Hispanic/ Latinx	Asian/ Pacific Islander	Black	White	Multiracial
15	8	1	0	11	11	8	4	0	9	2

Note. All information was self-reported.

Table 4

Biology 1 Focus Group Subset Participants

Pseudonym	Gender	Year in school	Race/ethnicity	Major(s)	Parent in STEM field	Focus Group or Interview Number
Clara	F	3	White	Business Administration	No	4
Diego	M	4	Hispanic/Latinx	Liberal Arts	Father	2
Elena	F	3	Hispanic/Latinx	Business Administration	No	3
Felicity	F	3	White	Psychology	No	1
Iliana	F	4	Hispanic/Latinx	Sociology	Mother	2
Jenna	F	4	White	Hispanic Studies and International Political Science	Father	2
Rose	F	4	White	International Studies and Hispanic Studies	No	1
Sophia	F	4	Hispanic/Latinx	International Business	No	1
Theo	M	3	Asian/Pacific Islander	Sports Medicine	Both	3

Notes. All information was self-reported. Two focus groups contained three participants each, one had two, and the final participant took part in an individual interview.

Table 5

Groups and Final Presentation Topics

Group	Group Members (Pseudonyms)	Project Title
1	Leia, Samuel, Adriana, Elena, Liam	Can Excessive Athletic Training Make Your Brain Tired?
2	Jenna, Rose, Sophia, Clara, Isla	A New Study Says: Drinking Coffee Does Not Affect Your Heart
3	Miles, Robert, Alejandro, Diego	Sleep and the Heart: Naps May Be Good for Your Health?
4	Lucia, Viviana, Felicity	Human Body Temperature
5	Analisa, Iliana, Miriam	Cow Com-moo-nication: The Difference Between Moos
6	Theo, Ella, Anthony	Sleep and Academic Performance

B. Data Collection

Data collection occurred in the spring semester of 2020 (January-May). In January 2020, I offered a pre-course survey by email along with the consent forms for final reflections and video and audiotaping presentations, group work, and focus groups. Qualtrics (SAP, 2019) was used for survey data collection regarding scientific literacy and identity (see Appendix A). In April and May, student groups were recorded during the group project workday and their final presentations (only the audio was analyzed but video was recorded to more easily identify speakers), three focus groups and one individual interview were held (see Appendix B), students submitted final reflections, and they completed the post-course survey via Qualtrics. Due to the COVID-19 pandemic and cancellation of face-to-face instruction, all audio and video of the workday and presentations along with the focus groups was collected via Zoom (Archibald et al., 2019; Zoom Video Communications Inc., 2020). All students at Canyon University were offered the option to change up to eight units from letter grades to credit/no credit, but none of the students chose to do so for Biology 1. In this study, I was both the researcher and the instructor, positioning me in the role of participant-observer, specifically as a complete participant (Spradley, 1980). Therefore, all focus groups and data analysis took place following the posting of final course grades. Additionally, while analyzing observational data which I had been a part of (the group workdays and final presentations), I took the stance of an outsider to truly understand the student-instructor dynamic.

To address my research questions, I collected multiple types of data. First, to examine students' perceptions of science identities and scientific literacy (addressing both research questions), I offered a survey in both January and April to see how their self-perceived science identities had changed, if at all (Crowell & Schunn, 2016; Gardner, 2016; Vincent-Ruz & Schunn, 2018). Next, I video and audio recorded participants' project workdays (in groups), video recorded their final presentations, and analyzed their final reflection papers as artifacts. Participating in class discussions requires a particular comprehension of content, phenomena, and application of knowledge (Westby & Torres-Velasquez, 2000). Thus, if students were engaged in classroom discourse, they were constructing scientific literacy. Roth and Lee (2002) added that, "it is in the interaction, in the questions and answers that scientific literacy emerges. The adult's questions are as much a part of collective scientific literacy as the answers they solicited from the student" (p. 282).

Because scientific literacy is not solely an individual attribute, examining interactions between individuals was essential. While Roth and Lee (2002) discussed this in terms of a teacher-student relationship, it is reasonable to extend this to peer-peer interactions as well, because these interactions make up the scientific literacy of the group of peers. Examining how peers discuss science with one another was a way assess this cooperative scientific literacy, specifically coding for language that is rich in scientific descriptions and explanations. Analyzing conversation for support of an argument is also useful in demonstrating scientific literacy, not solely the use of scientific vocabulary (Westby & Torres-Velasquez, 2000). Additionally, conceptual knowledge, scientific problem-solving, and communication of knowledge are all evidence of scientific literacy, which can be demonstrated through analysis of artifacts as well (Holbrook & Rannikmae, 2007, 2009). Artifacts such as writing assignments can also be used to demonstrate how students connect science to their daily lives, which is another way to view scientific literacy (Rathburn, 2015).

Video and audio recordings of the workday and presentations also addressed students' scientific literacy (research question 2). Table 6 provides an overview of the research questions and the data collection methods I used to respond to each question. The pre- and post-course survey in its entirety is found in Appendix A, and the interview protocol is found in Appendix B.

Table 6

Data Sources and the Research Question(s) they Address

Data source	RQ1: How did non-STEM majors perceptions of themselves as science people change through the course of a semester?	RQ2: How did non-STEM majors engage in identity work in a non-STEM majors biology course?	RQ3: How did engaging in biology coursework (focusing on a project examining science in the news) affect non-STEM students' scientific literacy?
Survey	X	X	X
Focus group	X	X	X
Project workday		X	X
Final presentation		X	X
Final reflection		X	X

Focus groups at the end of the semester with nine interested participants were used to concentrate more in-depth on science identity and scientific literacy (addressing both research questions). The focus groups (Krueger & Casey, 2009) encouraged groups of peers to discuss ideas surrounding identity and scientific literacy, to learn more about how students recognized themselves as science people, and more details about their emerging scientific literacy. One participant did not participate in a focus group because of a last-minute schedule conflict and participated in an independent interview instead. The pattern of questioning followed Krueger and Casey's (2009) opening, introductory, transition, key, and ending format to fully focus on identity work and scientific literacy within the participants. The interview protocol in its entirety can be found in Appendix B.

C. Data Analysis

Participant demographics were collected through a self-reported questionnaire at the beginning of the semester, including gender, race/ethnicity, year in school, post-graduation plans, parents' career(s), and the declared major/minor along with a science identity and science literacy assessment. Participants completed the science identity and scientific literacy sections (see Appendix A) at both the beginning and end of the semester. All survey items originated in or were adapted from previous research (Gardner et al., 2016; Vincent-Ruz & Schunn, 2018).

Wilcoxon Rank Sum tests were conducted using students' responses to the Likert identity items to determine how their responses changed from the beginning to the end of their experience in Biology 1. Wilcoxon Rank Sum tests were appropriate because I matched pre- and post-semester survey responses by participant, and this allowed me to determine whether differences in median between the two time periods were significant. The belief items were adapted from Gardner et al. (2016), who utilized a larger set of terms and analyzed them not by level of agreement but rather how students moved from one belief toward another.

Responses to focus group questions, open-ended survey questions, and final written reflections, along with observations of the project workdays and final presentations were coded using the codes of (1) science person, (2) STEM identity work, and (3) scientific literacy (see Table 7 below for these main codes, sub-codes, definitions, and examples). This allowed me to examine how students' ideas of themselves as science people, the identity work they engaged in, and how their scientific literacy changed through the course of the semester in a biology class. Coding of all data was done in two rounds: a priori coding using the main codes of STEM identity work and scientific literacy, followed by coding using the sub-codes to fine-tune the findings.

All qualitative data were coded using talk related to identity and identity work along with scientific literacy. That is, the responses were coded to understand how students performed and described themselves, and the ways others described and recognized them (Carlone, Scott, & Lowder, 2014) along with evidence of scientific literacy, scientific problem-solving, conceptual knowledge, communication of knowledge (Baldwin et al., 1999; Holbrook & Rannikmae, 2007), and foundational knowledge, foundational critical thinking skills, or the application of these two attributes to everyday decision making (Crowell & Schunn, 2016). Table 7 shows the codebook used for coding qualitative data from all sources: focus groups, project workdays, final presentations, and open-ended survey questions.

Table 7

Codes with Definitions and Examples

Code	Sub-codes with definitions	Example(s)
1. Science person	*Description of self as a science person or not* Students saying they are/are not a science person, are/are not a scientist; can/cannot do science (might also include context); qualities they ascribe to scientists that they also say they possess	And so, I think if I can explain something that makes me feel like a science person. (Theo)
2. STEM Identity Work	*Scientific performance* Students verbally presenting scientific information, either formal or informal, to someone else (peer or instructor)	So, when coffee is nitrogen rich, you see the healthy green leaves at the top and when it's nitrogen deficient the leaves are yellow and slowly dying and when coffee is over-fertilized with nitrogen, then the caffeine content is a lot higher than intended. And as we learned in class, the coffee plant takes in

		carbon dioxide from the air, water from the roots and energy from the sun absorbed by chlorophyll. (Group 2 Final Presentation)
	Recognition Back and forth discussion of scientific material (peer-peer or peer-professor); can be positive or negative (someone agreeing or hearing negative reinforcement from teacher/instructor)	Elena: Has the observation given rise to a clear and measurable hypothesis? Samuel: I think if the hypothesis is that overworking your body could have an effect not only on your mental fatigue, or sorry, on physical fatigue, but also on mental fatigue, then I think that's a legitimate hypothesis. Liam: Yes. (Group 1 Workday)
3. Scientific Literacy	*Scientific beliefs, attitudes or interests* Students discuss beliefs/attitudes about science in general, or refer to specific scientific material or science in general as personally interesting, hard, terrible, fascinating, etc.; Also, a comparison between grades and interest	This project now has me looking closer at articles that are in the news because there could be reporting on sources that are not very reputable especially in a time such as these because there can be a lot of misinformation or claims that are not very researched currently. (Anthony final reflection)
	Self-efficacy Description of self as able to learn and know/understand scientific content or not.	It doesn't just naturally click in my head. So, I think it just frustrates me because I actually have to really try hard. And if I think about it, I think I got it, I really don't have it. (Sophia)
	Content knowledge demonstration Students sharing content knowledge (verbal or written) and/or the nature of science/publishing, including discussion of credentials, pseudoscience/science	So first we'll discuss a little information about coffee and connect it to the topics we learned in class and then we'll use factors to determine whether the article is based on real or pseudoscience and how closely it follows the scientific method. And finally, we analyze if the new story accurately conveys information from the scientific study. (Group 2 final presentation)
	Content knowledge application Description of ways in which content was used in "the real world" or any applications, also examples they give, also includes what they will look for in news reports or studies to verify the science	Being able to understand and act on scientific claims, particularly as they affect cells and our bodies, is vitally important to not just believe the claims being made in popular media, but understand them and be able to explain and justify them. (Jenna, final reflection)

To organize the findings, I began with the main codes (science person, identity work, and scientific literacy), and proceeded by exploring themes within the sub-codes. Additionally, as I was coding the data I noticed that there was overlap in the literature surrounding science identity work and scientific literacy, so I created a matrix in NVivo to explore where the data did and did not demonstrate this (Maxwell, 2013). The intersection of identity work and scientific literacy is explored in Chapter VII.

The codes were discussed with another researcher, and we then independently coded approximately 40% of the qualitative data across all sources (open-ended survey questions, focus groups, group project workdays, final presentations, and written reflections). We reached a Cohen's Kappa of 0.841, verifying that agreement between raters exceeded chance.

Chapter IV: What Does it Mean to be a Science Person?

"Everyone is a science person, they just may not know it." – Analisa

My first research question surrounded the idea of what it means to be a science person and how participants identified themselves as such. Specifically, I wanted to uncover how non-STEM majors' perceptions of themselves as science people change through the course of a semester. This chapter will examine what it meant to be a science person according to this group of non-STEM majors, along with the experiences the participants had prior to Biology 1 that impacted their feelings of themselves as science people and how their perceptions of themselves changed. In this chapter, I (1) present findings from the survey data, including how participants described a *science person,* along with how their feelings of themselves as science people changed over the course of the semester, followed by (2) findings about how participants identified as science people or not due to a variety of reasons. Considering students' identity work prior to completing Biology 1 and their ideas about whether they felt they were a science person or not was a key consideration, as this affected their identity work during the course as well, which will be discussed in the following chapter.

A. How Biology 1 Students Defined "Science Person"

All 23 survey participants were asked to describe what they thought it meant to be a science person, which allowed for understanding what participants meant when speaking of themselves as science people and the development of a definition of "science person" by this group of non-STEM majors (Carlone, 2012). The survey responses defining “science person” are summarized in Table 8 below.

In their initial survey responses, the most frequent attribute participants noted was that a science person is one who is interested in science (8 responses). For example, Elena wrote that a science person, “enjoy[s] science-related topics.” Participants also shared that a science person is someone who expresses scientific curiosity, specifically outside of the classroom context (7 responses). For example, Rose stated that this is, “[s]omeone who is curious about the natural world and actively seeks to obtain more knowledge about the things around them.”

Studying science and being good at school science were not always intertwined requirements for being a science person in these responses. For example, Miles stated that, “a science person feels as though their strongest core subject is science,” and Theo wrote that a science person is “engaged in the study of science.” They each described an aspect of learning science, but Miles felt that it was necessary to be successful. However, for Theo it was important to study the subject, whether successful or not.

Table 8

What is a Science Person? Survey Responses

	Pre-semester survey	Post-semester survey
Interested in science	8	11
Skilled or gifted in science	4	6
Express scientific curiosity outside of school context	7	3
Knowledgeable about science	3	5
Studies science	4	5
Good at school science	3	0
Practicing scientist or actively doing science	0	4

In the post-semester survey, participants described science people in similar ways as they did in their initial surveys. As with the pre-semester survey results, interest was the top characteristic mentioned, but more participants included this attribute in their description (11 responses). For example, Clara wrote that a science person is “interested in and naturally understand[s] scientific concepts.” Similarly, Isla wrote that to be a science person is “[t]o be really knowledgeable and interested in science.” Simply doing science was a quality of a science person that four participants included in their responses, which was unique from the pre-semester survey. For example, Robert wrote that a science person is “an individual who studies the world and its processes around us.” He separated this idea from studying science in school or as a career, and rather applied the idea to a more general context.

While some differences were evident in the pre- and post-survey responses, the ideas shared by participants regarding the description of a science person were generally the same. Most notably, being successful at school science was not suggested as part of being a science person in the post-semester survey, but actively doing science in some way was. In her final survey response, Analisa described a science person as follows:

> To be a science person is to express curiosity in the everyday things. Whether that be routine occurrences or a rare phenomenon, one can be interested in science and not even know it. Everyone is a science person, they just may not know it.

This echoes previous work in which identifying as a science person was related to studying science in school (Brickhouse et al., 2000; Calabrese Barton et al., 2013), or having outside interest in science (Hughes et al., 2013).

Participants were also asked to what extent they agreed with the statement “I see myself as a science person.” Results from this survey question are found in Table 9 below.

Table 9

Pre- and Post-semester Survey Responses to the Question: "I See Myself as a Science Person"

Response	Pre-semester Survey	Post-semester Survey
Strongly agree	4	6
Agree	5	6
Neutral	3	6
Disagree	7	5
Strongly disagree	4	0

These results showed that participants' ideas of themselves as science people shifted in a generally positive direction, with zero students strongly disagreeing that they felt like science people following their experience in Biology 1. Overall, participants moved from neutral toward agreement with the phrase "I see myself as a science person." The median score on this survey item shifted from 3 (neutral) on the pre-term surveys to 2 (agree) on the post-term surveys, and that shift was statistically significant using a Wilcoxon Rank Sum test ($p < .01$).

For students in science courses meant for non-STEM majors, this is important information regarding their recognition of themselves as science people, because it demonstrates an outcome of their identity work while in the classroom context (Carlone et al., 2014). This will hopefully result in a continuation of this identity work in future contexts when interacting with scientific material as well as solidifying a science identity (Calabrese Barton et al., 2013).

B. Prior School Science Experiences

Science identity work can and should be recognized by peers and science educators (Kelly et al., 2017). The impact of this recognition was evident in that school science experiences played an important role in terms of how Biology 1 students viewed themselves as science people or not prior to their experiences in the course (Calabrese Barton et al., 2013). Identity work for undergraduates may be noticeable while engaging in undergraduate research, including course-based research (Robnett et al., 2015), courses designed specifically for non-science majors to engage in identity work (e.g. Bozzone & Doyle, 2014; Garcia et al., 2015), or opportunities for students to experience success and enjoyment in learning the content (Calabrese Barton et al., 2013). Likewise, expanding the idea of school science to include students' outside interests within the classroom context can also provide the opportunity for engagement with science and therefore an environment in which science identity work can take place (Carlone et al., 2014).

Participants felt that success in school science validated their perceptions of themselves as science people. Five of the nine focus group participants discussed grades as a factor in feeling like a science person. For example, Elena said she felt like a science person "when I d[id] well in the class," (Line 100). Sophia expanded on this idea, considering how success in class made her feel like a science person in that particular context, but considered how this impacted her life outside of biology coursework:

> Being successful in the class of science can make me sort of a science person, but I feel like it's a very limited scope. Like, I'm a science person from that class specifically, not, like, I am now a science person outside of, like, life, you know that one area. But I think, like, the things I've learned from the class could be applied to my life. (Lines 406-10)

While Sophia initially considered the course as separate from her life, as she was talking through this idea she was clearly connecting the material from the classroom context to science she might encounter outside of the classroom. This recognition of her ability to apply what she had learned outside of the classroom context is important in demonstrating science identity work (Carlone et al., 2014; Kelly et al., 2017).

Generally, success in science in terms of grades has been shown to affect students' science identity in elementary school (Brickhouse et al., 2000). At the same time, this contradicts results from the survey, where success in school science was not included in the definition of a science person given by participants. From the survey results, it is possible that participants did not feel that high grades in science courses was the most vital factor in feeling like a science person. However, considering focus group responses, success did have some measure of importance to the participants' science person identity.

While several participants did talk about feeling like a science person hinged on grades, six of the nine focus group participants also shared that a deeper understanding of the science content and how to apply it to their lives was essential. For example, Diego said, "in science class, like, if I understand something, or can make the connection, see it, I'm like, yeah, like, makes me feel good." (Lines 138-9). Likewise, Theo combined the two ideas of success and understanding, saying he feels like a science person, "when I do well in the class. But when I understand the concept and can, I guess, apply it" (Line 103). This expands upon previous findings of success as important but understanding being a marginal factor in science identity work (Brickhouse et al., 2000). Students recognized both factors as important in identifying as science people.

All nine focus group participants shared that they entered Biology 1 with stereotypes of science and scientists from prior school science experiences, and these had an impact on their views of themselves as science people along with providing evidence of identity work.

Following her experience in Biology 1, Elena stated, “I wouldn’t say I’ve become more of a science person, but I will say that I think like some other negative connotations I’ve had have gone away, which is good” (Lines 322-3) Similarly, Clara stated that,

> I guess the stereotype of a science person is that they are less personable, maybe... Or, that they would rather work on science, than, like, speak to someone or write- or read a book, like a, like a fiction book. Like, they only focus on math, facts, and stuff like that. And I don't view myself as that, in that way. So, I think that's how I would not be a science person. But I don't think that's a fair assumption, but that is the stereotype that I have. Yeah, and just having like, I am pretty good at math, but I feel like a real good science person would be very good at math and physics. (Lines 191-198)

Considering negative stereotypes about science or scientists is important in science identity work. In particular, such negative stereotypes hinder engagement in science by women, and this has been negatively linked to science identity (Starr, 2018). Thus, Elena’s dismantling of negative connotations of science or scientists should make her more likely to take on a science identity in contexts where she would utilize it.

However, Clara appeared to be holding on to some of the stereotypes of scientists, making her potentially less likely to take on such a science identity. She did go back and forth, talking about how she feels that she is good enough at mathematics but not very good at math or physics specifically. Sophia said something similar about prior science coursework, saying “I didn’t take physics because that’s just too daunting, because I’m not a science person” (Lines 60-61). This is an important point, that non-science majors view science as mainly math and physics. Clara began to recognize the generalization she had been making, that science is very technical, and broadened her perspective to demonstrate the very different work she was doing in Biology 1:

> Maybe before this class, I wouldn't have thought of it as like science-y, because it wasn't as technical...And I think it is largely viewed as that in that way in different communities, so while, it didn't feel as science-y because it wasn't as like technical. It was just as science-y because we are using like the scientific method, and pseudoscience versus real science, and we were also learning about the coffee plant and how it grows and how it affects the human body. So, there was a lot involved in that, that before I may have not viewed as very scientific, but it actually is. (Lines 211-220)

Previously, an aversion to STEM has been linked to negative experiences with or self-concept in math, physics, and chemistry (Hannover & Kessels, 2004). Therefore, engaging undergraduate non-STEM majors all sciences can contribute positively to their identification as science people, because even if they do not feel like they are mathematics or physics people, perhaps they will identify as such in life sciences.

C. Informal Science Experiences Prior to Biology 1

Informal experiences with science, such as visits to science museums or as a childhood hobby, can build a foundation for an identity as a science person (Campbell et al., 2012; Dou et al., 2019). Such experiences allow for open-ended and interactive exploration of science topics, as well as provide spaces for scientific discussions outside of the classroom as a way to develop a science identity (Dou et al., 2019). As Felicity said, “science museums were always my favorite museums to go to like if we were going on a trip...because they usually have like interactive stuff’ (Lines 68-71). Jenna described a childhood interest in science, stating, “the first thing I remember wanting to be when I was little was a geologist. I was like, so interested in rocks, like I still have the collection because it was like, little gemstones and stuff I found” (Lines 121-4). Jenna decided not to pursue science as a college major or career, but in her survey she agreed that she felt like a science person in general.

Early interests in science have an effect on later identification as a science person (Dou et al., 2019). For example, Rose described the transition from childhood interests to her college major, saying,

> If you look at all my books here, they’re like, philosophy and intercultural communication and stuff like that. But then, like, when I think back to my childhood bedroom, like, my bookshelves were full of books on like dinosaurs, and my wildlife explorer binders, and all this different stuff. And I am not majoring in science, but I can still, I still think I would consider myself a science person, and I think it’s just, like, science can be a hobby. (Lines 384-89)

Rose’s childhood interests in science did not translate to majoring in science or pursuing a career in STEM, but they did result in her having a broader view of what it meant to be a science person. Later, Rose added to this idea, saying, “I think just wanting, like, having a, natural curiosity and then, like, exploring that, like, makes me feel like a science person” (Lines 429-31). Past informal experiences expanded Rose’s ideas of what it meant to be a science person and also represented the contexts that non-science majors are more likely to encounter science. As such, activities that encourage individuals to experience science in contexts outside of the classroom require science identity work and science identity formation in order to successfully interact with and understand science content (Calabrese Barton et al., 2013).

D. Conclusion: Biology 1 Students Entered their College Science Course Lacking a Strong Science Person Identity

In general, students entered Biology 1 with a mixed science person identity, occasionally feeling like science people and in other cases lacking this feeling. Frequently, feeling like a non-science person was attributed to having unsuccessful experiences in previous science courses, feeling a lack of understanding of scientific material, or entering the course with negative stereotypes surrounding science or scientists. At the same time, they did not include "success in school science" as part of their definition of a science person, so how they were defining success might differ. There were ideas participants shared that offer a glimpse of when they did feel like science people in the past, such as informal science experiences that were viewed as fun and interactive, having encouraging teachers, or the ability to apply the scientific knowledge they gained to their lives outside of the classroom. It is important to understand students' perceptions of themselves as non-science people upon entering a class, and the ways an educator can encourage students to work toward identifying as a science person by the end. This idea will be further examined in the subsequent chapters regarding identity work and scientific literacy.

Chapter V: Science Identity Work by Non-STEM Majors

"We're the scientists right now, like, we're solving the problem." – Diego

My second research question examined how non-science majors engaged in identity work in Biology 1. Recall from Figure 3 on page 18, this includes the second and third sections of the flowchart within the Biology 1 context. From prior research, science identity work has been described as the actions and exchanges surrounding science within a particular context (Calabrese Barton et al., 2013). Biology 1 was designed to encourage students' science identity work in a positive trajectory toward a science person identity by creating a space for students to share their thoughts, ideas, content understanding, and insights into the application of scientific knowledge, all of which culminated in their final project presentations. It was important to understand students' participation in the identity work, along with the ways such participation was recognized or described by others (Carlone et al., 2014). In this chapter "positive identity work" refers to identity work that aligned with ways students spoke about or acted like science people.

Biology 1 students' identity work findings are organized as follows: (1) identity work in the context of lab and case study experiences in Biology 1 (Chemers et al., 2011; Potvin & Hazeri, 2013), (2) scientific performance in terms of presentation of scientific material (Hazari et al., 2013), and (3) recognition by others as a science person or as having scientific knowledge (Chemers et al., 2011; Robinson et al., 2019; Rodriguez et al., 2019), because these are three important aspects of identity work.

A. Identity Work in Biology 1: Labs and Case Studies

Participants engaged in identity work in a variety of ways, and differentiated between various contexts and experiences. The participants' characterizations of positive and negative STEM identities primarily fell within the context of school, childhood informal science experiences, science discourse or making connections, and in comparison to characteristics they recognize within science people.

1. Labs Were Key Aspects of Identity Work

In focus groups, six participants shared that engaging in lab was part of feeling like a scientist, which contributed to feeling like a science person and was part of the identity work that occurred during these experiences (Tan & Calabrese Barton, 2008). In her focus group, Iliana shared, "I would say definitely our labs made me feel like a scientist" (Lines 569-70). One such lab was surrounding forensics, where students performed gel electrophoresis, and combined those results with hair, fingerprint, and chemical analyses to solve a crime. Sophia discussed her participation in lab with something she viewed as what scientists do, saying, "I think like, I loved our labs because I felt like a true scientist, like, doing an experiment and getting something out of it and like when we did the DNA...gel" (Lines 173-5). In terms of identity work, providing opportunities for students to act as a scientist is positive in terms of moving her toward a science person identity. Similarly, Theo remarked that active participation in lab made him feel like a scientist, saying,

> So, like, that kind of situation really made me feel like I'm a scientist, you know, like, extracting DNA or running different tests or doing different observations. That made me really feel like, okay this is this is like legit science 'cause it's not like just...reading an experiment or, like, a lab report, like you're, you're the one doing it. (Lines 289-94).

The importance of engaging in the process of science cannot be understated, as experience in a laboratory or course-based research has been positively associated with increased science self-efficacy and science identity development (Robnett et al., 2015). Because many labs for undergraduate science courses do not allow for exploration, adding opportunities for constructing understanding positively affects students' science identity work as well (Kelly et al., 2017).

2. Case Studies Provided Opportunities for Participants to form Identities as Science People

This study revealed that engagement with real-life case studies during class was also part of participants' identity work. An example of a case study used in Biology 1 surrounds the Tylenol cyanide poisonings of 1982, during which students use their content knowledge surrounding cellular respiration and work together to determine what caused the deaths of seven people in the Chicago area along with the biology behind those deaths (Gazdik, 2014). Five of the nine focus group participants discussed the case studies as putting them in the role of scientist, which was a way they engaged in identity work (Archer et al., 2010; Carlone & Johnson, 2007). In particular, they connected their engagement with these case studies to feeling like scientists, in that they were solving a problem, making observations, and connecting the science content to situations outside of the classroom context.

Feeling like a scientist is one aspect of the identity work engaged in by the participants. For example, Jenna said, "the case studies were big for making me feel like a scientist, because I think like they're real world situations" (Lines 588-9). Jenna focused on the application of her knowledge to a situation she might encounter outside of the science classroom as important in identifying as a scientist, which is a manifestation of her identity work (Kelly et al., 2017). Likewise, Diego stated, “we’d get the case studies and we'd go through them and I kind of felt like...we’re the scientists right now, like, we’re solving the problem, we’re figuring out why” (Lines 573-5). In this way, Diego considered problem-solving to be an important characteristic of a scientist, and he noticed that was his role.

Clara connected the case studies to the process of science as well. She specifically highlighted the application of these case studies to contexts outside of the classroom. Responding to the question about what made her feel like a science person in Biology 1, she said,

> All of our activities that we do, like our cases, those were really, it made you feel like you're a scientist ,you know. Yeah, like making one - like making a conclusion off of different observations and just each one like...whether kids should get vaccinations and how that affects them. (Lines 205-9)

Clara, Diego, and Jenna all found real-life applications of science content important in terms of identifying as a scientist or science person. School science standards have moved toward application of content to real-life situations (NGSS Lead States, 2013), and such application engages students with science, positively contributing to their science identity work (Calabrese Barton et al., 2013; Carlone et al., 2014; Hodson, 2014b).

3. Non-STEM Majors Identity Work Should be Separate from STEM Majors

Finally, there is evidence that the design of a course specifically meant for non-science majors impacts STEM identity work. Experiences that are specifically designed for non-STEM majors to engage in this work, separate from science majors, provided a space for students to feel comfortable participating in class and a context in which identity work took place. Five of the focus group participants discussed the importance of having separate biology courses for majors and non-majors. For example, Iliana said,

> I think it makes, like, a more comfortable environment to ask questions and to be like, to like, openly speak out knowing that you could be wrong because like, I feel like if, if it was like non-STEM majors and, like, majors, I think there might be that like, almost underlying stigma, where these non-STEM majors don't know what they're talking about. (Lines 185-9)

Participation is an important factor in identity work because active engagement in scientific activities can be recognized by peers and instructors, which is another vital factor in positive science identity trajectories (Brickhouse et al., 2000; Calabrese Barton et al., 2013).

Felicity recognized the significant role that a non-STEM majors science experience played in helping her to take the first steps toward a science identity. In particular, she said, "I still definitely don't feel like I'm a master or anything, 'cause it was baby bio, but I feel like I can make more of those little baby steps thanks to this first one" (Lines 593-5). In this way, Felicity described her trajectory toward identifying as a science person due to the initial experience in Biology 1, allowing her to rely on this identity work in future science experiences both in the classroom or in outside contexts (Carlone et al., 2014).

B. Positive Identity Work Transpired through Scientific Conversations and Connections

One way students participate in science identity work is by connecting the material learned in the classroom to other contexts (Brickhouse et al., 2000). These connections can be made through conversation (Brown, 2004), the use of current events (Tinsley, 2016), or community-based research (Calabrese Barton & Tan, 2010). All nine focus group participants shared that making connections between material they were learning in class to their lives outside of the classroom was important in terms of feeling like they were learning, successful, or becoming more of a science person. All of these are examples of identity work that took place in the Biology 1 context.

Iliana described this application as making her feel like she was good at science, saying, “I definitely like, like, kind of connecting, like, what we’re learning in class to, like, broader...concepts or something like that...That makes me feel good” (Lines 141-4). Along these lines, Jenna said, “I feel like a science person when I can, like, take something that I am learning and then apply it easily to, like, I don’t know, a given situation” (Lines 506-8). Iliana and Jenna both felt successful at science when they were able to connect the content knowledge to situations they felt they would encounter outside of the classroom. Their identity work as science people therefore hinged on these connections. Frequently, such application happened while participants engaged in science conversation with one another or as a class, which allowed them access to one another’s ideas and expand their own science identity work (Brown, 2004). Diego described the importance of participating in conversations in the classroom, saying,

> I think even being confident enough to ask the question makes me feel good because it’s like, you know, I know enough to phrase this or word this, or even if I don’t [say it] like I want to. So just inherently that makes me feel like, yeah, you know, I’m good at this, I can do this. (Lines 169-73)

By engaging in scientific discourse in the classroom, Diego gained confidence in participating in science identity work and in turn, increased feelings of self-efficacy in science (Brown, 2004).

C. Positive Identity Work in Biology 1 Students Occurred when they Recognized Qualities of Scientists within themselves

Focus group participants shared qualities they ascribed to scientists, and then reflected on the list and discussed the aspects they also saw in themselves. Participants in all four of the focus groups included the following qualities in their characterizations of scientists: smart, inquisitive, curious, and observant. Additional qualities that were shared in one focus group each were: flexible, detail-oriented, logical, determined, problem-solving, analytical, not afraid to be wrong or ask questions, and creative. Participants talked about how they saw some of these qualities within themselves, which provided insight into their own identity work.

Felicity felt that she was observant, and said, "I'm always just like looking around at things, commenting on things, noticing patterns" (Lines 279-80), and comparing this to her characterization of scientists she said, "scientists are smart. They're observant. It's part of the scientific method, you know, make your observations, everything's gonna be based on something around" (Lines 293-5). Felicity described herself as one who noticed her surroundings or made observations, which she recognized as an important part of the scientific process. Theo shared a similar idea about himself, saying, "yes, I notice a lot of little things. I'm curious about a lot of the little things like how stuff happens like why it happens" (Lines 186-7). Jenna also said she was curious, "wanting just to know and understand fully like how so many different facets like of the world today work and like, just like wanting to understand. So, I think that I'm like, I'm just very unafraid to ask questions" (Lines 315-18). Sophia shared,

> I think I'm very determined, if I have my mind set to something like I'll pretty much get it done...for scientists would means, like, they're determined to get to their goal and their answers, whether that be like through creating an experiment or through constant research. So, I think that's how I thought of determined. (Lines 246-53)

While Sophia was unsure whether she felt she was a science person or not (she marked that she was neutral on the post-course survey), she connected her own determination to that of a scientist. Clara made the most explicit connection between a character trait she sees in both herself and scientists, saying,

> I'd say I think logically and science is a lot about like going from one like observation and then what do you- like making a reference to the observation and then you need to connect them. And then that needs to be logically, so I feel like I think in that way, so that makes me pretty good at science. (Lines 84-8)

Not only did she remark that she thinks logically like a scientist, but this way of thinking gave her confidence in her scientific ability.

The importance of participants recognizing traits they feel scientists possess and seeing how those exist within themselves is twofold. First, this allowed them to make an implicit connection to their science identity rather than an explicit connection. For non-science majors in particular this is important, because they have not chosen to pursue science in their studies and have likely been telling themselves that they are not science people for some time. However, they most likely possess character traits that they would also use to describe science people. Providing them the space to reflect upon qualities they share with science people is therefore important for their identity work, because it gave them an opportunity to recognize the commonalities themselves (Carlone et al., 2014). Second, this identity work transcends the context of the science classroom in that participants described traits that they possess in all facets of their lives (Calabrese Barton et al., 2013). Therefore, the knowledge and recognition that they have character traits in common with scientists should result in successful future interactions with science.

D. Scientific Performances Positively Impacted Biology 1 Students' Identity Work

Scientific performances where students communicate scientific knowledge or integrate that content knowledge with information from outside the classroom context influence individuals' identities (Hazari et al., 2013), and this is particularly true when others recognize the performer as competent (Carlone & Johnson, 2007). This type of performance is distinct from assessment performances, such as exams, where one individual is trying to prove to another that they are in possession of scientific knowledge (Carlone et al., 2011). Rather, for science identity work, impactful scientific performances include discussions, equal sharing of knowledge, and application of knowledge (Brickhouse et al., 2000; Carlone et al., 2011; Hazari et al., 2013). During Biology 1 there were multiple opportunities for students to participate in such scientific performances, including group work to solve real-life case studies and planning group presentations. Focusing on the final group workday and presentation allowed for analysis of the culmination of their identity work in the class context in terms of scientific performance.

In their observed group project workdays and presentations, all participants demonstrated the ability to communicate their knowledge of concepts learned over the course of the semester within their groups as well as to the rest of the class during the presentations. The example that follows is an excerpt from one presentation by a group focusing on a study called "Can Excessive Athletic Training Make Your Brain Tired?" Liam presented this portion of the project:

> So, in investigating how this study fits into the concepts that we've learned in class we- we established that it fits into three concepts really well: biomolecules, cellular respiration, and ATP. So, I'll be talking a little bit about biomolecules, most specifically lipids and carbohydrates. The reason why lipids fits so well into this study is because the brain is actually the fattiest organ. So, there's a huge amount of lipids in the brain. Some functions of lipids include: providing structural integrity necessary for protein function. So that's how it connects to another one of those biomolecules. Lipids also function as an energy reservoir. So, they are they're able to store energy very, very well. Carbohydrates are also able to do this but not nearly as efficiently as lipids and effectively. They also have a huge role in the central nervous system, which includes the brain and this is how it really fits into the study on the athletes' brains. So, lipids serve as a precursor for various second messengers, in going off of that they have a huge role in tissue physiology and cell signaling. So, when for example our neurons are firing to each other lipids have a huge role there, which is one of the main ways that it connects to the study. One of the ways that we know that lipids are so important for these processes is because there are several neurological disorders that involve deregulated lipid metabolism. Some very common ones include Alzheimer's and Parkinson's. (Lines 162-180)

Liam relied on some common knowledge built in the classroom regarding biomolecules and their basic functions, demonstrated his understanding of lipids, and also made connections between the study his group presented and topics previously learned in the class. This enabled him to engage in a performance of his scientific knowledge, while gaining recognition as competent by the rest of the class by including knowledge they had in common (Carlone & Johnson, 2007), and making connections between concepts learned in class and the real world (Hazari et al., 2013). Each of the six groups successfully engaged in these performances in similar ways during their final presentations, using their own topics and a variety of connections to concepts learned during the course.

In one focus group, Rose explained why this was an important process to undertake along with the other students in the class who had common content knowledge:

> Normally when you present, it's like, I have this knowledge they want to impart on you, but it was also like we I felt like we all kind of had this knowledge that we like, it was like a combined knowledge which was really nice and like also a confidence booster that it was like, I understand what you're saying and like I am confident communicating what I'm saying that like you understand it because like we have this similar like base knowledge. (Lines 811-17)

Rose specifically mentioned that she gained confidence in both presenting as well as being able to understand the content presented by other groups. Gaining confidence in talking about and understanding science was a key aspect of Rose’s identity work, and such confidence is especially critical for females engaging in this work (Eccles, 2009).

Jenna also shared the importance of presenting scientific information to the class in her focus group, saying,

> Like the best way to make sure you know something is to be able to teach it to someone else. So, I think that is definitely like being able to stand up in front of the class and be like this is why we think this, this is like the steps we took to get there.

> And, like, being able to do that without like having to look at your notes or like without, I don't know, whatever context, like being able to say what you know and explain it in a way that helps other- someone else understand it is, like, a huge checkpoint in, like, understanding a concept. So, I feel like that is something we did pretty well. (Lines 768-75)

Demonstrating her scientific knowledge gave Jenna confidence that she understood the material, which again underscores the importance of providing students with opportunities to engage in identity work to increase this confidence (Eccles, 2009).

Additionally, Diego differentiated between learning with the goal to pass tests versus learning for application or connections:

> I took biology in high school, but like I said earlier, like I, I learned enough to pass the test and then I forgot a lot of things. And I feel like, just as we go through and like you know go through an education just going through life it’s nice to know things and be able to have conversations or even just be able to identify certain things. (Lines 965-9)

Again, it is important to discern between these two types of performances. Performing well on tests is typically how scientific competence is measured in the classroom (Carlone et al., 2011). This is different from performing to make connections or apply concepts, which generally results in students’ viewing science as useful in their lives (Brickhouse et al., 2000). Diego also made this particular connection between the classroom and his life, sharing, “say I have kids one day. It's like, explain to my kids, like hey, you need to take your antibiotics, because I know you feel good right now, but you need to finish it or else this can happen,” (Lines 976-8). In this way, he was engaging in identity work by both demonstrating his knowledge about a particular concept from the classroom, finishing antibiotics, and connecting this idea to something he felt would be applicable in his life.

It was a critical component of the Biology 1 class that students worked together to build knowledge (Partin & Haney, 2012), rather than try to prove they were the keepers of the scientific knowledge (Carlone et al., 2011), which was accomplished by designing the class as a non-STEM majors course. In this environment, students felt comfortable sharing their knowledge with one another, built confidence throughout the course of the semester, and positively contributed to their identity work (Carlone & Johnson, 2007).

E. Recognition as Having Scientific Knowledge was a Key Aspect of Biology 1 Students' Identity Work

Recognition as having knowledge during scientific performance or as a science person, and encouragement in learning science are foundational in science identity work (Carlone & Johnson, 2007; Kelly et al., 2017; Robinson et al., 2019), and can include peer-peer recognition or recognition by an expert. Recall that during Biology 1 final project workdays, peers collaborated to determine whether their chosen topic was scientific or not, evaluate how the popular media presented the science, and how it specifically connected to course content. They presented these projects to their peers and instructor for their final experience, and wrote a reflection on what they had learned. They engaged in dialogue about their topic with each other and this also offered the opportunity to be recognized as having scientific knowledge or as a science person by peers and the instructor. Recognition can also include encouragement by the instructor as having knowledge (Carlone & Johnson, 2007) or as being a science person (Aschbacher et al., 2010), which results in a stronger science identity.

As a way to understand how participants felt others viewed them as a science person or not, they were surveyed twice. Over the course of the 15-week term, participants moved toward more agreement with the belief that their science professor saw them as science people, with post-semester scores significantly higher than pre-semester scores using a Wilcoxon Sign Rank test ($p < .01$). The median score moved from 3 (neutral) to 2 (agree) from the beginning of the term to the end of the term. While the change in scores was not significant for other types of recognition (from family, friends, or past teachers/professors), the proportion of students agreeing that their biology professor felt they were science people was significant, and this has been shown to have a positive impact in terms of increased identification as science people (Kelly et al., 2017). Following the surveys, participants in focus groups discussed the importance of recognition as a science person or of having knowledge, and this recognition was also demonstrated during final presentations and during final workdays. (Carlone & Johnson, 2007). Both the recognition of others and self-recognition as having scientific knowledge or understanding are important in identity work (Carlone et al., 2014).

1. Recognition by the Instructor of Biology 1 Students' Scientific Performances as Competent

Recognition by myself ("instructor") was important for students' identity work in Biology 1 in that I was able to identify various scientific performances as competent. This was both perceived by the participants and observed in the analysis, where I took an outsider's view on conversations and presentations to determine when I recognized students as possessing and sharing their knowledge.

The Importance of Perceived Recognition. When one who is positioned as the expert (e.g. a course instructor) recognizes that others possess knowledge, this results in positive science identity work in the student (Carlone et al. 2014). Participants shared about the importance of an encouraging classroom environment, and were also recognized as having scientific knowledge by the instructor during group workdays and their final presentations. Elena discussed feeling encouraged and how that impacted her sense of self as successful in science, saying "I remember talking to [my instructor] after I had my first test. And, like, that did not go well. And then [the next test] went well and [I thought], oh, maybe I'm not as bad as I think I am at science" (Lines 248-250). Therefore, instilling a sense of encouragement and positive classroom climate provided opportunities for positive science identity work (Aschbacher et al., 2010).

Sophia came into Biology 1 with previous negative experiences with science, but the support she felt throughout the class shifted how she viewed herself in relation to science:

> Biology was, like, my fear because I did horrible, I got a B in biology in high school. And that was like my first and only B ever, so that sort of made me fear what this class would be like. But Rose is spot on, like [the instructor's] encouragement totally made me feel like, 'Okay, I can do this,' and made me like change my mind about this class. Like, I looked forward to going to this class...So, I think definitely the professor and who surrounds you changes your mindset of what the class is for people who initially were like super hesitant about going. (Lines 495-500, 503-505)

Sophia's thoughts highlight the impact that providing encouragement to students in the science classroom context (Aschbacher et al., 2010).

As students are more interested in the subject and feel that they are successful in learning it, they are engaging in science identity work (Campbell et al., 2012). Specifically, this resulted in participants' excitement and confidence to engage with content in the classroom together with the instructor. In her focus group, Sophia discussed the classroom context and environment, "I think that the environment is crucial to, I think, one's understanding of science" (Line 1065). In a separate focus group, Diego also shared how the environment could be supportive, saying that in Biology 1 he felt that, "It's okay, like we're all going to ask questions, are all going to be here. You know, don't be afraid to go write on the board because, you know, we're gonna talk about it" (Lines 215-17). These actions resulted in the students being recognized by the instructor, in that they were willing to share their knowledge along with their uncertainties, knowing that they would be encouraged. As Sophia said, this contributed to making her feel that she was successful in learning, saying "I just think, like, like, just getting encouragement and being like, 'No, like, you're right, like, or you're super close, like, you're halfway there,' like those types of things made me feel okay, I'm on to something" (Lines 518-20).

This sense of encouragement in terms of having knowledge and the ability to learn science cannot be understated, and can make the difference in students' major and career choices. Rose summarized this idea during a focus group, saying,

> Maybe [I] would have continued being, like, a science major had I not had such like a terrible experience with it. Like it's not that I didn't necessarily, like it's not that I couldn't do it, it's just that I wasn't like encouraged, so I think we are, as like in this class. I'm going to go be a scientist now, like this is the best thing ever. (Lines 1050-1054)

While Rose was referring to being a scientist within the classroom (i.e. going to lab or engaging with case studies), she recognized the importance of feeling supported by the instructor in terms of also feeling like a scientist or capable of taking part in the process of science. She generalized this idea and highlighted how important it is, saying,

> Whether or not [someone] see themselves as a scientist, like whether if that's like instilled in them from a young age from their teachers or if it's like if they were discouraged, like maybe that's why some people like don't see themselves as a science person. (Lines 1060-1063)

The participants highlighted specific examples in which they perceived recognition from their instructor, either in their science identity work, knowledge, or their ability to understand the science content. This echoes and expands upon previous quantitative findings about the value of recognition and encouragement for students in the high school science classroom context (Aschbacher et al., 2010), along with qualitative studies with elementary- and middle school-age children (Carlone et al., 2014), demonstrating that these are important factors for post-secondary non-science majors' identity work.

Observed Recognition. Presenting scientific material in the context of how science is depicted in the news gave participants the opportunity to demonstrate their scientific knowledge and be recognized for having such knowledge by the instructor. For example, the following exchange took place following a group presentation on a shift in human body temperature over the last 150 years. The instructor asked a question regarding controlling the thermometers throughout time, and Viviana (one of the group members presenting) responded.

Instructor: Any questions for them? [pause] I have a quick one. And I may have just missed it toward the beginning, but how did they say they, they figured out that the thermometers were similarly calibrated, if they did? I'm interested in that.

Viviana: It actually did not go into detail about that they just said, I remember the phrasing was, we used thermometers that were expected to be similarly calibrated. So, I also kind of noticed that they didn't really explain how.

Instructor: Yeah, that's interesting. I feel like that's an important thing about their study. Alright, good job. (Lines 781-90)

During their project workday, one member of this group discussed their thoughts with the instructor:

Felicity: We're all right, we're kind, of we're discussing how it's, it's kind of a good study, but there are a couple issues like that there's miss- there's like huge gaps in the data of like years or time periods and like also the one that was like there's an experimental variable and a control group, there's not, they just like took a bunch of data and analyzed and like even the things that they said are like the independent variables, like age height, weight, etc. Those are subject variables. They're not like- they didn't manipulate anything. So, there could have been some confounding thing like exercise or place where the people live and they didn't even look at that stuff.

Instructor: I think that what you're saying all sounds very important and you might not come to like one or the other conclusion about the- the research, like you could say, well, these things are good. These things aren't good. We can't necessarily make a conclusion like about whether or not it's a good study, but that, I think differentiation is really important and that discussion. So, that is fine, like you wouldn't lose points for not making a complete conclusion because you might not be able to.

Felicity: Because we're like, we don't know how else they could have done it because it’s not like they can go back in time and, like, but at the same time, it's just like a difficult thing to study you know longitudinally.

Instructor: Totally. I think that that is really important so while, like, their conclusions might be valid, they also might not be, I think is, is what you're saying. So yeah, I think that that's really good. That sounds really interesting actually. And you can kind of start to see why just hearing like a little bit about a study doesn't give you the whole picture.

Felicity: Oh my gosh. I have become so skeptical of just anything I hear anymore, like, this causes that, I'm like, but what about…

Instructor: That makes me really happy. So that's exactly what you should be doing – asking all the questions all the time. (Lines 593-626)

In the transcript excerpts above, the instructor asked a question about the process the original researchers used to validate their study. Viviana was able to respond to the question knowledgably and she noticed that it was important that this particular point was not well-explained in the study itself. The instructor recognized Viviana’s input and knowledge of the scientific study and affirmed her ideas (Carlone & Johnson, 2007). Additionally, during the workday, Felicity clearly explained her concerns with the scientific study, which were validated by the instructor.

A similar situation occurred regarding the recognition of participants' scientific knowledge in the context of a study on cow communication:

Instructor: You mentioned this, just a little bit. I can't remember who was talking, but you talked about how the study of kind of animal communication could be important. I think it might have been you Analisa. And did you either read or come up with any like specific reasons why? I'm just kind of curious about where that research is kind of headed?

Analisa: Yeah, so I think a lot of it, a lot of it was kind of focused on like noticing like a distress call versus like oh, they're in like their positive setting and like they're not like showing signs of distress. And so, while they were saying like, while an animal like may not physically be showing like signs of distress, like if farmers can identify, like, oh, that's like a distress moo or whatever sound the animal makes for future research, then they can kind of like to see like, oh, like, are they physically or visually as it kind of like, notice that there is a problem. And then work around that, to ensure that like the cow is like thriving in its best place and I think like when they said like when they noticed it was in distress, even if like they weren't showing signs of like throwing a tantrum, or just kind of like slowing down or like not doing well, and that when they were saying that is kind of like slowing down, like the whole production of like the farm. And so, by kind of working out like this Google Translate and being like, Oh, you're in distress based on your moo, then they can kind of like work from there instead of like realizing later like maybe the cow's not doing too well. So, it's kind of like thinking of a step in advance before like, before it's too late.

Instructor: That's really interesting. Oh yes, go ahead, Iliana.

Iliana: I just wanted to expand on Analisa's point too, I think I'm just kind of like hearing that you can also kind of think a little bit more like bigger picture about how like, how we're moving forward with having animals in captivity and stuff like if the researcher was doing something about penguins and they can be doing it with other species and then kind of seeing like they can kind of change their environment there. And I think too on the other flip side, as we're increasing our industrialization and we're expanding into their environments and destroying their habitats, like obviously they're going to have to be relocated. Or we could just also stop, but that's a whole 'nother discussion right there. But essentially like kind of seeing like, I think if we're able to know, like if we're able to identify and then realize what they mean, I think that would also kind of like inform our next decisions when it comes to like those two topics as well. And so yeah.

Instructor: Awesome, that's really interesting. All right, thank you. Good job. (Lines 1048-1090)

This example also demonstrated the students' confidence answering a question about the science in the article and in making connections to other science topics, and in turn their knowledge was recognized by the instructor. In terms of science identity, the participants were actively working as experts on their chosen scientific study (Bricker & Bell, 2012), and relied upon science identity work in the classroom context to position themselves as such (Calabrese Barton & Tan, 2010). It was important that their expertise was recognized by the instructor, because it is in the recognition that identity work is valued and strengthened within the classroom context and therefore, potentially extended to additional contexts (Calabrese Barton et al., 2013).

2. Recognition by Peers and Self as Competent Scientific Communicators is Important for Positive Identity Work

As with recognition by the instructor, it was also important for students to recognize one another as competent performers in science. This recognition was perceived by the student and observable through their interactions with one another, both informally in group work, and during their presentations.

Perceived Recognition. Recognition by others or self as possessing knowledge or understanding is a critical factor in science identity work, particularly repeated recognition by others (Carlone & Johnson, 2007). Identity work resulting from recognition particularly occurs within a community of practice (Potvin & Hazeri, 2013), which is Biology 1 in this context. Recognition of having scientific knowledge can appear as building collective knowledge or understanding (Kelly et al., 2017), or the positioning of oneself as having knowledge (Calabrese Barton & Tan, 2010). For example, Felicity explained during a focus group that she had experiences with others who she perceived were better than she was at science and contrasted that with the idea that she felt more knowledgeable in Biology 1 than some in the course. Furthermore, she acknowledged that the other students in her focus group (Sophia and Rose) were smart as well. She said,

> Yeah, I think, like, who surrounds you is important, like in the high school biology, I don't know, maybe I've just [been] unlucky and gotten a class, full of kids who were really good at science. So, they were all like understanding and doing well but then like this time around, I mean, you guys I always felt like were smart and understand that because you're here, but there were kids who obviously didn't really want to be there or were like, this is my like requirement to graduate or something. And that made me feel like I'm a little better at science because like I was getting it because I was trying. (Lines 486-93)

Felicity connected the idea of recognition to being good at science, which in turn is a way to view her identity work (Calabrese Barton et al., 2013). She recognized that she had scientific knowledge and that some of her classmates did as well, but also shared that some were disengaged with the course, which she inferred was a contributing factor to their not being good at science.

Jenna also connected her identity work in science to her interactions with peers in the Biology 1 class during a focus group, saying,

> And I don't know, maybe this is just the nature of what I studied, but like when you start to get into your major classes or classes that you know like count for if you want to go to grad school or stuff like that they tend to get a lot more competitive and cutthroat and like not super, like I can't think of the right word, but not conducive to a like healthy learning environment. And I think like the nature of science is like to ask questions and to be okay being wrong. And I think that it's good

> to have people who like, this isn't their like primary field they want to go into because it makes it more like, I like, I like I feel functional like that's not the right word, but like it makes it more of a learning experience rather than like, I already know all of this and have to display how much I know. (Lines 195-205)

Jenna found importance in being comfortable expressing her scientific knowledge, without the fear that others would think she was wrong. This allowed her the space for identity work to take place, because she had the agency to talk about science with others without fear of being marginalized in this context (Calabrese Barton et al., 2013). For Jenna, being recognized as having knowledge allowed her to feel comfortable talking about science in the classroom context.

Similarly, in her focus group, Rose stated that, "being able to do [labs] in groups I think also really helps because I feel like being able to like bounce ideas off of each other was really helpful" (Lines 540-542). Like Jenna, Rose felt that engaging in science with her peers in the class was significant for her building of scientific understanding and was therefore part of her identity work as well. In general, identities are authored in specific contexts, including science identity (Carlone, 2012), and Rose implied that the recognition she received from her peers while working in lab groups was helpful, in terms of learning and understanding the context, and therefore for her science identity work. Identity work resulting from recognition by self and others as being knowledgeable in science can carry over from the classroom to other contexts, which is how future identity work takes place (Calabrese Barton et al., 2013).

Observed Recognition. Final presentations gave peers the opportunity to recognize scientific knowledge in one another by asking questions and engaging with the content and one another (Carlone & Johnson, 2007). Group 3 presented on the topic of whether or not naps have an effect on human health. Following their presentation, I allowed a few minutes for questions. The exchange below occurred during this question and answer period.

Jenna: When they, I know you said they, like, self-reported their naps. But is there, like, I don't know, I feel like that is different for different people. So, I wonder if there, like was in the actual study a way to, like certain level of REM that like qualified as a nap?

Miles: Well, the study did mention that they were using certain devices and methods to measure their sleep data. It didn't really go into detail of what those what those methods or those devices really did and how it worked. But they did say they used some sort of method and devices to measure quality of sleep. It says sleep duration was assessed by the Pittsburgh Sleep Quality Index. Things like that. Polysomnography was performed. So, it's- it's things that, to be honest, I didn't completely understand how they were measuring the sleep, but they did use certain processes.

Jenna: Ok thanks. (Lines 589-608)

While Miles admitted that there were aspects of the study he was unsure of, he was knowledgeable about the study, willing to explain the methods used to Jenna even if he was uncertain of what some of them meant. Also, in asking the question, Jenna believed that the group would be able to provide more insight. This echoed Felicity's earlier discussion of being surrounded by others who you feel are capable, which contributes to both parties' identity work (Calabrese Barton et al., 2013).

Halfway through the presentations, I gave some time to discuss the ideas of media depictions of science, what people believe and why, and how information is transmitted. The following transcript excerpt demonstrates interactions during this discussion between peers in the class as well as with the instructor.

Instructor: Miriam, do you have something to add?

Miriam: Yeah, I was gonna say similar to [non-participating student] our article was titled, like, cow-moonication and it was like immediately, like, hilarious and funny and I feel like the article actually did do pretty good job of, like, including like some of the highlights of like the study, but I think that's kind of the job of like news articles, right. is to like get people's attention. And so, whether it's like a funky like funny title or like a serious one that's like alarming like unlike research like just presents things plainly without any sort of objective in mind, whereas news articles tend to have like a like a "get you" factor to get people invested in it and to want to click on and find out about a certain like body of research. So, I found that too.

Jenna: Yeah, I also like I kind of, I don't know. I, maybe this is just because like I study political science, so like, this is the way I interpret everything, but I feel like so much of like what fact is or what like science is fundamentally based on is like politicized today. So especially like in the world of coronavirus like as we're currently living through it like it's, like, most reputable news sources I feel like, do a good, pretty good job of stating things as they are, but then like there - I'm just skeptical of everything and I think there's like an agenda behind everything these days. So-

Instructor: Healthy skepticism is good, though. Miles, I think you had something to say.

Miles: Yeah, I kind of mentioned it in our presentation. But I think the order of information, they, they don't always expect you to read the whole article so they kind of present you with all the good stuff. And like what you want to hear. For example, and ours was just right away, sleep is good for your heart. Just kind of telling us that, and then at the very end in like a very, a very small paragraph, it kind of mentions like the discrepancies within the study so it does, kind of like Jenna said it seems like it does have an agenda to kind of just present the information without all the proof. And I think you do see that a lot of times, like with people in our society, kind of like they just say information that they see. But there's not, I mean, it's not entirely their fault because they're not presented with all of the arguments.

Instructor: Yeah, I think that that’s a good point. Anything else from anyone?

Leia: I found in our article that like it kind of made it seem like they were making the headline be something that made it seem more relatable than it was. So, ours was, can excessive athletic training make your brain tired? But it doesn't mention in the headline, oh, like these are, like athletes, like endurance athletes that are being tested not like just the average person. So, I felt like it kind of like tried to make it seem applicable to everybody, when it really isn't. (Lines 1126-1173)

This set of interactions demonstrates how a college classroom can act as a space for science identity work in terms of forming a collective understanding of scientific research and how it is presented in the news (Kelly et al., 2017). Students were required to interact with the science material in their study of choice by preparing a presentation and delivering it to the rest of the class who were unfamiliar with the content, requiring them to recognize that they were the experts in this set of knowledge (Calabrese Barton & Tan, 2010).

Likewise, recognition of others' knowledge took place during the workdays to prepare for these presentations. In this case, the group was discussing their article on athletic training affecting the brain in terms of the science or pseudoscience criteria from their textbook (Houtman et al., 2018).

Elena: Is there an initial observation based on observable and quantifiable phenomenon? What did they base this off of?

Liam: So, they did fMRI scanning.

Elena: OK OK.

Leia: It says this study suggests a connection between mental and physical effort.

Samuel: Yeah.

Elena: Has the observation given rise to a clear and measurable hypothesis?

Samuel: I think if the hypothesis is that overworking your body could have an effect not only on your mental fatigue, or sorry, on physical fatigue, but also on mental fatigue, then I think that's a legitimate hypothesis.

Liam: Yes.

Samuel: Not sure they put it like that, though in the article.

Elena: Yeah it says the studies suggest a connection between mental and physical effort.

Samuel: Yes, I think so. Yeah.

Elena: That's like, that's an iffy yes but okay. We'll keep going.

Samuel: I know, this is gonna, I think on the rubric. It says like for the real science/pseudoscience question is, like, is it kind of ambiguous?

Elena: Yeah, literally, it's like if I, if you say no, it says pseudoscience often begins with a vague or and clearly stated to research question. I'm like -

Samuel: Which is kind of-

Liam: So, so they do have the question here. It says, did this overtraining syndrome arise in part from neural fatigue in the brain, the same kind of fatigue that can also be- or it can be caused by excessive intellectual work?

Elena: Okay, so, yes.

Samuel: They proved that right?

Liam: Yeah. They at least had a correlation. (Lines 224-71)

This group was attempting to come to an agreement about whether their chosen study was scientific or pseudoscientific using a set of standards from their biology textbook (Houtman et al., 2018). Throughout this discussion, they were contributing to the group's understanding of the study, and recognizing each other's knowledge. For example, Elena asked "Has the observation given rise to a clear and measurable hypothesis?" Samuel then offered his understanding of the hypothesis, which Liam agreed with, and Elena found the exact language from the article to support their conclusion that it contained a clear and measurable hypothesis. While no one in the group specifically named an individual's contribution or knowledge in the discussion, they implied that they noted the knowledge in one another by listening to each other's contribution, and either adding to it or agreeing with it. This is a way of observing identity work among these students, as the interactions within the group to make sense of their article showed them recognizing each other's contributions to the conversation, all of which were part of the process of science (Kelly et al., 2017). Additionally, this type of recognition is also important for identity work because over time, it contributes to individuals' seeing themselves as science people (Carlone et al., 2014).

There is an interesting idea to note from the excerpt above. While Elena, Samuel and Liam were discussing the conclusions from the scientific study they were reading, Samuel asked "They proved that right?" The idea that hypotheses can be proven is frequently observed in science classes (Schwartz, 2007), but a hypothesis is a statement that is either falsifiable or supported through evidence and not provable (Houtman et al., 2018). Liam responded to Samuel, saying, "Yeah. They at least had a correlation." While he initially was responding to the "proved" part of Samuel's question, Liam then qualified his agreement with saying that the researchers had shown a correlation in the article (excessive athletic training and mental fatigue), which provides support for the hypothesis. Taken together, this exchange demonstrated identity work taking place in the interactions between Samuel and Liam.

F. Conclusion: Identity Work in Biology 1 Led to Increased Positive Identity as Science People

While students in Biology 1 were not planning to pursue careers in science, their experiences prior to the course had an impact on these future plans. Therefore, science identity work that took place in the years before Biology 1 left participants with the story that they were not science people. In contrast, the identity work that occurred during Biology 1 was important in changing this internal narrative. As a whole, engaging in experiences that placed participants in the role of scientists (i.e. labs, real-life case studies, the final project), recognition from the professor and peers that they were competent in the role of scientists, demonstrations of understanding of the science content and applicability through presentations and discussions, and application of scientific concepts to contexts outside of the classroom all contributed positively to participants' science identity work. Together, these experiences resulted in a change in students' feeling that they were science people between the beginning and end of the term.

Chapter VI: Demonstrations of Scientific Literacy by Non-STEM Majors

"It is important to have this ability to distinguish between science and pseudoscience so you know whether to trust the advice you are given and apply it to your own life" – Adriana

My final research question was focused on scientific literacy in non-science majors. In particular, I was interested in learning about how non-STEM majors demonstrate their scientific literacy through engagement in biology coursework (focusing on a project examining science in the news). Recall from Figure 3 on page 18, this is the final box within the Biology 1 context, an outcome of the identity work that occurred within the course. Scientific literacy findings are organized based on the definition that was synthesized from prior research, starting with (1) scientific beliefs, attitudes, or interests (Gardner et al., 2016), as these are generally attributes students come into class having based on prior science experiences and they may evolve during their time in a non-STEM majors' science course. Next is (2) self-efficacy, which is defined as whether individuals believe that they are able to learn science (Ryder, 2001). The final section is (3) content knowledge demonstration and action, especially how students will use their knowledge to impact their decision making (Crowell & Schunn, 2016; Holbrook & Rannikmae, 2007). I recognize that there is overlap between the science identity work and scientific literacy constructs, and I will explore these ideas further in Chapter VII.

A. Biology 1 Students' Evolving Scientific Beliefs, Attitudes, and Interests

Understanding incoming non-STEM majors' beliefs about science, their attitudes toward science, and what they find interesting in science is foundation for learning more about their overall scientific literacy. In particular, determining whether and how these ideas change as they progress through a general education biology course sheds light on how the experience in class affects these aspects of scientific literacy (Gardner et al., 2016).

In the survey, participants were asked to what degree they agreed or disagreed with phrases that positively or negatively characterized science (Gardner et al., 2016). Twenty-three survey responses were used for analysis, which had interesting results. Table 10 records the percent agreement with each phrase at the beginning and end of the course.

Table 10

Belief and Attitude Terms Regarding Science.

Term "Science is..."	Percent Agreement (initial)	Percent Agreement (final)
Relevant to life^{+}	100	100
Meaningful^{+}	100	100
Based on observation^{+}	96	100
Based on ideas^{-}	96	96
Empowering^{+}	96	96
Subject to change^{+}	96	87
Personally helpful^{+}	91	96
Intriguing^{+}	87	91
Practical^{+}	87	91
Confusing^{-}	78	74
Frustrating^{-}	61	61
Ethical^{+}	52	56
Certain^{-}	39	35
Biased^{-}	30	17
Beyond my capabilities^{-}	21	13
Worthless^{-}	4	0
Only one method^{-}	4	8

Note. Total survey responses per item, $n = 23$. $^{+}$Positive term, $^{-}$negative term (Gardner et al., 2016).

Overall, there were no statistically significant changes in beliefs from the beginning and end of the semester, likely due to the fact that the initial beliefs of most students were positive toward science, as observed by generally low percent agreement with the negative terms and high agreement with the positive terms. However, it is important to note results that have practical significance (Maul, 2017) in the surveys. For example, all Biology 1 students agreed that science was based on observation, was relevant to life, and meaningful. None of the survey participants felt that science was worthless following their experience in the course, and nearly everyone (n = 22) felt that science was personally helpful.

There are noteworthy results in some of the positive categories. For example, "science is subject to change" is a positive belief (Gardner et al., 2016), and the percent agreement in Biology 1 students decreased from the beginning to end of the term. The nature of science is tentative due to new techniques, discoveries, and interpretations of scientific knowledge (National Science Teaching Association [NSTA], n.d.). However, the public attitude toward science and scientists has recently become more negative, partially due to the opinion that scientists do not agree on large issues like climate change (Motta, 2018), or the perspective that scientific recommendations keep changing so people do not know who or what to trust (Jarry, 2019). Therefore, it is impossible to know whether participants were responding to the idea of science being subject to change as having a negative or positive connotation, and would be useful to investigate further using qualitative methods.

It was also interesting that the proportion of Biology 1 students who believed that science is frustrating remained the same. While frustration was initially marked as a negative term (Gardner et al., 2016), this may not have been something that participants felt was overwhelmingly the case. Therefore, this information is useful for instructors, but also can be used to frame future studies about scientific beliefs and attitudes in non-science majors.

Finally, those in agreement with science being ethical was just over 50% in both the pre- and post-semester surveys. It went up slightly from 52% before Biology 1 to 56% following the course. The perception of science or scientists being unethical has pervaded areas such as biotechnology for many years (e.g., Savadori et al., 2004; Simonneaux et al., 2013), and during Biology 1 we spent time discussing Henrietta Lacks and medical ethics over time (Skloot, 2010). While students concluded that there were more safeguards to protect human subjects following this discussion, the idea that pharmaceutical companies in particular are more concerned with profits than people continues to infiltrate their thinking about ethics in science in general (e.g., Olsen & Whalen, 2009; Robbins et al., 2011).

Additionally, survey participants chose two of the terms from the list in Table 10 that they felt most captured what science meant to them. Table 11 shows the pre- and post-course choices by belief or attitude term. It is interesting to note that in both surveys, participants chose “based on observation,” and “relevant to life” more frequently than the other choices to describe what they believed science was. This is promising information regarding the participants’ attitudes toward science itself both entering Biology 1 and exiting the course, in terms of an overall positive feeling toward science.

Table 11

Pre- and Post-Course Survey Counts by Belief and Attitude Term.

Pre-semester Survey Term (count)	Post-semester survey Term (count)
Relevant to life (11)	Relevant to life (13)
Based on observation (9)	Based on observation (12)
Subject to change (7)	Practical (5)
Practical (6)	Based on ideas (3)
Intriguing (4)	Intriguing (3)
Empowering (3)	Empowering (3)
Meaningful (3)	Meaningful (3)
Based on ideas (2)	Subject to change (3)
Personally helpful (1)	Personally helpful (1)
Frustrating (1)	

Note. For the pre-semester survey, each participant chose two terms with the exception of one participant who chose three, and for the post-semester survey, each participant chose two terms (n = 23 participants).

Focus groups and interviews along with analysis of final written reflections expanded upon the survey data and allowed for more detailed analysis of what Biology 1 students believed about science, their attitudes toward various aspects of science, along with their interests in science following their experiences in the course. For example, Lucia described her understanding of science as a process in her final reflection:

> I also enjoyed this project because I became more familiar with the process of determining whether a study ultimately is pseudoscience or real science. This is a process based on observable and quantifiable information, clear and measurable hypotheses, testable and falsifiable predictions, reproducibility of the experiments, the logical form of analysis, and review from practicing scientists.

Scientific literacy is partially composed of the understanding of science as a process, rather than a set of steps with a beginning and endpoint (Glaze, 2018; Hodson, 2014b). Therefore, Lucia's reflection was particularly meaningful in terms of understanding how she viewed science along with the lens she planned to use in order to evaluate information (Benjamin et al., 2017).

Along these lines, Anthony shared the importance of critical evaluation of popular media, saying,

> This project now has me looking closer at articles that are in the news because there could be reporting on sources that are not very reputable especially in a time such as these because there can be a lot of misinformation or claims that are not very researched currently.

Diego further drove home this point in his written reflection: “Once we have the ability to evaluate the scientific merit of what we are reading, watching, or listening to, there is a freedom from ignorance.” People are learning more about science increasingly through internet sources (Takahashi & Tandoc, 2016), so understanding how to evaluate the claims presented in such platforms is a crucial outcome of science coursework. Anthony, Diego, and Lucia exhibited their scientific literacy by demonstrating their ability to scrutinize studies promoted by various media sources.

Attitudes toward science and scientists have been shown to be an important dimension of scientific literacy (Benjamin et al., 2017). Participants shared their attitudes toward science in focus groups. For example, Sophia spoke about her initial feelings and compared them to her final thoughts about Biology 1, saying, “I really was fearful about science, but now it’s, literally it was my favorite class this past semester” (Lines 510-11). Interest in science has been shown to predict the retention of scientific knowledge (Takahashi & Tandoc, 2016), so Sophia’s shift in attitude from intimidation to enjoyment of science was significant in terms of knowledge retention, and both attitude toward science and content knowledge are pieces of scientific literacy (Gardner et al., 2016; Holbrook & Rannikmae, 2007). Additionally, attitude toward science has been shown to change from more negative to more positive throughout other general education science courses (Gardner et al., 2016), and this appears to be the case from the Biology 1 surveys as well.

Finally, students' interests in scientific topics expanded throughout the term along with their knowledge and understanding. Clara described an experience with her family, saying,

> I was on a walk with my stepdad and my mom and we're talking about the environment and global warming and climate change. And we're talking about how deforestation may affect that, and it was actually after our class. Honestly, I guess before that class I, I didn't have any real tangible knowledge of, in my opinion, anything very science-y. After that, I just became more interested in it as one does when they learn a little bit about something. (Lines 146-52)

When individuals are interested in scientific topics, this results in their desire to learn more, which in turn allows for increased interest, which can also change their attitudes and beliefs (NASEM, 2016). Scientific literacy is influenced by attitudes, beliefs, and interests (Gardner et al., 2016), so it is important for educators to both understand these attributes and utilize pedagogical tools to move toward more positive beliefs and attitudes, and stoke students' scientific interests (Glaze, 2018).

Taken together, individuals' beliefs about science, attitudes toward science, and interest in the material are all critical for their success in learning content (Gardner et al., 2016; Takahashi & Tandoc, 2016). Because scientific literacy is at least partially composed of content knowledge (Holbrook & Rannikmae, 2007), this implies that the more positive these beliefs, attitudes, and interests are toward science, then the greater scientific literacy individuals will have.

B. Biology 1 Students Demonstrated Increased Self-Efficacy in Science Following their Experiences in the Course

Self-efficacy in terms of the ability to understand and use scientific information is important for students to increase their scientific literacy, and can be leveraged by educators in their pedagogical choices (Baldwin et al., 1999). In particular, tasks involving discussion or writing, cooperative learning, and analysis of scientific articles are all ways to simultaneously increase science self-efficacy along with scientific literacy (Baldwin et al., 1999).

Over the course of the 15-week term, students moved from agreement toward strong agreement with the phrase “I feel confident in my ability to evaluate a scientific study as presented in the popular media (i.e., news, social media),” with post-semester scores significantly higher than pre-semester scores using a Wilcoxon Rank Sum test ($p < .01$). Specifically, the median score on this survey item changed from 2 to 1, meaning that overall, students moved from feeling agreement regarding their self-efficacy in terms of evaluating science in the news toward strong agreement. Additionally, in the pre-semester surveys most participants reported either agreeing (7 participants) or disagreeing (7 participants) with this statement. Therefore, the responses were relatively lukewarm, with no strong agreement or disagreement, and evenly divided between agreement and disagreement. The mode in the post-semester surveys was strongly agree (13 participants), with zero responses below agreement. These changes are important because it demonstrates the contribution of a non-STEM majors biology course to student self-efficacy regarding evaluation of scientific material outside of the classroom context. As this course is likely their last formal experience with science it has repercussions in the form of their real-world opinions and actions (Rathburn, 2015). Self-efficacy in terms of enacting a science identity combined with the feeling that they are able to learn and understand science has been shown to play an important role in students' interest in science along with influencing their actions or behavior surrounding scientific material (Benjamin et al., 2015; Carlone et al., 2014; Eccles, 2009; Hodson, 2014b).

Students in Biology 1 also demonstrated their increasing self-efficacy in the classroom context and beyond. This self-efficacy manifested in the particular contexts of either content knowledge or the ability to evaluate the coverage of scientific studies by the media. Three participants included information about self-efficacy in their final reflections. For example, Jenna wrote that,

> Also, a small fact that I learned was where caffeine comes from, and how it does, or in this particular study it does not, affect the body. Being able to understand and act on scientific claims, particularly as they affect cells and our bodies, is vitally important to not just believe the claims being made in popular media, but understand them and be able to explain and justify them.

Through her discussion of the importance of comprehending and acting on scientific claims along with specific knowledge she gained from her final project, Jenna showed that she felt capable of learning, understanding, and acting on her knowledge. Jenna's ability to recognize herself as competent in both understanding as well as communicating scientific ideas to others boosted her own as well as her peers' scientific literacy (Dragos & Mih, 2015).

Actively engaging students with science content and application to specific issues, particularly a scientific study presented in the news, encourages self-efficacy as well (Glaze, 2018). Referencing the Biology 1 final project, Analisa said, “This project prepared me to be ready to do some digging in terms of fact-checking, but to also spread this knowledge to those around me.” Analisa was confident that she had the ability to investigate the science presented in the news and share what she learned with others. If one person feels confident enough to share what they have learned with others, this contributes to the scientific literacy of the collective (Roth & Lee, 2002).

Additionally, self-efficacy is critical for success within STEM coursework, and impacts individual scientific literacy (Benjamin et al., 2015). In particular, students gain confidence by evaluating scientific content and explaining their ideas, which contributes to their overall scientific literacy. Overall, each of the nine focus group participants demonstrated self-efficacy in learning and understanding science. For example, Felicity described how she felt when initially presented with a scientific concept in the form of a case study to work through, and how she gained confidence in her ability to tackle difficult content:

> Yeah, like when there’s like a complex-looking concept and it’s handed out on a paper or on the screen or something and it looks daunting. And then we work through it and everything. And I’m like, I did it. And then I like when I can look back at it again just to get a glance, and it looks complicated again. And I’m like, nice, I did something complicated. (Lines 529-33)

In this case, Felicity demonstrated that she gained confidence because she had learned and utilized her knowledge to unpack a complex concept. In this way, she was leaning on both her understanding of science content as well as the evaluation of concepts (Baldwin et al., 1999; Benjamin et al., 2015). These are both indicators of self-efficacy, and contribute to scientific literacy (Laugksch, 1999).

Another example of self-efficacy was shared by Diego, who felt confident that he not only possessed scientific knowledge but also that he understood how to go about gaining more necessary knowledge. He shared,

> Yeah, and like I think that's a big thing to just, like, you know, to feel good at something, it's like, I think I jumped in too soon, like, they have to get it right, but like, even just a sense of discovery. Like, it makes you feel like you're good at it when you're like, you know, not only do I know what I need to do to do it right. (Lines 164-67)

This attitude of not needing to have all of the knowledge in order to interact successfully with scientific material is vital, because non-science majors will likely need to understand how to find reputable sources for scientific information rather than know it from memory (Halpin, 2016; Roth & Lee, 2004). Therefore, the confidence to interact with science in contexts outside of the classroom is an important finding.

Finally, self-efficacy in terms of feeling capable of understanding scientific material can also come from recognition by others. However, the distinction is not solely the recognition by an outsider, but the subsequent recognition of competence within oneself (Carlone et al., 2014; Westby & Torres-Velasquez, 2000). As Rose explained,

> My best friend is a nursing major, like, at a different school and, and she, like, a lot of just like telling me, like, everything that about, like, what she's learning and stuff but she'll always, like, she won't use like the terms from her class, she'll kind of just

> like dumb it down. Because she knows, like, I'm not a science major kind of thing. And so, when we were doing this project, I got, like, super excited though. Like, I just read this article, it's like the one that I read about like caffeine and I was like, it's really cool. And I was like, talking to her about it and she was like, wow, like do you actually understand what you're saying. I was like, no, like, I actually do. (Lines 798-806)

Her friend, whom Rose viewed as more knowledgeable in science by virtue of her chosen major and career path, recognized Rose's understanding of the science of caffeine through their discussions (Benjamin et al., 2015). Likewise, Rose noted that she had gained knowledge and comprehension that she did not previously have and she found on her own, therefore extending her self-efficacy outside of the classroom context. In this way, Rose demonstrated her scientific literacy in terms of self-efficacy (Benjamin et al., 2015; Laugksch, 1999), along with her interest in a scientific topic (Gardner et al., 2016) and confidence in learning and understanding content knowledge (Benjamin et al., 2015).

C. Biology 1 Students Demonstrated and Acted Upon Content Knowledge Learned in the Course

Self-efficacy in terms of learning and understanding science is not the only aspect of content knowledge that impacts scientific literacy. Increased science education experiences generally result in higher scientific literacy (Crowell & Schunn, 2016), but the demonstration of scientific literacy has not been studied qualitatively, especially when considering actions and not solely knowledge gains. Scientific literacy is partially composed of conceptual knowledge and the communication of such knowledge (Holbrook & Rannikmae, 2007), along with scientific conversation as a context-dependent demonstration of knowledge (Brown et al., 2009). Therefore, focusing on both the content knowledge students communicated in the classroom context, along with how they talked about ways in which the science content impacted their actions was important to understand non-STEM majors' scientific literacy as a connection to their daily lives (Rathburn, 2015).

1. Biology 1 Students Demonstrated Content Knowledge

Participants demonstrated their understanding of science content as well as the nature of science in multiple ways throughout the term, including their final presentations and reflections, which allow for a snapshot of their scientific literacy at the end of the course. While scientific concept knowledge has been argued to be less important in terms of scientific literacy (Hodson, 2014a), the ability to make connections between concepts and real-world observations or issues is paramount (Rathburn, 2015). Therefore, considering instances where participants demonstrated their concept knowledge was still valuable. However, perhaps more crucial is the ability to convey an understanding of the nature of science (Hodson, 2014b), which is part of scientific literacy as well.

Conceptual Understanding of Science Topics. All nine focus group participants demonstrated their understanding of scientific concepts by discussing them in their final focus groups. All 23 students who consented to share their final reflection also demonstrated their conceptual understanding, as well as by connecting topics learned in class to their final project articles during their final presentations. The ability to connect scientific concepts to other topics is valuable, as this demonstrates that students are applying science to their lives (Rathburn, 2015), and is therefore a skill they will take with them out of the school context (Greenhow et al., 2015). For example, in her final reflection Ella wrote:

> Something specific that I learned was that teens have disrupted sleep cycles because their bodies have delayed melatonin production. I knew that there must be a reason that teens fall asleep and wake up so much later, but it was interesting to learn that this was a hormonal reason and not just a social phenomenon. I also learned more about the role sleep has on overall health. I knew that there was a correlation, but I specifically learned about the cytokines and signaling processes that the immune system repairs itself with as we sleep. Further, it was interesting to connect stress hormones to this idea. I knew that sleep suppressed these hormones, but it was interesting to learn that there is a correlation between sleep, stress hormones, and illness.

Ella had an instinct that there must be more of an explanation for teens' sleep cycles. At first she assumed that it was a social explanation, but through her project she found that there was a scientific one. She very clearly expressed what she learned about sleep, hormones, and the immune system, and it appears that she had a genuine interest in the subject. Interest in science is a pivotal starting place for learning (Takahashi & Tandoc, 2016), and is also predictive of scientific literacy (Gardner et al., 2016).

Similarly, in her final reflection, Rose shared conceptual knowledge she learned while working with her group to prepare their final presentation:

> I learned a lot from this project in conducting research in regards to the effects of caffeine on the body. I learned that 99% of caffeine is dissolved into your bloodstream within 45 minutes after consumption. This statistic shocked me, but also explains a lot on why people would drink more than one cup a day if the caffeine presence in the body is not sustainable for long periods of time.

Like Ella, Rose expressed an interest in what she learned, and made a scientific connection to something she had observed outside of the classroom context. Again, this ability to connect scientific content to real-life observations is important (Rathburn, 2015), and connecting concepts to experiences outside of the science classroom positively impacts scientific literacy as a whole (Greenhow et al., 2015).

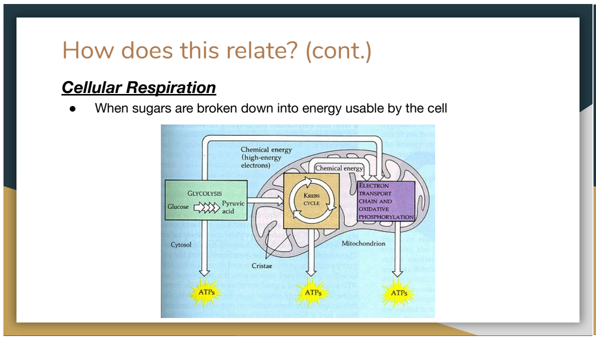
Two focus group participants echoed these observations of making connections between science learned in class and their final presentations. Elena said, “The concept of knowledge was seen when we tied concepts from class to our study, and then we communicated our science knowledge through the presentation itself” (427-29). As students learn to effectively communicate their scientific knowledge, this also positively impacts scientific literacy as they will use it outside of the classroom context (Pelger & Nilsson, 2016). Clara echoed this, saying specifically that, “I spoke a little bit about photosynthesis and we definitely learned that really thoroughly in class, so that was definitely clear. And then communication of science knowledge, that was what the whole project was about for us” (330-32). While clear scientific communication is critical for scientific professionals (Pelger & Nilsson, 2016), it is also important for the general citizenry when considering general functionality in society or socio-scientific issues (Holbrook & Rannikmae, 2007).

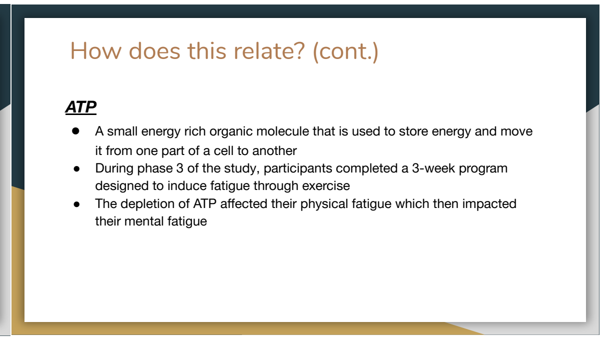
Finally, to demonstrate specific content understanding, all six student groups included connections to content they learned during Biology 1 to their final topic. For example, group 1 explained the concept of cellular respiration as background for their article. Below are two slides from this section of their presentation (Figure 4), along with an excerpt from their presentation. Elena was presenting these two slides for her group:

So, continuing, how this relates to the course, our study is also centered around cellular respiration, which is when sugars are broken down into energy that is then usable by the cell. So, looking at the diagram here. There are three stages: Glycolysis, the Krebs cycle, and the electron transport chain. So, we get two ATP molecules from glycolysis, two more from the Krebs cycle and then up to 34 from the electron transport chain. So, the main thing to notice in this diagram is that each stage produces ATP. So, from one glucose molecule we can get up to 38 molecules of ATP. Moving on to the next slide. ATP is a small energy rich organic molecule that is used to store energy and move it from one part of the cell to another. As Adriana mentioned earlier, during phase three of the study participants completed a three week program designed to induce fatigue through exercise. Fatigue is the overall feeling of tiredness or lack of energy. It means your body is not motivated and has no energy or ATP to continue to going about their day. The depletion of ATP through intense exercise affected their physical fatigue, which then impacted their mental fatigue. But when we looked at the study, we saw that the language showed a causation- causal relationship, rather than a correlation. (Lines 194-210)

Figure 4

Two Presentation Slides from Group 1 Connecting their Article to a Concept Learned in Class





As scientific literacy includes a component of communication of scientific knowledge (Hodson, 2014a; Holbrook & Rannikmae, 2007), the students' ability to present this information to the class was a clear demonstration of their scientific literacy. Elena was a student who previously described herself as lacking confidence in her science content knowledge, but she clearly described cellular respiration and the importance of ATP, making the connection between these concepts and her group's scientific study. In particular, evaluating a scientific study in terms of the media presentation, asking relevant questions about the claims made in the study itself, and making connections to the science content they learned throughout the term supported learning and scientific literacy in terms of communication (Pelger & Nilsson, 2016).

Understanding of the Nature of Science. Along with science concept knowledge, understanding that science is a process is also vital for scientific literacy (Hodson, 2014a; 2014b). In this context, students used the scientific process to examine claims they found within their news and scientific articles. They also learned more about how scientists themselves used science to answer questions. In her final reflection, Ella wrote "This project allowed me to view the scientific method differently—as an investigative tool rather than a series of events." Historically, science has been taught as a single, step-by-step method rather than an iterative process (Houtman, et al., 2018; McPherson, 2001), and it is apparent that Ella recognized this distinction, along with the utility of science.

Learning to do science through the application of ideas or scientific problem solving demonstrates to the student how science works in the real world. Specifically, the more students do science, the more they learn about science, both in the school context and beyond (Hodson, 2014a). Clara discussed this idea:

> In our project we really, we had one big focus connecting what we learned in the class to our project and one of them was the scientific method. So, I feel like that is just an example of scientific problem solving, and applying the scientific method to the news and going step by step to see whether they followed the scientific method and stuff to me is like very representative of scientific problem solving. They're using the scientific method, which all procedures or experiments are supposed to follow, and seeing whether some news you're being fed follows that is step by step is an example of that. (Lines 314-22)

Providing students with the opportunity to engage with scientific content in which they are interested has a positive impact on scientific literacy (Glaze, 2018; Rathburn, 2015), and engaging them with the idea of science as a process rather than a body of knowledge does so as well (Hodson, 2014b). This project engaged student interest by allowing them to choose their topic, and required them to examine the methodology utilized by the original study authors as well as how the science was presented to the general public in the media. Therefore, they were engaging with science as a process, making connections, and communicating their findings, all of which was a demonstration of their scientific literacy.

The nature of science also encompasses understanding that science is not just one method (Gardner et al., 2016). Viviana explained what she learned about science as a process in her final reflection:

> Another thing I learned was how not all science needs to have an experiment component to be real science versus pseudoscience. The study that we looked at examined trends over time and collected more measurements but did not have variables that it was testing. This study was still real science because it was based on a method and was peer reviewed. This taught me that one of the most important parts of distinguishing between real science and pseudoscience is that the researchers are not making far-reaching or unsupported claims.

Viviana's perception of the nature of science along with how she would use this knowledge outside of the classroom context were both part of this reflection, and illuminated these aspects of her scientific literacy. Specifically, she mentioned that science does not need to utilize an experiment to be valid, which shows that she grasped that science could be done using more than one method (Gardner et al., 2016). She also discussed that evaluating claims made by researchers was a critical aspect of understanding and evaluating science, which is key to scientific literacy as well (Hodson, 2014b).

2. Biology 1 Students Acted Upon their Scientific Knowledge Following their Experiences in the Course

The employment of case studies or socio-scientific issues as part of the curriculum allows students to act as scientists (Ryder, 2001), or provides the opportunity for them to confront controversial issues and take a position (Hodson, 2014b). This results in students taking science-based actions, either in the classroom context or beyond (Vandegrift et al., 2020; Viera & Tenreiro-Viera, 2016). Biology 1 was a space for students to practice engaging with scientific studies and media presentation of studies, and these actions manifested in the evaluation of science in the news and other beliefs or interests outside of the classroom context.

In their final reflections, five students discussed how they would use the skills they learned in class in their lives (Majetic & Pellegrino, 2014), which was a meaningful demonstration of scientific literacy translating from the classroom context to the real world (Rathburn, 2015). In her final reflection, Adriana wrote,

> [I]t is important to look at the methods, the credentials of the person behind the study, whether or not it was peer reviewed, etc. It is important to have this ability to distinguish between science and pseudoscience so you know whether to trust the advice you are given and apply it to your own life.

Adriana was describing the actions of investigation of science and applying scientific-sounding advice to her own life. Providing an encouraging space for students to engage with scientific studies and teaching them how to make connections between the content they have learned along with fostering interest in real-world science allows for further development of scientific literacy (Holbrook & Rannikmae, 2007).

Regarding the practice of investigating claims both within the classroom context and beyond, Liam wrote:

> Also, by analyzing whether the study was science or pseudoscience, I was able to practice investigating the credibility of sources and paying closer attention to the details of studies that may be used to merely pull attention, without providing actual evidence or admitting to the inherent biases involved. Although I already knew to investigate sources well before believing everything I saw on the news, this project helped me to practice this skill further.

This demonstrates ways in which Liam planned to use not only the science content beyond his experiences in Biology 1, but how he could use the skills he learned outside of class as well (Majetic & Pellegrino, 2014).

Ella wrote something similar in her final reflection, saying, “I feel prepared to evaluate science in the news. I have always known to read beyond the headlines, and look for credentials, but now I feel more prepared for what to actually look for.” Ella specifically connected the usefulness of what she had learned in the classroom context and how it will translate into action in the future, which builds scientific literacy (Roth & Lee, 2004; Vandegrift et al., 2020).

Iliana wrote about actions she could take, such as asking questions and investigating details:

> This project has prepared me to evaluate science in the news by asking the right questions such as who is reporting it, who created the study, why was the study created, who is funding it, etc. Ultimately, the importance of knowing the little details rather than the big claims is where we can find some answers and possible validity. It never hurts to ask questions and find the answers to them, too.

Opportunities for students to form opinions and act on them in the classroom are helpful practices for how they will confront science outside of this context (Hodson, 2014b). Science education needs to include these specific, applied activities, because content knowledge alone does not result in action in contexts outside of the classroom (Crowell & Schunn, 2016).

In focus groups, three students demonstrated the actions they learned how to take when specifically evaluating science in the media. When presented with the headline, “Go

Ahead, Take a Nap. A New Study Says They May Be Good for Your Heart," Clara expressed the following things she would ask about the article:

> So, I'd ask how long of a nap, because that's important. And a lot of people say power naps, you know, short naps actually give you more focus. Well, if you take a two or three hour nap it'll just make you more tired. I know that- so I feel like that could also relate to - is it good for your heart, is that what it says? Okay. So how long of a nap? Is it a nap every day? And, and then, just the science of how in the world does sleeping- well, it actually makes sense. Sleeping is good for your health. So, is there like a danger of oversleeping or under sleeping- effect on your heart? I haven't really, 'cause I know sleep is good for you, but I've never heard a connection of sleep to your heart, so I'd be interested in learning about that because I don't understand why, and that would help your heart and then- Yeah, I would want to know, like where they got- where the news story got the study, and actually read the scientific study and see if it actually makes- if it proves the hypothesis true, and if actually tests this hypothesis or if it's just kind of like grab-your-attention news. And then just like we learned in class, I would learn, like has it been peer reviewed, were they, were they heart scientists, like were they already cardiovascular scientists and like were doctors involved in the study, as well as just scientists. And the credentials. (Lines 367-83)

Clara's thought process is evidence of her scientific literacy in terms of both demonstrating content knowledge (Holbrook & Rannikmae, 2007), along with actions, specifically how she would ask questions about or look to find the source of a scientific-sounding headline (Hodson, 2014b). Clara also wanted to know if the hypothesis was proven true, which is a common question for science students (Schwartz, 2009), and a way that she was demonstrating a misconception of an aspect of the nature of science (Houtman et al., 2018). While she was showing that she had gained scientific literacy through Biology 1, this also shows a place where she had not fully grasped the nature of science.

Finally, Biology 1 offered students the opportunity to practice taking action surrounding scientific topics, specifically asking questions and evaluating science in the news. In a focus group, Theo said,

> I think my mindset has just, like, changed like through the doing the project and it's heavy emphasis on, on like, looking at how the media portrays science. I think that really just like changed my mindset to, like, look more into that, like, whereas before I wasn't, like, really even like thinking about that sort of thing. I think definitely, like, one of the things, like, is like, looking at the source. (Lines 583-88)

Theo highlighted what he learned about acting in terms of looking for and questioning source material. The skill of finding reliable scientific sources is valuable, and this needs to be taught as a part of scientific literacy (Desy et al., 2009; Perez et al., 2013). In the 21st century, media literacy is an integral part of scientific literacy (Hodson, 2014b), and if students are taught to find and utilize reliable sources for scientific information they will continue to do so outside of the classroom (Halpin, 2016).

D. Conclusion: Biology 1 Students Scientific Literacy Increased Following their Experience in a Non-STEM Majors' Biology Course

Through their evolving and more positive beliefs, attitudes, and interests surrounding science, self-efficacy in terms of learning and communicating scientific knowledge, along with demonstration and action surrounding science content, the participants in the study displayed scientific literacy. However, the idea of proving a hypothesis true still remained in two of the students' statements, and this is an example of an area where they still needed to build understanding of the nature of science. This is important as they move from the science classroom context to graduate school or careers outside of STEM, along with other areas of daily life because they will rely on this scientific literacy to make decisions for themselves or their families.

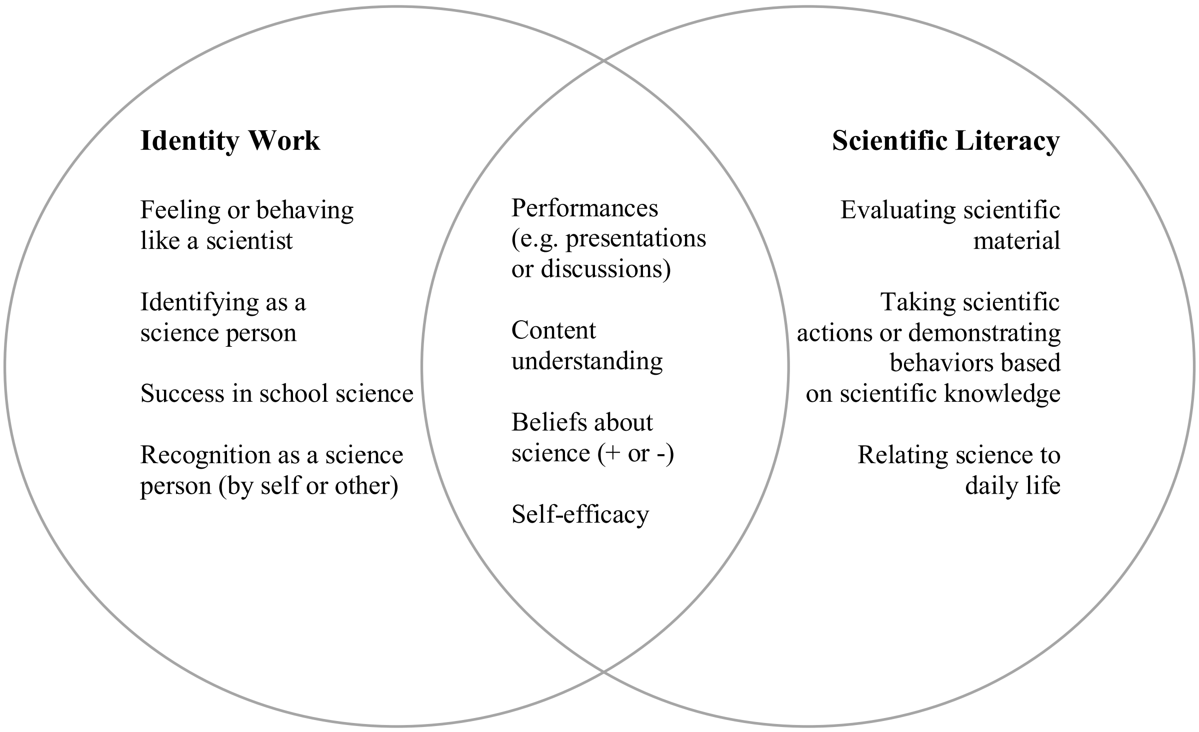
Chapter VII: Identity Work and Scientific Literacy are Overlapping Constructs

"When you feel like a science person, you're kind of more inquisitive, you're more curious, and then that makes you develop a scientific literacy." – Diego

While some facets of science identity work and scientific literacy are easily distinguished as separate from one another, there were multiple occasions when participants described themselves as scientists or science people and used a feature of scientific literacy as part of their reasoning, or vice versa. This follows from prior research; for example, increased self-efficacy in science is a potential outcome of science identity work (Carlone et al., 2014; Eccles, 2009), and increased self-efficacy has also been shown to contribute positively to students' scientific literacy (Baker & Sivaraman, 2018). Therefore, it is important to examine how identity work in science and scientific literacy are intertwined because it reveals how students may rely on their identity work when interacting with science in the world outside of the classroom. Figure 5 shows the aspects of scientific literacy and science identity work that overlap, either based on prior research (e.g., Baker & Sivaraman, 2018; Carlone et al., 2014; Chemers et al., 2011; Eccles, 2009) or illuminated from this study. I conclude this chapter by examining how the data did not show overlap I expected to see from the literature.

Figure 5

Overlap of Science Identity Work and Scientific Literacy Constructs



In particular, I am focusing on instances when participants demonstrated scientific literacy along with describing themselves as science people for further analysis of how these two attributes were related. Identifying oneself as a science person is one piece of science identity work (Carlone et al., 2013; Hazeri et al., 2013). Table 12 displays instances of focus group participants discussing both an aspect of scientific literacy along with describing themselves as a science person or not. The connection between being a science person or not due to at least one aspect of scientific literacy was made by all nine focus group participants, as noted in Table 12.

Table 12

Instances of Participants Describing Self as Science Person Overlapping with Scientific Literacy

Aspect of Scientific Literacy	Description of Self as a Science Person or Not	Focus Group Participants Making this Connection
Belief, Attitude, Interest	9	5
Self-Efficacy	25	9
Scientific Performances	13	6
Content Understanding	2	2

The constructs of science identity work and scientific literacy have elements that overlap with one another, as illustrated by my qualitative data collection and analysis (see Figure 5 and Table 12). For example, I asked focus group participants what made them feel like a science person. In particular, Jenna spoke about a sense of confidence about her scientific knowledge as making her feel this way, saying, “you know the material and so, like, being able to identify where you made the mistakes too...I think also makes you feel confident” (Lines 157-9). Jenna described the process of understanding science content including discovering her own errors, which is part of the identity work that occurred in the classroom. She also discussed having scientific knowledge, which is part of scientific literacy. The idea of self-efficacy, or having confidence in his abilities, was the overlap of the two constructs.

Diego also shared what made feeling like a science person complicated in terms of feeling successful and confident:

> It’s the balance, because like you know, as part of being a science person we said like, it’s like having that kind of inquisitive nature and being okay to fail. But once you fail, you kind of no longer feel like the science person that you’re striving to be. (Lines 551-4)

Diego described the tenuous nature of feeling like a science person because it relies on success and self-efficacy. Therefore, finding ways to build confidence in non-science majors is vital to their identity work and in turn, their scientific literacy.

In terms of self-efficacy in science courses, Diego also specifically pointed to the non-science majors course as helpful in both feeling like a science person and not being intimidated by others who know more, saying,

> I'm interested in [science], but this is their major, like these guys probably, you know the guys, gals, you know, they would know more...And that would kind of be discouraging, if you like, with the discouragement comes the feeling of not feeling like a science person. (Lines 526-30).

Diego described detractors from his scientific literacy, specifically that others might view science as beyond his capabilities (Gardner et al., 2016), especially when feeling a lack of confidence (Perez et al., 2013). In a different environment, one populated heavily by science majors, Diego would have struggled to build a science person identity. This is consistent with findings that science identity impacts confidence toward interacting with scientific material (Rodriguez et al., 2019), as well as findings that community impacts students' interest in and affinity toward scientific disciplines, resulting in further science identity development (Potvin & Hazeri, 2013).

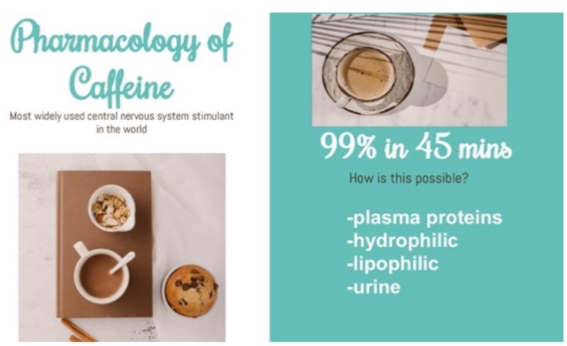
Additionally, scientific performances that include aspects of content knowledge are aspects of both identity work and scientific literacy (e.g., Carlone & Johnson, 2007; Roth & Lee, 2004). An example of one scientific performance was from Rose's part in her group presentation on a study surrounding the effect of coffee on the heart, where she shared the following along with the slide in Figure 6 below:

Alright, so next we looked at the absorption, distribution, metabolism of coffee, so also the pharmacology of coffee. And so, one thing is that it's the most widely used central nervous system stimulant in the world. So that kind of ties into- I'll bring that back around to how that relates to our study. So, one thing that I wanted to mention first. If you see these numbers right here, so 99% and 45 minutes. So that means that caffeine is very rapidly and completely absorbed in humans. So, 99% of the caffeine that you ingest is absorbed within 45 minutes in your body. (Lines 257-64)

Recall that science identity work encompasses the actions individuals take that result in feeling either more or less like a science person (i.e., engaging in discussions of scientific material and being recognized by others as having scientific knowledge), while scientific literacy is observable as either part of identity work or an outcome of that work (i.e., demonstrating conceptual understanding).

Figure 6

Rose's Presentation Slide on the Pharmacology of Caffeine.



Rose was engaging in identity work while explaining the topic of caffeine absorption along with being recognized by her group and instructor as having this knowledge. Simultaneously, she was demonstrating scientific literacy through explanation of a scientific concept while applying her scientific knowledge to a topic that she felt confidence in her ability to comprehend, found interesting, and applied to her life. Rose spoke about this process during a focus group, saying “and so when we were doing this project, I got like super excited though, like, I just read this article, it's like the one that I read about like caffeine and I was like, it's really cool” (Lines 802-4).

In particular, students frequently discussed their feelings about being a science person because of an aspect of scientific literacy. For example, considering her thoughts prior to Biology 1, Felicity said, “Yeah, I didn’t think I was a science person. And science in general just sounded like that hard thing that, that, that’s what the smart people major in” (Lines 588-9). Recall that beliefs about science are an aspect of scientific literacy, so in this case Felicity was sharing her belief that science was difficult, which in turn negatively affected her identity as a science person.

Theo connected an interest in science content to being a science person when he stated he felt like a science person when, “in high school I took an anatomy class with this specific professor and I just remember she...allowed us to kind of explore what we were interested in” (Lines 205-7). Theo’s statement echoed the proposed quantitative model that interest in science was predictive of science identity (Renninger, 2009), and that interest in science also impacted scientific literacy (Gardner et al., 2016). Additionally, Theo mentioned that he “realize[d] that there's a lot to learn and...that like I liked digging deeper into it” (Lines 209-10). In this way, he connected learning more content to feeling like a science person, which is consistent with theory that content knowledge is also an aspect of scientific literacy (Holbrook & Rannikmae, 2007).

When asked what makes her feel like a science person, Clara also connected the ideas of interest in science and feeling more like a science person, saying,

> I think maybe the fact that I do think about science things. So, the fact that I think about how science and trees and deforestation and like gases, greenhouse gases would affect global warming and how I’m interested in that, even if I don’t know about it. (Lines 179-82)

Clara spoke about specific science content she found interest in and how that made her feel like a science person, and her lack of what she perceived as complete knowledge did not negatively impact this identity work. In particular, Clara connected the ideas of herself as competent in thinking about science (Calabrese Barton et al., 2013), with her interest in specific topics related to real-world contexts (Gardner et al., 2016), which demonstrated how her identity work impacted her scientific literacy.

Another way in which science identity work impacts scientific literacy is through the encouragement of student questioning (NASEM, 2016). Iliana stated, “because usually, people don’t like getting a bunch of questions, but the one thing I was found comfort in science was that like they obviously welcome questions. And I’m like, cool” (Lines 146-8). Because scientific inquiry centers around asking questions in the natural world, allowing for questions in the classroom context results in continued identity work and scientific literacy outside of the classroom context (Hodson, 2014a; NASEM, 2016).

Finally, Diego integrated his thoughts regarding science identity with scientific literacy, saying:

> When you feel like a science person, you're kind of more inquisitive, you're more curious, and then that makes you develop a scientific literacy; and once you develop a scientific literacy, you have the skills and ability to look at things, at least from a more informed lens, more critically. (Lines 1023-27)

The connection of these ideas is important for understanding how non-STEM majors interact with science outside of the classroom context, and why engaging in identity work contributes to successful interaction with science outside of this context. Specifically, science identity is central in terms of how it impacts student learning, in that a stronger science identity results in more retention of science content (Hazari et al., 2013; Renninger, 2009), and content knowledge is one part of scientific literacy (Holbrook & Rannikmae, 2007). Self-efficacy in terms of doing science is also an important facet of science identity (Eccles, 2009), and for scientific literacy in terms of confidence in content understanding (Baker & Sivaraman, 2018). Therefore, these findings are significant in terms of how identity work connects to scientific literacy in non-science majors, specifically in terms of higher self-efficacy and more concrete actions surrounding science.

Based on prior work connecting content knowledge to science identity (e.g., Calabrese Barton & Tan, 2010), I expected more results showing overlap between these two areas. However, as shown in table 12, only two focus group participants made statements that I coded as both including content knowledge and feeling like a science person. One was Jenna, who was talking about the importance of learning science during her focus group, and stated that “it’s easy to get caught up in like knowing enough but not like learning it...but it’s more important that I understand the concepts to be a functioning adult in society today” (Lines 996-1001). Even in this case, Jenna did not describe specific content she had learned, but rather the importance of this knowledge in terms of her future behavior. While science content knowledge remains a part of multiple definitions of scientific literacy (e.g., Holbrook & Rannikmae, 2007; NASEM, 2016), as well as science identity (e.g., Calabrese

Barton & Tan, 2010), data from this study do not support the idea that content knowledge is as important to both constructs at once.

Chapter VIII: Discussion

Taken together, the quantitative and qualitative data provided evidence that non-STEM majors engaged in science identity work while taking a non-majors biology course, and that this identity work within the Biology 1 course resulted in demonstrations of scientific literacy. This study expands upon previous work, in that most qualitative research has focused on children in grades K-12, trying to pique their interest in science (Calabrese Barton et al., 2013; Carlone et al., 2014) or are quantitative studies on scientific literacy alone (e.g., Baldwin et al., 1999; Chemers et al., 2011; Gardner et al., 2016). In terms of non-science majors, there is little research available encompassing both identity work and scientific literacy. Therefore, a holistic view of the ways in which undergraduates engaged with science identity work and how this impacted their scientific literacy adds to what we know about this population, can further research in these areas, and can better aid educators to encourage both attributes.

A. How Non-Science Majors' Perceptions of Themselves as Science People Changed through Identity Work in Biology 1

My first two research questions were: (1) How did non-STEM majors' perceptions of themselves as science people change through the course of a semester, and (2) how did non-STEM majors engage in identity work during a non-majors' biology course?

The participants in this study entered the course feeling like they were not science people. Both qualitative and quantitative findings demonstrated that by engaging in science identity work during Biology 1, this changed by the end of the semester and students viewed themselves as science people. Additionally, students felt that the instructor believed they were science people following their experience in Biology 1. Participants also described what made them feel like they were *not* science people, specifically when they were unsuccessful in a class or felt like others did not see them as science people. Non-STEM majors' prior experiences and how they affected their perceptions of themselves as science people were important to consider. This provided a way to understand changes in their perceptions of themselves as science people by the end of the semester.

Science identity work is comprised of a set of context-dependent actions that position the student as a science person and allow them to consider their possible future selves related to science (Calabrese Barton et al., 2013; Carlone et al., 2014), and it is critical that these actions are recognized by others (Kelly et al., 2017). In the Biology 1 classroom context, non-majors had many opportunities to engage with scientific material and the process of science through real-life case studies, discussions, and laboratory experiences, culminating in a final project and presentation. Focusing specifically on their final project of evaluating science presented in the popular media, this identity work especially manifested in the areas of scientific performance and recognition by the instructor and peers. Overall, positive identity work in Biology 1 occurred when students engaged in scientific discussions surrounding socio-scientific issues (such as case studies and labs), were recognized as science people by one another and the instructor, performed in ways that positioned them knowledgeable in the class context, and applied science in a context outside of the classroom.

These findings expand upon work by Calabrese et al. (2013) and Carlone et al. (2014) with elementary and middle grades students and their science identity work. Specifically, interest in science declined when students engaged in a more traditional science curriculum (centered on memorizing facts and few active learning experiences) during the late elementary school years (Carlone et al., 2014). Additionally, adolescents' science identity work in the classroom context can and should be recognized, encouraged, and supported in order to result in a salient identity as a science person (Calabrese Barton et al., 2013). This study expands on these findings, as participants highlighted that prior school experiences impacted their views of themselves as science people upon enrolling in Biology 1. Therefore, it is the responsibility of the instructor to recognize and value the identity work taking place in the classroom. In general, non-science majors entered the university with varying interest in and perceptions about science, but given opportunities for positive science identity work they began to see themselves as science people.

Understanding the experience of non-STEM majors is important because they compose the majority of college graduates (National Science Board, 2018) and generally feel some amount of anxiety toward science (Desy et al., 2009; Garcia et al., 2015), but it is still necessary for them to interact with science in their lives and non-science careers (Hoffman, 2019; Holbrook & Rannikmae, 2007). Additionally, many quantitative studies have modeled science identity and how it affects STEM interest and retention (e.g., Chemers et al., 2011). The qualitative findings from this study are helpful in illuminating previous quantitative studies on science identity in both STEM and non-STEM majors, along with extending them to the non-majors population and how science identity work impacts these students.

B. Non-STEM Majors Demonstrated Scientific Literacy

My third research question was: How do non-STEM majors demonstrate their scientific literacy through engagement in biology coursework? Specifically, I focused on a project examining science in the news. Scientific literacy, for the population of undergraduate non-science majors, is best viewed as a combination of scientific problem-solving, conceptual knowledge, and communication of knowledge (Holbrook & Rannikmae, 2007), along with the application of these attributes to real-life situations (Gardner et al., 2016; Holbrook & Rannikmae, 2007).

Students demonstrated scientific literacy through sharing their beliefs, attitudes, and interests surrounding science, by connecting concepts learned in class to their final project topic, and demonstrating their understanding of science content and the nature of science through focus groups and final reflections. Overall, students in Biology 1 believed that science was based on observation, practical, and relevant to life outside of the classroom context, all of which are positive beliefs surrounding science (Gardner et al., 2016). Participants also demonstrated scientific literacy through increased self-efficacy as learners and communicators (Baker & Sivaraman, 2018), specifically when presenting their final projects. In this setting, they were required to connect concept knowledge to a scientific study of their choice, as well as discuss how they would interact with science in the news outside of the classroom. Recall that Diego expressed that "know[ing] enough to phrase this or word this" during participation in classroom discussions made him feel confident. Such self-efficacy in terms of communicating science is an example of an outcome that helps build an identity as a science person, which in turn contributes to confidence in taking part in discussions of scientific material with others outside of the classroom context (Brown, 2004; Chemers et al., 2011; Potvin & Hazeri, 2013).

Finally, Biology 1 students demonstrated scientific literacy through action (Hodson, 2014b), such as evaluating scientific claims they hear in the media and through communication (Holbrook & Rannikmae, 2007), specifically by interacting with science in class through case studies and discussions as well as outside of the classroom when talking about science with their friends and family. As an example, recall that Clara described how she engaged her family in a scientific discussion while spending time together in nature, saying, “I was on a walk with my step dad and my mom and we’re talking about the environment and global warming and climate change, and we’re talking about how deforestation may affect that” (Lines 146-149). She described how she shared the content knowledge from Biology 1, and engaged in a thoughtful discussion of this material with others outside of the classroom context. Clara also shared that the knowledge she gained in class resulted in her finding interest in various scientific topics that she had not considered before, which is an aspect of scientific literacy that she demonstrated (Glaze, 2018; NASEM, 2016).

There is still room for non-science majors to expand their scientific literacy, particularly in their understanding of hypotheses and the nature of science. Both Clara and Samuel made statements about proving a hypothesis, which showed that they had a misunderstanding of hypotheses as falsifiable rather than provable. This offers insight into how to best teach about collecting evidence to test hypotheses, which can be done through practice during class time.

C. Being a Science Person and Scientific Literacy

Science identity work and scientific literacy interacted with each other as well, which contributed to the depth of the analysis of each and exposed the ways in which the attributes overlap. Specifically, as students gained scientific knowledge and were given opportunities to interact with science content during class and lab experiences, their perceptions of themselves as science people increased through the course of the semester. For example, Jenna highlighted that, “the case studies were big for making me feel like a scientist, because I think like they’re real world situations.” Giving the student the role of scientist is an opportunity for them to engage in identity work that moves them toward a science person identity (Carlone et al., 2014; Chemers et al., 2011), while simultaneously encouraging scientific literacy through content knowledge and application (Holbrook & Rannikmae, 2007). Case study teaching is one way to accomplish this goal.

Participants also spoke about how a lack of scientific literacy resulted in feeling less like a science person, specifically related to the amount of content knowledge they felt that they possessed or learned to apply. For example, recall that Jenna shared prior experiences in science classes that, “I can say things and [get] them to make sense and them to be the right answer, but like not grasp the concept,” and that this was frustrating for her and made her feel less like a science person. She also stated that, “when I’ve not felt like a science person, it’s probably usually historically when I’ve gotten grades back that are not that great.” This illuminates the idea that science identity work and learning go hand in hand and are part of scientific literacy (Renninger, 2009), which is an important outcome of science education (Baker & Sivaraman, 2018; Crowell & Schunn, 2016).

Both STEM identity work and scientific literacy can be demonstrated through students’ scientific beliefs, attitudes and interests (e.g., Gardner et al., 2016; Laugksch, 2000; Ryder, 2001; Tinsley, 2016), self-efficacy in terms of learning and understanding science content (Baker & Sivaraman, 2018; Ryder, 2001), along with content knowledge and how it translates to action in real-life situations (Holbrook & Rannikmae, 2007). Information regarding non-STEM majors’ self-efficacy surrounding their ability to become more scientifically literate is helpful for educators (Baldwin et al., 1998). In particular, feelings of competence are tied to use of scientific methodology, generalization of knowledge, and application of content and skill knowledge.

D. Limitations

One limitation of this research is that it took place within the class I taught, which potentially impacted how much information students were willing to share because they may have had reservations about me doing the analysis. To counteract this, analysis occurred following the submission of final grades for the semester. Data collection occurred during the semester with the exception of focus groups, which were held following the submission of final grades.

This study was also limited in that the focal population was a single class of students at a small, private university. This university offers a general education science class that is meant for non-STEM majors, which may not be the case at all universities. Additionally, the demographics of this university include approximately 49% of undergraduates who self-report as white, 14% as Latinx, 11% as Asian, 5% as Black, and 20% chose to self-report as "other", and therefore, the findings may not apply to students from minoritized backgrounds. For these reasons, this study should be repeated in other institutions with a greater diversity of students. It should be noted that the Biology 1 class demographics were more diverse than the university general population.

Additionally, in the midst of the semester of data collection, the university closed due to COVID-19, which potentially limited data collection and how students participated in the online-only environment of class. While the course content did not change, there were multiple factors related to the pandemic that could have affected student participation and engagement in coursework. Additionally, student presentations were delivered via Zoom, which likely impacted the number of questions following the presentations as well.

As primarily a qualitative study, the sample size for focus groups was also limited. However, nine students participated in focus groups, with varying backgrounds and experiences (Krueger & Casey, 2009), and this was about 33% of the total class enrollment. Likewise, students in focus groups may have been unwilling to share some of their thoughts with peers.

Finally, in this study I focused on a general education biology course for non-STEM majors. While some of the ideas may be extended to future work in other areas of STEM beyond life sciences, it is possible that some of the ideas do not apply. Therefore, further work on identity and identity work in other areas of STEM are necessary to make such conclusions.

E. Implications and Future Directions

There are two major implications of the findings of the study, one for practice and one for research. In terms of practice, this research can guide university professors in building courses that encourage students to identify as science people, along with increasing scientific literacy in the non-STEM majors who are required to enroll in a lab science course. In particular, this work illustrated that such courses should include multiple opportunities for non-STEM majors to interact with science content in real and applicable ways along with encouragement for students to discuss and present scientific ideas, and instructors should recognize the identity work taking place throughout the course.

The results of this study suggest that students should interact with science content in applicable ways through case studies, lab experiences, or projects surrounding science they will interact with in their daily lives. For example, knowing the definition of bioaccumulation may help a student answer a test question correctly but if they have no context for that vocabulary in their daily life they are unlikely to remember it outside of the classroom context (Seiler & Huggins, 2018). However, connecting the idea of bioaccumulation to that of mercury in fish and what this means in terms of the type of fish they should eat for dinner results in the likelihood that a student will remember more of the science content because it has relevance to their life (Rowe et al., 2015; Seiler & Huggins, 2018). Participants in this research described their engagement with the science content through case studies as one way they felt like scientists, which is one aspect of their identity work. This is related to the importance of interacting with science in the popular media as shown in this study, which is another way to connect science content to students' lives outside of the classroom. In this case, students can evaluate information they encounter through social media or the news, learn about bias in sources, and apply their science content and process knowledge using methods that are transferable to contexts outside of the classroom.

This study demonstrated that positive identity work can be encouraged in the classroom by providing students with opportunities to connect classroom science content to what they will encounter in their lives, along with venues in which they can present or communicate their scientific ideas. Such scientific performances can be informal, such as class or group discussions and problem-solving, or formal presentations of their work. This is a way for students to gain recognition from others regarding the identity work they are engaging in. From building on one another's ideas through discussion (Brown et al., 2005), to solving a problem together (Roth & Lee, 2002), these experiences provide opportunities for peers and instructors to recognize and validate identity work (Kelly et al., 2017). This resulted in students' positive identity trajectories toward feeling like a science person along with increased scientific literacy, which is a widely agreed-upon goal of science education (Gardner et al., 2016; Roth & Lee, 2002; Rudolph & Horibe, 2016; Tinsley, 2016).

The second implication, in terms of research in science education, is an addition to the understanding of how the constructs of science identity and scientific literacy interact with one another. Future research on science identity work and scientific literacy in science majors would be interesting as a way to build a complete picture of these attributes as a part of undergraduate science education. Additional work regarding the constructs of science identity work and scientific literacy is also needed, as they have overlapping definitions and are sometimes indiscernible from one another.

An in-depth look into how non-science majors talk about evidence in science would build on this study. Another area that warrants further investigation is the pre- and post-course survey, specifically the positive and negative belief, attitude, and interest items (Gardner et al., 2016). Further qualitative investigation of these items would be enlightening in terms of the meaning non-STEM majors ascribe to them, especially in terms of science being only one method, subject to change, and if it is based on observations or ideas.

Finally, the body of literature on identity work and scientific literacy is lacking in non-STEM majors. The focus on STEM education in the literature tends toward those students who declare STEM majors and how to retain them, or how to increase STEM interest in young children. Therefore, this study contributes to literature on both science identity and science identity work along with scientific literacy, particularly for non-STEM undergraduate students.

F. Conclusion

As demonstrated through students' conversations with one another, presentations on current scientific studies along with media representation of those studies, and their own thoughts from focus groups and surveys, non-STEM majors participate in identity work and this work has an effect on the scientific literacy of the individuals along with science person identities. Science courses meant for non-STEM majors are the ideal context for this work. In particular, the group in this study entered Biology 1 feeling like they were not science people and were unprepared to evaluate science in the news, and by the end of the course they felt more like science people and prepared to evaluate science in the news as well as interact with science in their lives.

Participants in this study provided multiple examples of both their STEM identity work, feeling like science people, and their ability to be scientifically literate citizens. This is a vital outcome: As noted during the COVID-19 pandemic (CDC, 2020), the American public observed the evolution of scientific knowledge about a novel virus in real-time, testing their ability to understand and synthesize information from multiple sources, which resulted in a variety of beliefs surrounding the virus and behaviors about mask-wearing and physical distancing.

As Hodson (2014b) stated, "Those who are scientifically illiterate are in many ways disempowered and excluded from active civic participation...Scientific literacy doesn't just result in more skilled and more knowledgeable people, it results in wiser people" (p. 916). Providing Biology 1 students with opportunities to take part in science identity work and increase scientific literacy empowered them to engage with science in their lives outside of the classroom context. This is a way to improve informed evaluation of scientific issues that individuals will encounter personally or in a larger societal context. Scientific literacy is critical for society as a whole, and improving ways in which this attribute is encouraged through identity work by non-science majors should be a focal point of science education.

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Appendix A

Pre- and post-course survey

Identity items (Vincent-Ruz & Schunn, 2018)

Items 1-5 below had answer choices of: Strongly agree/Agree/Neither agree nor disagree/Disagree/Strongly disagree, and item 6 was an open-ended question

1. I see myself as a science person.
2. My family sees me as a science person.
3. My friends see me as a science person.
4. In the past, my teachers have seen me as a science person.
5. My biology professor currently sees me as a science person.
6. What does it mean to be a science person?

Scientific literacy items (Gardner et al., 2016)

Items 1-17 and 19 below had answer choices of: Strongly agree/Agree/Neither agree nor disagree/Disagree/Strongly disagree, while item 18 allowed students to choose from the list of terms/phrases from items 1-17, and 20-21 were open-ended.

1. Science is based on observation
2. Science is based on ideas
3. Science is beyond my capabilities
4. Science is personally helpful
5. Science is intriguing
6. Science is confusing
7. Science is relevant to life
8. Science is worthless
9. Science is frustrating
10. Science is practical
11. Science is empowering
12. Science is meaningful
13. Science is only one method
14. Science is certain
15. Science is subject to change
16. Science is biased
17. Science is ethical
18. Choose two of the most accurate terms from above that most capture what you feel science is.
19. I feel confident in my ability to evaluate a scientific study as presented in the popular media (i.e. news, social media).
20. If you saw the following study in the news, what would you look for in the article to determine wither it is scientific or not?
    "Go Ahead, Take a Nap. A New Study Says They May Be Good for Your Heart"
21. What do you think it means to study something scientifically?

Appendix B

Focus Group Protocol

Interview/focus group questions (Krueger & Casey, 2009):

1. Opening
    a. Tell me about your previous science experiences (include classes, informal experiences like museum visits or home science, extracurriculars, etc.).
2. Introductory
    a. What sort of relationship would you say you have with science? (Describe this)
3. Transition
    a. I would like you all to list qualities of scientists – speak up at any point, you do not have to wait for one person to finish the list. While you are talking I am going to make a list to show everyone and we will discuss that.
    b. List qualities you have in common with scientists. (Explain)
4. Key
    a. Think back to a time you felt was important (positive or negative) in your journey with science, and describe it (when did it happen, who was there, what did you feel).
    b. What do you think it mean to be a science person?
        i. What makes you feel like a science person? What makes you feel like not a science person?
        ii. What experiences from this class made you feel like a science person? If none, discuss that as well.
    c. Think about how you felt about science in general and yourself in regards to science before taking a college biology class, and how you feel now. Share your thoughts about how this has changed, or if it has not changed please discuss that as well. (i.e. do you feel more like a science person now than you used to?)
    d. Scientific literacy can be defined as a combination of scientific problem solving, concept knowledge, and communication of science knowledge.
        i. In what ways did the final project help you develop these skills? Give (a) specific example(s).
        ii. In what ways did biology 106 help you develop these skills? Give (a) specific example(s).

    e. This question will sound familiar because I asked about it in the survey, but I want you all to discuss it with one another as well.
        i. You hear the news announce the following headline: "Go Ahead, Take a Nap. A New Study Says They May Be Good for Your Heart"
            1. What questions would you ask and/or how would you analyze claims made in the article?
            2. What are your other thoughts about this headline?

b. In general, how well do you feel that the popular media represents scientific studies? Explain.
c. What skills do you feel like you have gained regarding evaluation of science in the news due to the final project from class?

5. Ending
    a. What did you feel was most important about taking a biology class in college?
    b. What is one more thing you would like to share that you think I have not asked about?

Appendix C

Biology 1 Final Project Assignment

A New Study Says...

See the rubric for the breakdown of points.
Together with a group (3-5 people per group), you will do the following for your final project:
1. Choose a popular scientific story or study or concept from the news, and confirm your choice and group members with your instructor. Submit this information as a word document and fill in your topic on the class google sheet. Type “a new study” into Google to ***first*** find a news story and **then** find the actual study the news story is discussing. Make sure you choose something that appears scientific (not social science, so no psychology, sociology, education, etc.).

2. Use the criteria from the pseudoscience chapter (it is either 2, 19 or 24, depending on the edition you have) of *Biology Now* to analyze your story as pseudoscience or real science (or it could be ambiguous). Also include at least 3 science concepts you learned throughout the semester in your analysis. Additionally, discuss the way the news story represents the science.

3. Create a presentation (10-15 minutes long – practice to make sure you’re within the time limit!). This can be anything you would like: PowerPoint, interactive, you can teach a lesson, do a skit, make an infographic slide, a combination of approaches, etc. You should share the news story you found, along with your analysis.

4. Along with this, each individual must turn in a written reflection about the assignment. This should be at least 1 typed, double spaced page, 12 point Times/Times New Roman font; Includes self-evaluation and group members’ evaluation (was work evenly distributed, do you feel that one person more or less than their share, be specific!); Addresses the questions: (1) What did you learn from this project? (At least 2 things, be specific); (2) How did this project prepare you to evaluate science in the news, and why is this ability important?

GRADING RUBRIC – Possible points = 100

Criteria	Exceptional	Above average	Minimal	Missing
Choice of story/study	10 points: Done on time.			0 points: Not done
Comparison: News and science	10 points: Thorough analysis of how well the news represented the science. What was accurately represented? What was not? Overall	7 points: Missing any of the following: What was accurately represented? What was not? Overall thought of how much you trust this	5 points: Missing more than one of the following: What was accurately represented? What was not? Overall thought of how	0 points: Not done

	thought of how much you trust this news source with your specific scientific study.	news source with your specific scientific study.	much you trust this news source with your specific scientific study.	
Analysis: Science or Pseudoscience	30 points: Thorough analysis of science vs pseudoscience, credentials, source, correlation vs. causation, experiment design, and conclusion of science or pseudoscience. Include specific examples from study. Compare how the news presents the study vs. what the study is really saying	20 points: Missing one of the following: analysis of credentials, source, correlation vs. causation, and conclusion of science or pseudoscience or lacking specific examples	10 points: Missing two or more of the following: analysis of credentials, source, correlation vs. causation, and conclusion of science or pseudoscience	0 points: Not done
Analysis: Additional factors	30 points: Includes *at least* 3 additional scientific principles learned about in class this semester	25 points: Includes 2 additional scientific principles learned about in class this semester	20 points: Includes 1 additional scientific principle learned about in class this semester	0 points: No additional scientific principles included
Presentation	10 points: 10-15 minutes in length, good eye contact with class, creative, all group members participate, is interesting, includes references slide or list	8 points: Either too long or too short by 1-2 mins, participation seems uneven, somewhat creative, poor eye contact, references slide is incomplete	6 points: Either too long or too short by 3-5 mins, clear that one person is doing the entire presentation, somewhat creative, references missing	0 points: Presentation is too long or too short by 5+ mins, one person does the entire presentation (lack of collaboration)
Reflection (individual) Automatic 5 point loss if absent from	10 points: At least 1 typed, double spaced, 12 point Times page; One paragraph of self-evaluation and	8 points: Includes either self-evaluation or group evaluation but not both, does not fully reflect on	6 points: Evaluation is not well thought out with specific examples, little reflection	0 points: Not done

project workday	group members' evaluation (was work evenly distributed, do you feel that one person more or less than their share, be specific!); MOST IMPORTANT: Addresses the questions: What did you learn from this project? (At least 2 things); How did this project prepare you to evaluate science in the news?	learning, is less than one typed page.		