EXAMINING UNDERGRADUATE STUDENTS' APPROACHES TO LEARNING BIOLOGY WITH A FOCUS ON WOMEN OF COLOR

by

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DEDICATION

I dedicate this dissertation to the love of my life, my husband, Reggie, and my three amazing children, Ayanna, Trey and Josiah.

Reggie, I thank you for your unwavering love and support throughout this process. You have been a constant source of encouragement and motivation to embrace all that God has placed within me.

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ABSTRACT

Despite steady growth in national diversity, women of color continue to struggle in accessing higher education and persisting to graduation in STEM fields. Recent shifts in the national narrative from a deficit-based approach towards a strength-based approach to understanding women of color in academic settings, illuminate cultural and social factors that may contribute to positive student outcomes. Science education literature commonly associate deep learning approaches with high academic achievement, requiring students to develop life skills such as complex problem-solving, innovative-thinking, and adaptability to the rapidly changing knowledge base. However, the adoption of deep approaches to learning is strongly influenced by overlapping factors within social and academic environments. Women of color rest at the intersection of such personal and social factors; factors that were historically unexamined in women of STEM scholarship. This mixed method study first explored demographic and academic patterns associated with how introductory biology students approach learning biology, and then used these findings to purposefully select and examine the learning experiences of three women of color holding diverse approaches to learning. Through the lens of intersectionality, this study examines how the mutually constructed identities of race/ethnicity, gender, and science recognized by each woman of color impact their approaches to learning biology.

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CHAPTER I: INTRODUCTION

Maintaining economic prosperity and technological innovation continues to drive national initiatives to increase the number of skilled workers entering Science, Technology, Engineering, and Mathematics (STEM) fields (Museus et al., 2011; Öztürk, 2007). As the United States' population continues to become more diverse, the increased demands for skilled workers will not be met without the participation of individuals of all racial/ethnic backgrounds and genders (National Academy of Sciences, 2007). It is estimated that by year 2050, more than half of the U.S. population will consist of Blacks, Hispanics, Asian, and Native Americans (U.S. Census Bureau, 2008). Despite this steady growth in diversity, students of color continue to disproportionately struggle in accessing higher education and persisting to graduation in STEM as compared to their White counterparts (Banks & Dohy, 2019; Palmer et al., 2011). The STEM workforce does not currently represent the diversity in the U.S. population. In addition to diversifying the American workforce, Museus et al. (2011) classified the success of students of color in STEM education as a moral and ethical imperative and stressed the need for a more concentrated effort on increasing college enrollment, retention, and persistence of students of color in STEM fields (Hurtado et al., 2008; Museus et al., 2011; Palmer et al., 2011).

Similar patterns of disproportionate representation hold true when focused specifically on the field of science within the larger STEM field. Underrepresented minorities (URM), including Blacks or African Americans, Hispanics or Latinos, and American Indian or Alaska Natives, earned only 30.5% of the Bachelor of Science degrees awarded in 2016 and only half of those degrees were awarded to women of color (WOC)

(National Center for Science & Engineering Statistics, 2019). In fact, WOC are often “least recognized and valued, and most invisible and marginalized, among underrepresented groups in STEM” (Johnson, 2011, p. 79). If the STEM field has a diversity problem, WOC are a particularly strong area of concern for which STEM education reformers must focus change efforts.

To explain such underrepresentation of WOC in science fields, research has historically focused on measurable student outcomes, such as scores on standardized tests (Banks & Dohy, 2019). Standardized test scores are a problematic metric as they often do not take cultural validity into account and therefore serve as questionable gatekeepers to WOCs’ advancement in the sciences (Solano□Flores, & Nelson□Barber, 2001). Some research foregrounds women of colors’ lack of interests in science as an explanation for their underrepresentation; however, research findings overwhelmingly demonstrate that WOC, among other underrepresented groups do not persist in science due to social or interpersonal factors (Brown, 2000; Carlone & Johnson, 2007; Ong et al., 2011; Ong et al., 2018 ; Valenzuela, 2006; Varma, 2002; Varma et al., 2006), not because they are less talented, competent, or interested than those who persist in science (Tobias, 1990; Trujillo & Tanner, 2014; Seymour & Hewitt, 1997). All of these explanations remain insufficient as to causal explanations of WOCs’ persistence in the sciences. Thus, it is time we explore more comprehensive and structural explanations for the underrepresentation of women of color in science beyond blaming the individual.

This shift in perspective from blaming the individual student is reflected in recent shifts in the national narrative and research landscape from a deficit-focused approach to a strengths-based approach to understanding WOC in academic settings (Banks & Dohy, 2019; Brown et al., 2016). With this goal in mind research has shifted from the narrative of why WOC fail to examining factors that contribute to the successful navigation of WOC through the science pipeline (a resource-based perspective) (e.g., Byars-Winston et al., 2016**;** Chang et al., 2014; Espinosa, 2011; Hurtado et al., 2010; Johnson et al., 2011; Palmer et al., 2011). Such studies illuminate how successful unrepresented minorities including WOC authored new science identities, balanced competing identities, and continually developed their science identities amidst the sometimes hostile terrain of science (Johnson et al., 2011). Although such studies are informative at a macroscopic level, such as examining persistence across several academic years, there is a need for more microscopic examinations of how cultural and social factors (e.g., identity) affect WOCs' day-to-day academic decisions, such as the approaches they draw on to study for their science classes. While, how students approach learning has a direct impact on academic achievement (Davidson et al., 2019; Geller et al., 2018; Marton & Säljö , 1976; Milner, 2014; Rhodes & Rozell; 2017) microscopic studies are essential to understand, from a resource-based perspective, how WOC successfully navigate through the STEM pipeline and can possibly illuminate more practical aspects that influence the path for WOC to be successful in the science fields. Previous research would indicate that a better understanding of WOCs' science identity would support this work (Hazari et al., 2013; Morton, & Parson, 2018).

WOCs' day-to-day academic decisions, such as how to study for a science course, directly relate to successful academic performance in the sciences (Zeegers, 2001). In addition, successful academic performance is said to aid in WOCs' science identity development and ultimately encourage persistence and retention in science (Carlone & Johnson, 2007; Hazari et al., 2013; Morton, & Parson, 2018; Trujillo, & Tanner, 2014). This study will focus on students' approaches to learning and studying one particular science, biology. Students approach learning typically by utilizing deep-level processes (e.g., making tasks meaningful to their own experiences or the real world), surface level approaches (e.g., rote learning or selective memorizing with little understanding), or some combination of the two (Marton & Säljö, 1976).

Students are encouraged throughout post-secondary education to utilize deep approaches to maximize positive learning outcomes; however, there are many contextual factors that influence the likelihood of students adopting deep approaches, such as the teaching/learning environment, the course design, and/or assessment procedures (Asikainen, & Gijbels, 2017). In the field of biology specifically, education reforms are encouraging instructors to shift away from pedagogical practices that emphasize surface learning and focus on practices that foster meaningful learning through deep-level processing (Laird et al., 2008). Despite these calls and efforts to promote deep approaches, studies have shown that a large number of undergraduate students continue to rely on surface-level approaches to learning that then lead them to negative assessment and learning outcomes (Balasooriya et al., 2009; McNulty et al., 2012; Quinn, 2011; Quinnell et al., 2012; Walker et al., 2010).

In addition to contextual factors, personal factors (e.g., students' perceptions of learning environment) may heavily influence how students go about learning the course material (Zeegers & Martin, 2001; Laird et al., 2008). Personal factors are unique to the discipline of study due to the fact that, "different disciplines have different cultures that have different norms, values, aims, and problems and the role of teaching and learning vary in different academic environments" (Rytkönen et al., 2012, p. 253). For this reason, it is imperative to examine personal factors that might influence student approaches to learning at the discipline-specific level (e. g., Biology).

Researchers have used various methodologies to study the relationship between contextual or personal factors and student approaches to learning (e.g., Chiou et al., 2012; Quinn & Stein, 2013; Quinnell et al., 2018 [inventories], Balasooriya et al., 2009; Watters & Watters, 2007 [interviews], Knight & Smith, 2010; Hazel, Prosser, & Trigwell, 2002 [open-ended questionnaires]). However, many of these studies have examined students from specific geographic or cultural backgrounds (e.g., Balasooriya et al., 2009 [Australia]; Chiou et al., 2012 [Taiwan]; Rytkonen et al., 2012 [Finland] Walker et al., 2010 [New Zealand]). Studies exploring cultural differences in student approaches to learning predominantly compared the learning approaches from Asian countries with those who are born and raised in economically developed countries such as the United Kingdom, United States, Canada, and Australia or Western countries (e.g., Richardson, 1994; Saravanamuthu, 2008; Watkins & Ismail, 1994; Watkins et al., 1991). The majority of Asian students were found to use a combination of both deep and surface approaches, resulting in Asian students utilizing more mixed approaches to learning (Salamonson et al., 2013). Although these studies explore cultural differences, few take into account subcultural differences within the population of interests. For example, America is made up of racially/ethnically diverse sub-cultures, such as African-Americans, Hispanics/Latino, and Asian- Americans; therefore, more research is needed to explore the subcultural differences within a population of interest. Given the unique racial and ethnic identities of WOC, it is useful to examine how they approach learning biology through the lens of their cultural and science identities.

Implications from these geographically isolated and comparative studies indicate the strong influence of cultural traditions and values on student approaches to learning (Chiou et al., 2012). For decades, researchers have compared cross-cultural inventory results, in pursuit of an explanation as to what role social and culture factors play in impacting how students approach learning (Kember, 2016; Yin et al., 2018). However, few if any studies have viewed these social and cultural factors through the lens of the intersecting identities of the student embedded within a specific discipline. These intersecting identities personally held by the students are directly impacted by the social factors within the discipline-specific community and might vary based on their own personal identity experiences as scientists (Avraamidou, 2020).

Given the link between personal and social factors, it is helpful to examine such factors in relation to Bandura's (1986) social cognitive learning theory. The social cognitive learning theory describes how the interaction between environmental factors (e.g., social supports/ barriers, social norms, access to community, and influence of others) and cognitive/personal factors (e.g., identity, perceptions, expectations, and attitudes) influence behavioral factors (e.g., learning strategies and practices). Byars-Winston et al.

(2016) argued that current efforts to enhance persistence in sciences often ignore important personal (e.g., race, gender) and cognitive factors (e.g., confidence, motivation, identity, etc.) that interact with these social and environmental factors. Therefore, there is a need to understand how all contributing factors (e.g., environmental, social, personal, and cognitive) interact. In this study, I draw on this framework to illuminate how female students of color can successfully navigate the science pipeline. This study will draw on the social cognitive learning theory to examine how engagement within the undergraduate biology community (environmental factors) interacts with the race, ethnicity, gender, and science identities (cognitive/personal factors) of women of color to influence their approaches to learning biology (behavioral factors).

Collins (2000) emphasizes that research on women of color must consider the intersectionality of race, gender, and ethnic identities. The idea of intersectionality guides researchers to examine gender, sexuality, race, class, and nation as mutually-constructed systems of oppression (Collins, 2000) that are interrelated, rather than additive, components of identity (Johnson et al., 2011). Additionally, Riegle-Crumb and King (2010) argued that research that only examines one axis of stratification, either race/ethnicity or gender, may lead to problematic and non-generalizable assumptions that certain differences, patterns, and obstacles apply to all females, or all males. Therefore, to study student identity as an interacting personal/cognitive factor in social cognitive learning theory, it is essential to recognize and focus on the intersectionality of the identity of women of color. This study is not focused on women who also happen to be people of color or people of color who also happen to be women.

Based on the construct of intersectionality, the gender and racial/ethnic identities of WOC are mutually constructed and cannot be separated (Crenshaw, 1989). Intersectionality provides a guide to study the personal/cognitive factors that interact with environmental factors to influence approaches to learning biology, which may help us understand attrition and persistence in science of this population. Previous studies have described how successful women of color authored new identities, balanced competing identities, and continually developed their science identities (Johnson et al., 2011). However, a salient characteristic of science identity is that it is relational to multiple other identities, such as gender identity, religious identity, and ethnic identity (Avraamidou, 2020).

For WOC, science identity is shaped by the magnitude in which they view themselves as a part of the science community and how they are viewed by others within the science community (Carlone & Johnson, 2007). Critical experiences along their path of science education influence this recognition component of their science identity and these experiences mutually impact their identity as WOC. It is with this understanding that the lens of intersectionality best explains the interactions of personal/cognitive factors outlined in the social cognitive learning theory. It is also important to note the factors influencing WOC being recognized by others within the science community stems from environmental/social factors within that same community (Carlone & Johnson, 2007).

Purpose of the Study

The goal of this research is to understand how culture shapes undergraduate students' approaches to learning biology. This study will draw on the social cognitive learning theory to understand how personal factors of the student interact with social factors of the environment to influence the behavior of how WOC approach learning biology. I will first examine how a diverse array of undergraduate students' approach learning introductory biology. Next, I purposefully select a sub-group of WOC holding contrasting approaches to learning for the original sample. I will apply an intersectional lens to examine the personal/cognitive factors of race/ethnicity, gender, and science identity for WOC. I will examine how this mutually constructed identity recognized by each woman of color interacts with the social factors of recognition within the undergraduate biology community to better understand how this interaction between cultural and social factors account for her approaches to learning biology outside the classroom space.

Research Questions

This mixed-methods dissertation research examines how undergraduate students approach learning biology in an introductory course, with a specific focus on women of color. The dissertation is composed of three stand-alone articles (Chapters II, III, and IV) that examine the following research questions:

Chapter II (C2): Measuring Undergraduate Students' Approaches to Learning Biology: A Systematic Review of the Literature

C2Q1: What rationale have researchers given for examining student approaches to learning biology in higher education?

C2Q2: What institutional-, classroom-, and individual student-level factors are related to the adoption of various approaches to learning biology in higher education?

Chapter III (C3): Examining Undergraduate Students' Approaches to Learning Introductory Biology

C3Q1: What demographic and course context patterns emerge from undergraduate biology student scores on the approaches to learning biology survey?

C3Q2: What is the relationship between student approaches to learning biology survey scores and student learning outcomes?

Chapter IV (C4): Approaches to Learning Biology of Women of Color: The Intersectionality of Race, Gender, and Science Identity

C4Q1: How do undergraduate students approach learning biology in the context of introductory biology?

C4Q2: How do women of color experience the phenomenon of studying introductory biology as it relates to their conceptualizations of studying, approaches to learning biology, and their learning outcomes?

C4Q3: How do the intersecting identities of science, race/ethnicity, and gender of women of color shape how they experience the phenomenon of studying introductory biology?

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CHAPTER II: REVIEW OF LITERATURE

MEASURING UNDERGRADUATE STUDENTS' APPROACHES TO LEARNING BIOLOGY: A SYSTEMATIC REVIEW OF THE LITERATURE

Effective teaching to support students' conceptual understanding is a common focus for undergraduate biology educators and researchers (American Association for the Advancement of Science (AAAS), 2011). Yet, a key component in connecting effective teaching to desired student outcomes is understanding the students' experiences of learning. Students' learning experiences are strongly influenced by their *approaches to learning,* or how they go about studying course material (Minasian-Batmanian et al., 2006). In one conceptualization, students can adopt deep approaches to learning (e.g., by making tasks meaningful to their own experiences or the real world), surface approaches to learning (e.g., rote learning or selective memorizing without understanding), or some combination of the two (e.g., an intent to understand followed by memorization for an assessment).

Post-secondary biology educators generally aim to foster the development of deep approaches to learning biology as opposed to encouraging the persistence of surface level approaches (AAAS, 2011; Buchwitz et al., 2012; Handelsman et al., 2004; McGuire, 2006; Tomanek & Montplasir, 2004). Biological proficiency involves complex problem-solving, innovative thinking, and adaptability to the rapidly changing knowledge base, which are components that develop via deep approaches to learning (Watters & Watters, 2007). To promote biological proficiency, it is important to consider how undergraduates approach learning biology, what factors influence the adoption of deep or surface approaches, and how to foster deep approaches to learning biology. Due to the complexities associated with student learning, it is imperative to examine factors that might influence how a student approaches learning biology at multiple levels: factors associated with an individual student, factors related to a biology course in which students are enrolled, and factors related to the institution of higher education that the biology courses and individual students are embedded in. For example, the choices a professor makes to design classroom instruction that models deep approaches to learning is a course-level factor, while implementing student success initiatives in STEM is an institution-level factor that might affect student approaches to learning biology (Rytkönen et al., 2012).

Factors that affect student approaches to learning at the individual level can be understood using constructivist theories of learning. From a constructivist perspective, learning biology is a generative process that requires students to actively integrate prior knowledge and domain knowledge to develop rich domain-specific conceptual knowledge and form new connections to make sense of the natural world (Chin & Brown, 2000). Successful integration involves "activities or methods used by an individual to encode information into long-term memory in the category of experiences that produce changes in mental representations" (McNulty et al., 2012, p. 1). This means that learning strategies that involve changes in mental representations or connections between prior and new knowledge are more effective in terms of relevant retrieval of information. Such strategies are characterized as deep approaches to learning. Students who incorporate key elements of science practices such as asking thoughtful questions, constructing scientific explanations, and reflecting on their learning process into their study approaches, are more likely to have positive biology learning outcomes (Chin & Brown, 2000; Tomanek & Montplasir, 2004; Watters & Watters, 2007). Therefore, to understand how to support students to use deep approaches to learning biology, it is critical to examine how individual students think about their learning process and how that connects to their approaches to learning.

Factors that affect student approaches to learning biology at an individual level must be considered in light of the biology course in which individual biology learners are situated. Students' approaches to learning are context-dependent, which means that they are heavily influenced by both course factors (e. g., teaching/learning environment, course design, assessment procedures) and individual factors (e.g., each student's unique perceptions of the biology learning environment that are shaped by their prior experiences) (Zeegers & Martin, 2001; Laird et al., 2008). For example, students are more likely to utilize surface approaches when faced with learning environments that reward the rote memorization of facts. Hence, it is important for post-secondary educators to foster learning environments that support autonomous learning and shift away from elements of course design and instruction that emphasize surface approaches to learning biology (Laird et al., 2008). However, instructors frequently make decisions in their courses, and it is important to understand how each decision might implicitly or explicitly prompt students to use deep or surface approaches for learning.

Individual students and biology courses are situated in an institution of higher education. Institutional-level interventions designed to help students learn discipline-specific, deep strategies have long-term positive impacts on students' learning approaches and their self-confidence (Zeegers & Martin, 2001). Such institutional interventions have increased in frequency in an effort to increase the number of graduates in Science, Technology, Engineering, and Mathematics (STEM) fields by over 100,000 per year over the next decade to keep up with global demands (President's Council Advisors on Science and Technology [PCAST], 2012; Hoskins et al., 2017). To achieve this goal, institutions of higher education must decrease attrition rates of STEM majors, which are often attributed to poor performance in introductory classes (Hoskins et al., 2017). Poor performance in introductory STEM classes is related to poor preparation for college-level courses, undeveloped reasoning skills, and poor study skills (Tomanek & Montplaisir, 2004). Institutional interventions often introduce skill-based learning strategies and metacognitive awareness to incoming undergraduate students that are seen as an integral part of the language and scholarship of the disciplinary content (Clanchy & Ballard, 1995; Vermunt, 1994, 1995; Zeegers & Martin, 2001). Thus, institutional initiatives can also shape how students approach learning STEM in general, and biology specifically.

Understanding how and why undergraduates adopt varied approaches to learning biology is important to inform efforts to promote biological literacy in the individual student, reform classroom environments, and develop institutional student support programs. This review examines the existing literature related to undergraduate biology students' approaches to learning biology. Previous reviews have focused on student approaches to learning in general educational settings (e.g., Dinsmore & Alexander, 2012). However, there is a need for a specific focus on student approaches to learning within a specific discipline. For example, science is both a body of knowledge and a process (Derry, 1999), in which scientific knowledge is constructed by engaging in specialized practices shared by the science community. When biology education supports students to learn biology content knowledge through the specialized practices that generate biology knowledge, students can develop a deeper understanding of both aspects of biology (Manz, 2012). The specialized practices of generating knowledge in biology have nuances that differentiate them from the specialized practices of generating knowledge in other science disciplines, as well as disciplines outside of science (Ford, 2015), thus illustrating the need to apply a discipline-specific focus to examining how students approach learning biology. Gaining an understanding of the underlying complexities within a discipline related to why students adopt one approach to learning over another and how to effectively promote appropriate approaches is important for students to develop biological proficiency. These initiatives will benefit from a better understanding of the correlations between student characteristics, learning contexts, learning outcomes, and student approaches to learning. This understanding has implications for the design of biology instruction, especially in light of the push for instructional reform across undergraduate biology. Discipline-based education research on student approaches to learning is a relatively new area of study and the literature on student approaches to learning biology (or any specific discipline) has not been systematically reviewed to provide a basis for what is currently known. This review has two guiding questions:

(1) What rationale have researchers given for examining student approaches to learning biology in higher education?

(2) What institutional-, classroom-, and individual student-level factors are related to the adoption of various approaches to learning biology in higher education?

This review is divided into four sections. In the first section, I discuss how the construct of student approaches to learning was historically conceptualized and measured in the context of non-discipline specific higher education contexts. In the second section, I discuss the methods used for inclusion of literature for this review. In the third section, a detailed description of the findings guided by each research question are provided. Finally, the last section provides future directions for practice and research.

Conceptualizing Student Approaches to Learning in General Education

Foundational studies to conceptualize student approaches to learning.

The term "approaches to learning" is often credited to the work of Marton and Säljö (1976a, b). However, the majority of their work focused on ways of processing information and its relation to learning outcomes (Richardson, 2015). Richardson (2015) published a detailed outline of the development of the approaches to learning construct from Marton's original work. A brief review of the findings from this publication is discussed below.

In early work, Marton conducted his doctoral thesis on learning organization and memory (Richardson, 2015). This work involved 30 paid volunteers who were asked to recall a list of 48 famous names delivered through 16 different randomized audio recordings. Participants were asked to say aloud as many names as they could remember in any order. After concluding this task, the volunteers discussed how they carried out the learning task during a semi-structured interview. Participants who imposed an organized hierarchical structure to the list of names recalled more names than participants who tried to remember to original sequence of names. Marton's research aimed to understand the process each participant used to organize their learning during the task and how their processes related to their ability to remember the names. This methodology has since been known as a phenomenographic method which is a qualitative approach to investigating students learning experiences within an educational context (Marton, 1981; Prosser & Trigwell, 1998).

Marton continued his work in collaboration with other researchers from the University of Göteburg and went on to test previous findings in a more naturalistic setting. They conducted a series of replicated experiments asking paid volunteers from the educational psychology program to read a newspaper article and discuss what the article was about during semi-structured interviews (Richardson, 2015). After a comprehensive analysis of the data, Marton grouped the responses into four categories that reflected various levels of student understanding of the article based on how student understanding aligned with the author's intentions. In other words, participants who displayed outcomes closer to the desired responses displayed a deeper, or higher level, understanding of the articles.

Marton also examined how the participants carried out the task of reading the article. Adapting a framework by Craik and Lockhart (1972), Marton analyzed the same qualitative data set from the newspaper article study using the analytical perspective that "human memory could be regarded as a hierarchical system of representations or *levels of processing"* (Richardson, 2015, p. 242). Craik and Lockhart's (1972) framework described two ways participants could go about learning the material; Type I processing, where the participants attempted to repeat key terms or details as accurately as possible or Type II processing, where participants sought to understand the authors' intended meaning (Biggs, 2001; Richardson, 2015). Marton later renamed these levels as "surface" (Type I) and "deep" (Type II) levels of processing. From this second analysis of the newspaper article study, Marton determined that all of the participants who used deep-level processing also displayed the highest levels of understanding of the newspaper article. Likewise, all but one of the participants who used surface-level processing displayed the lowest level of understanding of the newspaper article (Richardson, 2015).

Marton's next line of research inquiry examined whether students used the surface and deep levels of processing that he characterized in the newspaper article study within the student's normal academic studying. Marton and Säljö's (1976a, b) work initially addressed processing strategies students used while reading a text, like the newspaper article, but these experimental studies did not consider the way students generally go about studying in their daily lives (Asikainen & Gijbels, 2017). To help differentiate the context of experimental studies from the context of students' daily lives, Marton operationalized the term *approaches* to specifically refer to the variety of students' attitudes that inform their intentions behind activating either deep or surface level processes while reading in different contexts (Richardson, 2015). The combination of a students' intention toward an activity and the processing strategies activated in response to those intentions was encapsulated by the term *approaches to learning* (Baeten et al., 2010). Through contributions from Marton and Säljö (1976a, b), Biggs (1979), and Entwistle and Ramsden (1983), the body of research on approaches to learning consistently demonstrated relationships between different approaches to learning and different learning outcomes. However, the research contributions on approaches to learning from Biggs (1979) and Entwistle and Ramsden (1983) diverged methodologically from Marton and Säljö (1976a, b) because they predominately used survey-based methods and were more narrowly focused on authentic educational settings (Asikainen & Gijbels, 2017). The contributions of these different researchers to the body of research on student approaches to learning will be described in the next section.

Student approaches to learning and other terminology

The term *student approaches to learning* specifically refers to the different qualitative ways in which students carry out learning tasks and the intentions behind their study methods (Asikainen & Gijbels, 2017). The term student approaches to learning is synonymous with the terms *learning strategy*, *cognitive strategy*, and *processing strategy*. These terms all describe the "learning or thinking activities students apply to process the learning material" (Ferla et al., 2009, p. 186). I will use student approaches to learning, or SAL, throughout this article.

Approaches to learning are often discussed alongside self-regulation strategies in the literature, but it is important to note that these are distinct activities. Self-regulation strategies highlight metacognitive regulatory actions and describe how students direct their learning activities towards the attainment of personal goals (Vermunt & Vermetten, 2004; Zimmerman, 2000). An example of a self-regulation strategy is when students self-diagnose their own progress towards a learning goal and then make necessary adjustments to meet the learning goal. The distinction between these terms is that SAL refers to cognitive level strategies and describes what the student did to learn the course material. Self-regulation describes metacognitive level strategies of how students think about their learning process. Both SAL and self-regulation strategies complement each other to characterize a student's overall study habits, however the two terms fundamentally describe different activities.

There are two topics, learning orientations and serialist and holistic learning strategies, that are related to SAL, but that are not very common in the SAL literature. SAL is often associated with learning orientations. Learning orientations describe a students' tendency to adopt either deep or surface approaches regardless of the academic context (Lonka et al., 2004). Lonka et al. (2004) characterized students as holding either a *meaning* or *reproducing* orientations towards learning. Students holding a meaning orientation, seek to understand the intention of the task, whereas a reproducing orientation, simply seeks to memorize and repeat the task. With this said, learning orientations describe a more desirable approach that is independent of context. In this light, learning orientations are more stable or static, compared to SAL because students are said to adopt the same learning orientation for different tasks (Lonka et al., 2004).

Other researchers have characterized student approaches to learning along two levels, like Marton and Säljö's (1976a, b), but they used different terminology for this same dichotomy. Pask (1976) conducted similar experiments as Marton and Säljö (1976a, b), and defined the dichotomy as serialist and holistic learning strategies. Serialist strategies involve students concentrating on details and using step-by-step approaches, often failing to see the big picture. Students using holistic strategies take a broad view of the task, constructing a framework of interconnected ideas (Cuthbert, 2005). Again, the terms serialist and holistic learning strategies are referred to the similar dichotomy as surface and deep approaches to learning respectively.

As described earlier, Marton and Säljö (1976a, b) described the original distinction between different approaches to learning as deep and surface level processing. Biggs (1987) took up Marton and Säljö's distinction, and then added a third approach, termed *achieving,* to capture how students organized their studying in order to gain recognition for achieving top performance. Tait and Entwistle (1996) also identified an approach that was conceptually similar to *achieving*. This approach was labeled the *strategic* approach to learning. In this review, I call this third approach the strategic/achieving approach to learning to recognize both Tait and Entwistle (1996) and Bigg's (1987) contributions.

The SAL construct is generally connected to student motivations to learn (Vermunt & Vermetten, 2004). As described earlier, Marton's conceptualization of approaches encapsulated the student's intention for drawing on deep or surface processing strategies. The next section provides an extended explanation of the three approaches to learning that are most frequent in the literature (deep, surface, achieving/strategic), and how each approach is connected to aspects of student motivation to learn.

Deep approaches. A deep approach to learning is based on an individual's perceived need to learn and driven by intrinsic motivations to understand the intentions of the educational tasks (Asikainen & Gijbels, 2017; Biggs, 2001). Students who adopt deep approaches search for inherent meaning of the tasks, make tasks meaningful to their own real-world experiences, integrate aspects of a task into previous knowledge, and form hypotheses or theorize about the tasks (Kember et al., 2004; Richardson, 1994). Students using a deep approach to learning also engage in appropriate meaningful learning activities, where appropriateness is measured based on alignment with the instructor's intentions of the task. For example, if an instructor presents a task requiring students to explain how two or more biological concepts are related, then a student may construct a concept map to appropriately prepare for that assessment. Research indicates that deep approaches are synonymous with independent, high-quality, meaningful learning, which eventually leads to a deeper understanding (Ferla et al., 2009; Vermunt & Vermetten, 2004).

Surface approaches. A surface approach to learning is based on motives and intentions that are extrinsic to the real purpose of the educational task, typically fear of failure or keeping out of trouble (Asikainen & Gijbels, 2017; Biggs, 2001). Students using surface approaches invest little time and effort into understanding the task. Students inappropriately engage in low-cognitive level activities with tasks that are designed to promote high-cognitive activities. Most commonly, students use rote learning or selective memorizing without understanding as a quick way to gain enough information to satisfy the bare minimum of learning goals. Surface approaches are linked with negative student outcomes (Biggs, 1987, 2001).

Strategic/Achieving approaches. Tait and Entwistle (1996) and Bigg (1987) introduced a third approach to learning called strategic or achieving. The strategic/achieving approach to learning refers to how students organize their studying in order to gain recognition for achieving top performance (Bigg, 1987; Tait & Entwistle, 1996). The strategic/achieving approach describes how students manage their time, workspace, and syllabus coverage to maximize their chances of achieving the highest grades. This differs from deep and surface approaches to learning in that the strategic/achieving approaches are not focused on the different ways students engage in learning, just how they organize their study time (Asikainen & Gijbels, 2017).

Not all inventories assessing SAL measure students' achieving/strategic approaches to learning. Among the most prevalent SAL inventories, *The Study Process Questionnaire (SPQ)* (Biggs, 1987) and the *Approaches and Study Skills Inventory for Students (ASSIST)* (Tait et al., 1997) capture this variable. Neither of the discipline-specific inventories identified in this review [i.e., *Approaches to Learning Science* (Kember et al., 2004; Lee at al., 2008; Liang et al., 2010) or *Approaches to Learning Biology* (Chiou et al., 2012)] measured strategic/achieving approaches to learning which may speak to limitations of these instruments' ability to capture the richer nuances commonly associated with SAL in a discipline-specific setting.

Measuring general (not discipline-specific) student approaches to learning.

Early studies primarily used a phenomenographic method to measure SAL, in which individuals' learning processes were derived from introspection of their own learning experiences (Marton, 1981; Prosser & Trigwell, 1998). Later studies operationalized the SAL construct into inventories suitable for larger samples and statistical generalizability (Biggs, 2001). Using a traditional two-step methodology, constructs were derived from qualitative interviews and then itemized into quantitative surveys. These surveys were then validated for the intended audience and used in additional studies. Instruments measuring SAL are arguably referred to as quantitative or 'atheoretical' despite the traditional two-step methodology (Lonka et al., 2004).

For the past 40 years, researchers have developed learning/study process inventories from two distinct theoretical positions. First, the Information Processing (IP) theoretical position derives from cognitive psychology (e.g., Moreno & DiVesta, 1991, Schmeck et al., 1977; Weinstein et al., 1987) and second, the Student Approaches to Learning (SAL) theoretical position derives from qualitative analyzes of students' descriptions of their study processes (e.g., Entwistle & Ramsden (1983)- *Approaches to Study Inventory (ASI) and* Biggs (1987)- *Study Process Questionnaire (SPQ)).* These theoretical positions differ in two fundamental aspects: (a) student motivations, and (b) bottom-up or top-down use of theory (Biggs, 1993). In regard to motivation, the SAL framework is multidimensional comprising of both motives and strategy components. Students' intentions are directly related to how they study. Whereas IP theorists keep cognitive and motivational aspects distinct (Biggs, 1993).

As for bottom-up/top-down use of theory, the 'bottom' in this metaphor refers to the learning context or environment in which the student engages with the learning task. The 'top' in the metaphor refers to cognitive processes adopted by the individual. Approaches to learning are derived in a bottom-up way due to the emphasis on motivation and context (Biggs, 2001). SAL methodologies attempt to capture the different kinds of relationships between learners and tasks, which is based on the assumption that students will modify their approaches to learning in different contexts (Biggs, 1993, 2001). In other words, the 'bottom' or the learning context is said to influence how a student approaches learning. In contrast, IP derivations come from the top-down notion that students hold unique cognitive or learning styles that are constant regardless of changes in the learning context. The 'top' or cognitive processes of the student are said to remain the same despite the change in learning context. This assumption follows the psychology of individual differences. Inventories with top-down foundations are criticized for a lack of ecological validity, in that they are rarely derived from educational context (Biggs, 1993). Given these two theoretical distinctions for measuring the learning/study process, it is important to specify that this systematic review focuses just on research from the SAL perspective.

Researchers in many countries have developed inventories to measure SAL (e. g., Biggs, 1987- [*Study Process Questionnaire,* SPQ; Australia]; Entwistle & Ramsden, 1983- [*Approaches to Study Inventory,* ASI; England]; Vermunt, 1998 [*Inventory of Learning Styles*, ILS; Netherlands]; Schmeck et al., 1991 [revised *Inventory of Learning Processes*, ILP-R]; Pintrich et al., 1991[*The Motivated Strategies for Learning questionnaire*, MSLQ, United States]). Most of these inventories were designed to capture SAL in a generic learning context. In addition, some inventories designed for generic learning context have been modified to address discipline-specific factors (i.e., course, units, topics, or task). For example, a group of researchers from Taiwan modified the *Revised Learning Process Questionnaire* (Kember et al., 2004) to measure students' approaches to learning science specifically (Lee et al., 2008). Chiou et al. (2012) modified Lee et al.'s (2008) inventory to more specifically measure students' approaches to learning biology.

Different methodological techniques and inventories have been used to capture the construct of SAL in general settings and discipline-specific settings (i.e., biology). More research has emerged in recent years that attempts to capture SAL in different discipline-specific contexts, yet findings are derived from different instruments and different theoretical perspectives. Given the influx of research on how students approach learning in disciplinary specific context, it is imperative that we build a more cohesive body of research examining SAL in biology. It is important for the field of biology education to understand the affordances and constraints of different approaches to researching SAL. The following review will shed light on the methodologies that have been used to explore SAL in the context of undergraduate biology education and the various factors that influence student adoption of different approaches.

Methods

Eligibility Criteria

For this review, there were five criteria for inclusion of selected manuscripts. First, each study needed to be empirical, meaning that it collected, analyzed, and reported on either quantitative or qualitative data. Second, each study needed to explicitly reference the student approaches to learning research model (Biggs, 1987; Entwistle & Ramsden,1983; Marton & Säljö, 1976) which also included approaches to learning, study strategies, learning processes, and learning strategies. Third, all studies needed to target students participating in higher education or post-secondary education. Fourth, all studies involved participants who were enrolled in a biological science course and/or a biology major at the undergraduate level. Lastly, studies were captured within the date range of 2000-2019 (justified below).

Literature search and selection

To review existing literature, I searched four databases (Scopus, ERIC, JEWL, and Google Scholar). For each database, I searched seven different loose phrases ("Approaches to Learning", "Student Approaches to Learning", "Study Strategies", "Learning Strategies", "Student Learning Strategies", "Cognitive Processes", and "Metacognitive Regulation") plus two additional terms. The first additional term was "undergraduate", the second additional term consisted of one of three discipline-specific terminology [biology, science, or STEM]. Thus, each search included "loose phrases" + undergraduate + discipline term. (e.g., "Student Approaches to Learning" + undergraduate + biology).

This review followed the methods for inclusion outlined by The PRISMA Group (Moher et al., 2009). There were 273 articles identified by Scopus and 56 articles identified by the other search engines combined. Duplicates were excluded, leaving 219 articles. Abstracts in this sample were carefully scrutinized resulting in the exclusion of an additional 163 articles, leaving 56 eligible articles for full text review.

Next, I conducted an extensive full-text review of the remaining 56 articles, and 32 articles were excluded. During the full-text review, studies focused on medical students and teacher education candidates were excluded because of the unique educational context that were outside the scope of this review. In addition, articles were excluded if they did not specifically examine student study strategies. Some studies described how students approached learning a particular subject solely based on learning outcomes (e.g., test scores). Following this exclusion process, I utilized the snowball sampling technique to search for further relevant research by reviewing the reference list of the remaining articles (Greenhalgh & Peacock, 2005). This process identified 10 additional articles. A flow diagram of this method of inclusion can be found in Appendix A. The resulting review includes 34 empirical studies.

The literature review was limited to the past 19 years (2000-2019) to include relevant literature before and after the 2011 publication of *Vision and Change in Undergraduate Biology Education: A Call to Action* (AAAS, 2011). This publication is a commonly cited reform document that underlies the focus of biology education research and practice on reforming instruction. In addition, this publication marks a pivotal time in undergraduate biology education history that brings necessary structure to those previously promoting student-centered learning and direction to a field of research aimed at educational improvements.

The resulting 34 studies were analyzed with regard to their methods used, study purpose, factors influencing students' adoption of a particular approach to learning, and major findings. The purpose of each article was included to provide a more comprehensive understanding of the rationale behind researchers' methodological decisions. These areas are discussed under two main headings guided by the research questions of the review paper: Q1: *What rationale have researchers given for examining student approaches to learning biology in higher education* and Q2: *What institutional-, classroom-, and individual student-level factors are related to the adoption of various approaches to learning biology in higher education?* Appendix B provides a complete list of the papers with information about the methods used and rationales.

Analysis

To analyze the sampled studies, I created an analysis grid adopted from procedures developed by Potvin and Hasni (2014). Sections were modified to align with the current research questions. The analysis grid was comprised of five sections. Section (A) included general article information, such as the author(s), journal, publication year, and location of study. Section (B) included the stated rationale of each study. The rationale of each article was described using one sentence and grouped based on similarities. Codes were generated describing each unique rationale. Section (C) included methodological information including research design, participant information, data sources, constructs measured, instruments, and data analysis. Each article was categorized based on three types of data analysis: qualitative, quantitative, and mixed methods. Section (D) included major findings, and Section (E) included implication/recommendations. Results from sections D and E were categorized according to the appropriate level of impact; individual, classroom, or institutional. The information categorized at each level was then sub-coded according to emergent themes. Particular attention was paid to the measurement instruments the authors used to assess student approaches to learning.

Findings

Findings are organized according to the guided questions of Q1: *What rationale have researchers given for examining student approaches to learning biology in higher education?* Q2: *What institutional-, classroom-, and individual student-level factors are related to the adoption of various approaches to learning biology in higher education?* In addition, Appendix B provides a detailed breakdown of the specific context in which the

SAL construct was examined. Each study examined either how students approached learning biology within an institutional level program, within an entire course, across a content unit, or of a particular topic. For example, some studies examined how students approached learning across an entire Biochemistry course, either through a pre-post or single snapshot analysis. In this instance, this study would be labeled a course level analysis. Whereas, if a study examined the topic of photosynthesis within a General Biology course, this study would be labeled a topic level analysis. In all cases, how students approach learning serves as the unit of analysis. This information has been added for supplemental information yet will not be explicitly addressed in the findings section below because it does not directly answer the research questions. However, this distinction of analysis is important given the context-dependent nature of the SAL construct and adds to the understanding of the task or learning context in which the students linked to their learning approaches.

Q1: What rationale have researchers given for examining student approaches to learning biology in higher education?

There were four reoccurring rationales for examining students' approaches for learning biology: (1) validating of a new instrument, (2) testing relationships between student approaches to learning and other student characteristics, (3) determining the impact of curriculum or instructional change on student approaches to learning, and (4) describing frequency and distribution of approaches to learning within a specific student sample. A detailed description of each rationale and the corresponding studies follows and sometimes a single study had more than one rationale.

Validation of a new instrument

Four studies validated a new instrument to measure student approaches to learning (Appendix B). Of the four studies, two were mixed methods (Metzger et al., 2018, Milner, 2013) and two were quantitative (Chiou et al., 2012; Lee et al., 2016). These studies administered a new or modified instrument measuring undergraduate student approaches to learning biology. These four studies were published between 2012 and 2018, which is the more recent end of the timeframe included in this literature review.

Chiou et al. (2012) validated a modified version of *Approaches to Learning Science* (Kember et al., 2004; Lee et al., 2008; Liang et al., 2010) which originally consisted of four constructs: deep motives, surface motives, deep strategies, and surface strategies. Chiou et al. modified *Approaches to Learning Science* by adding discipline-specific language, basically replacing text referencing learning science with learning biology. They validated the *Approaches to Learning Biology* and the *Conceptions of Learning Biology* instruments by administering them to 582 biology majors across 10 Taiwanese universities. Conceptions of learning refers to how student conceptualize what it means to learn biology. Lee et al. (2016) modified *Approaches to Learning Biology* (Chiou et al., 2012) by removing the motivation factors and named the new instrument *Strategies for Learning Biology* (SLB). Lee et al. (2016) validated *Strategies for Learning Biology* by administering the instrument to 303 biology majors across 10 different universities in Taiwan. The SLB survey was examined in combination with two other pre-existing surveys, *Conceptions of Learning Biology* and *Epistemic Beliefs in*

Biology, in which epistemic beliefs describe students' beliefs about the nature of biological knowledge.

Milner (2013) modified the *Approaches and Study Skills Inventory for Students* (ASSIST) (Tait et al., 1998) and implemented a previously validated instrument to measure visual learning in biochemistry. Milner modified ASSIST to include the approaches to studying items and to exclude the conceptions of learning items. They further reduced the original 52 approaches to learning items to 18 items that were evenly selected for the three subscales of deep, surface and, strategic approaches to studying. Biochemistry students (*n* = 45) completed the modified ASSIST survey and 19 individuals completed Milner's new instrument to provide qualitative feedback on their attitudes toward using visual images to learn biochemistry. The students from this study were recruited from the University of Alberta in Canada.

Metzger et al. (2018) designed and validated a concise metacognitive inventory that was intended for instructors of flipped or active courses to evaluate how students adjust their approaches to learning after each unit exam. The *Student Metacognition, Affect, and Study Habits* (SMASH) inventory was a culmination of pre-existing metacognitive instrument items with an added emphasis on student views of the discipline-specific learning environment. Survey results were coupled with students' written informed reactions to their exam scores and feedback, through an assignment called a Writing, Reflection, and Planning (WRaP) exam wrapper (adapted from Achacoso, 2004, Ambrose et al., 2010; Lovett, 2013). Students (*N* = 174) were enrolled in an introductory biology course at the University of Minnesota.

Two studies (Chiou et al., 2012, Metzger et al., 2018) reported similar design and validation processes. The initial design process first established expert validity by outside researchers within the field of biological sciences and science education. Next, each study consulted a small group of students majoring in biology to examine wording and intended meaning of each item. After this initial process, select items were reworded or removed. Chiou et al. (2012) went a step further and conducted a pilot study involving 150 undergraduate students (not specified as biology majors) to examine the suitability of using the subscales and items. The two other studies (Lee et al., 2016; Milner, 2013) referenced the design process of the original instrument which they modified.

All four studies conducted a form of principle component analysis (PCA) to establish construct validity. The two novel instruments, *Approaches to Learning Biology* (ALB) (Chiou et al., 2012) and *Student Metacognition, Affect, and Study Habits* (SMASH) (Metzger et al., 2018), conducted exploratory factor analyzes and used a varimax rotation, due to limited correlation among factors. The analysis indicated that the ALB survey consisted of four factors (Deep Motive, Deep Strategy, Surface Motive, and Surface Strategy), and items were retained with factor loading greater than 0.4. The Cronbach's alpha coefficients of each scale were 0.92, 0.92, 0.85, and 0.86 respectively. The final version of the ALB included 28 items and 62.34% represented the total variance explained. Likewise, factor analysis results indicated that the SMASH survey was composed of four factors (systematic study habits, social learning, perceived difficulty, and help seeking) with alpha coefficients of 0.73, 0.77, 0.72, and 0.81 respectively. This factor structure accounted for 42% of the total variance.

The two remaining studies conducted factor analysis that confirmed the *a priori* factors of the original instrument. Lee et al. (2016) modified the ALB survey of Chiou et al. (2012), to the SLB (*Strategies for Learning Biology)* by isolating the strategy variables (Deep Strategy and Surface Strategy), as described above. Items from the SLB survey were combined with two other instruments, *Conceptions of Learning Biology* and *Epistemic Beliefs in Biology* to conduct a single confirmatory factor analysis including all dimension and items in one model. To determine which items remained, the convergent validity was judged based on item factor loads being higher than 0.6, composite reliabilities (Cronbach's alpha) exceeding 0.8, and the average variance extracted exceeding 0.5. The final version of this instrument had a total of 42 items, with 8 items for SLB. Likewise, Milner (2013) extracted three components from their PCA, deep, surface, and strategic approaches to studying. These three components explained 47.3% of the total variance, and the varimax rotation loaded six items onto each component with factor loading >0.4. The Cronbach's alpha coefficients for each factor were 0.75 (deep), 0.75 (strategic), and 0.70 (surface).

Testing relationships between student approaches to learning and other characteristics

There were 19 studies that examined relationships between student approaches to learning and other individual student characteristics (e.g., gender, grade level, epistemic beliefs, conceptions of learning, and perceptions of learning environment) or individual student outcomes/performance (Appendix B). Six studies used mixed-methods (Hazel et al., 2002; Knight & Smith, 2010; Milner, 2013; Quinn & Stein, 2013; Smith et al., 2019; Watters & Watters, 2007), two were qualitative (Minasian-Batmanian et al., 2005, 2006), and 11 were quantitative (Belzer et al., 2003; Chiou et al., 2012; Davidson et al., 2019; Geller et al., 2018; Hoskins et al., 2017; Lee et al., 2016; Quinnell et al., 2018; Rhodes & Rozell, 2017; Rytkönen et al., 2012; Sebasta & Speth, 2017; Walker et al., 2010). Of these 19 studies, a variety of SAL inventories were used to collect quantitative data. Four studies used *The Study Process Questionnaire* (SPQ) (Biggs, 1987); three studies used the *Approaches and Study Skills Inventory for Students* (ASSIST) (Tait et al., 1998) , one study used either the *Approaches to Learning Biology* (Chiou et al., 2012), the *Strategies for Learning Biology* (SLB) (Lee et al., 2016), *The Motivated Strategies for Learning questionnaire*, (MSLQ), (Pintrich et al., 1991), The *Student Metacognition, Affect, and Study Habits* (SMASH) Metzger et al., (2018), the *Experience of Teaching and Learning Questionnaire* (ETLQ) (Parpala et al., 2011), or the *Student Approaches to Learning* survey (SAL) (Marsh et al., 2006). The publication dates for these studies span from 2002 to 2019, which represents the entire timespan for articles included in this literature review.

Studies examined student performance or student outcomes as they related to different approaches to learning (n = 9), student conceptions of learning (n = 5), students' epistemic beliefs (n = 3), gender (n = 3), and perceptions/attitudes of learning environment (n = 3). Most of these studies used correlational analysis to determine statistically significant relationships between the aforementioned characteristics and student approaches to learning constructs. For example, Rytkönen et al. (2012) explored the relationship between 188 first-year bioscience students' perceptions of their teaching-learning environment and their approaches to learning as well as the overall relationship of learning approaches to academic achievement measured in terms of study success (e.g., GPA) and academic progression (e.g., number of earned credits). Rytkönen et al. used a modified version of the *Experience of Teaching and Learning Questionnaire* (ETLQ) that broadly focused on students' major subject as opposed to a specific course unit. The relationship between all variables were first examined with Pearson's correlations. Next, an univariate analysis of variance (ANOVA) was used to describe the relationship between factors enhancing and impeding studying, SAL, and academic achievement. Lastly, researchers used structural equation modelling to test how well the theoretical SAL and student perception models fit their data. Results related to SAL highlighted positive student perceptions of teaching-learning environment correlated positively with deep approaches to learning and negatively with surface approaches to learning. To address RQ1, only rationales of the studies are presented above and findings from studies are synthesized under RQ2.

Determining the impact of curriculum change

Eleven studies examined the impact of curriculum on student approaches to learning via a pre-post analysis. Four used mixed methods (Balasooriya et al., 2009; Buchwitz et al., 2012; Gouvea et al., 2019; Tomanek & Montplasir, 2004), one was qualitative (Minasian-Batmanian et al., 2005), and six were quantitative (Belzer et al., 2003; Kieser et al., 2006; Quinnell et al., 2018; Hoskins et al., 2017; Lin et al., 2012, and Walker et al., 2010). Of these 11 studies a variety of SAL inventories were used to capture quantitative data. Three studies used the *SPQ*, and one study used either the *MSLQ*, *ALB*, or *ASSIST* inventory. The publication dates for these studies span from 2003 to 2019, which represents nearly the entire window of publication years of the sample for this literature review.

Although the findings of these studies will be reviewed to answer RQ2, the following example illustrates how one study determined the impact of curricular change. Quinnell et al. (2018) first employed hierarchical cluster analysis to identify learner profiles, consisting of first-year students' approaches to learning (*The Study Process Questionnaire,* Biggs, 1987), conceptions of biology (*The Conception of Biology Questionnaire*, Crawford et al., 1998), and their perceptions of course experience (*Unit Evaluation Questionnaire*, Ramsden, 1991). These researchers compared how their typical lecture-laboratory curriculum impacted the approaches, conceptions, and perceptions of a diverse cohort of both generalist and professional biology majors (generalist = general biology majors, professional = pre-medical or pre-dental majors). Pre-semester survey results were analyzed through hierarchical cluster analysis to identify learner profiles (or students who shared similar approaches to learning), conceptions of biology, and perceptions of curriculum. These initial learner profiles were compared to end-of-semester learner profiles to reveal shifts or consistencies within each cohort of students. Findings indicated that their curriculum failed to engage students with dissonant approaches to learning (above average scores for surface and deep approaches to learning) at the start of the semester despite their major, due to them holding consistent scores or shifting to surface approaches by the end of the semester.

Describing frequency and distribution of approaches to learning

Fifteen of the studies described frequency of strategy use or percentage of students adopting one approach over another within the context of an undergraduate biology course. Seven of the studies used mixed methods (Buchwitz et al., 2012; Hazel et al., 2002; Holschuh, 2000; Knight & Smith, 2010; Quinn, 2011; Smith et al., 2019; Tomanek & Montplasir, 2004), four were qualitative (Dye et al., 2017; Hora & Oleson, 2017; Micari & Light, 2009; Stanton et al., 2015) , and four were quantitative (Quinnell et al., 2012; Kritizinger et al., 2018; Rytkonen , 2012; Sebasta & Speth, 2017). Of these 15 studies a variety of SAL inventories were used to capture quantitative data. Three studies used the *SPQ*, and one study used either the *MSLQ*, *SMASH*, or *ETLQ* inventory. The publication dates for these studies span from 2000 to 2019, the entire publication year window for the sample of studies in this literature review.

As an example of the rationale of describing frequency and distribution of SAL, Kritzinger et al. (2018) described the learning strategies of successful first-year biology students. These researchers compared the learning strategies of students pre-determined as at-risk, the murky middle, and those likely to pass, to determine if these pre-entry characteristics were an effective metric for success. The murky middle referred to students whose pre-entry data (i.e., high school GPA, SAT/ACT test scores, demographic data) classified them between students *likely to pass* and students at risk. Results from the *Motivational Strategies for Learning Questionnaire* and biographical data indicated statistically significant differences between all but one subscale (help seeking) between at-risk and *likely to pass* students. In addition, rehearsal strategies differentiated between at-risk and *murky middle* students.

Summary and Discussion of Rationales in SAL Research

In summary, there were four common rationales for researching SAL across the articles in this literature review. The most common rationale was to test relationships between SAL and other student characteristics, such as epistemic beliefs or perceptions of the learning environment. Many researchers were motived to study SAL to describe how a specific student population approached learning biology. Another prevalent rationale was to determine the impact of curriculum or instructional changes. Finally, four studies validated a new instrument to study SAL.

The studies categorized within each of the rationale themes were published throughout the timespan included in this literature review, with the exception of studies that validated a new instrument. These four studies were published more recently, which might indicate a more recent need to modify existing instruments or develop new instruments to capture the aspects of SAL that researchers are interested in, like discipline-specific or metacognitive influences.

To expand on the analysis of the studies seeking to validate a new or modified SAL instruments, all four studies used similar methods for determining construct validity, yet only two studies explicitly mentioned the specific student population their instruments were designed to measure. Both the ALB (Chiou et al., 2012); and the SLB (Lee et al., 2016) were specifically designed to assess student learning from a Taiwanese perspective. Across the total sample of studies in this literature review, most of the instruments used to study SAL were designed to capture student approaches to learning for students within a specific cultural region (e. g. *Study Process Questionnaire* (SPQ), Australia; *Approaches to Learning Biology* (ALB), Taiwan; *Approaches and Study Skills*

Inventory for Students (ASSIST), United Kingdom). This pattern is important to note because prior studies conducted cross-cultural analyzes to determine the portability of such instruments from one culture of students to another (e.g., Biggs & Rihn, 1984; Watkins & Regmi, 1996). Richardson (2004) conducted an in-depth literature review on instruments used to measure student approaches to learning in general (not in a specific discipline). He expressed concern with the internal structure (item-wording) of these instruments and the validity within other cultural contexts.

> "The content validity of these instruments is open to question because of changes both in higher education and in society at large since they were originally devised. The appropriateness of the original wording in these questionnaires when they are used with students from other social, cultural, or ethnic groups is highly doubtful" (Richardson, 2004, p. 353).

Recent literature has shifted to investigate such cross-cultural comparison of students approaches (e.g., Bonsaksen et al., 2019; Bowden et al., 2015; Fryer et al., 2012). In addition, most of the conclusions from these studies are drawn from conducting factor analysis, indicating similarities and differences in how students distinguished surface verses deep approaches at the item level. Such data are used to formulate assumptions about cultural values and traditions that may influence student approaches. Such complexities of culture or other personal factors require an in-depth examination to understand the influence they carry to student behaviors such as studying. Methodologies that only included quantitative data may be insufficient at capturing such complexities.

In addition to validation and modification of instruments, some studies used a pre-post analysis aimed to predict at-risk students' likelihood or preference for using surface strategies as an attempt to alter or change their approach through academic intervention (Balasooriya et al., 2009; Belzer et al., 2003; Buchwitz et al., 2012; Gouvea et al., 2019;

Hoskins et al., 2017; Lin et al., 2012; Kieser et al., 2006; Minasian-Batmanian et al., 2005; Quinnell et al., 2018; Tomanek & Montplasir, 2004; Walker et al., 2010). Smith et al. (2019) recommended midsemester is the optimal time for implementing reflective activities or interventions "as students demonstrated the best accuracy in performance" (p. 74). Similarly, Sebesta and Speth's (2017) results suggested that implementing an intervention to help students learn how to study after course midterm "may be too late for many students who have already experienced failure and are beginning to feel helpless" (p. 11). Therefore, collecting data with the purpose of identifying at-risk students must be done early enough in the semester to give time to implement effective interventions while simultaneously allowing enough time to capture an accurate representation of students' approaches.

Researchers must also consider the duration of time in which change is expected to occur after implementation of an intervention. Quinnell et al.'s(2012) results suggested that encouraging students who are not taking a deep approach or whose conception of biology is poor, " to shift in a pedagogically desirable direction…is likely to be difficult over the time period of a 13-week semester" (p. 1071). However, over the course of a students' degree program, after experiencing curricula predominately aimed at fostering biological thinking, a student is more likely to develop desirable learner attributes. With this in mind, Quinnell et al. emphasized the benefit of conducting longitudinal studies over the entire degree program to determine how well a program is able to foster deep approaches to learning and accurately identify positive factors that contribute to this development.

Q2-What institutional, classroom, and individual student factors are related to the adoption of various approaches to learning biology?

This section will present and discuss the findings for research question 2. The findings are organized by institutional level factors, course level factors, and individual level factors that are related to students' approaches to learning biology.

Institutional level factors

Colleges and institutions are increasingly aware of the benefits to students adopting deep approaches to learning and institutional initiatives designed to teach students more effective approaches to studying are becoming more common. The following studies explored results from such institutional initiatives.

Only three articles focused on institutional level interventions aimed at improving undergraduate students' study approaches (Buchwitz et al., 2012; Hoskins et al., 2017; Micari & Light, 2009). All three American studies implemented programs during the semester that modeled evidence-based strategies designed to encourage deep approaches to learning. Hoskins et al. developed a low-cost, graduate-student, metacognitive-based study skills course taught in conjunction with all of their introductory biology courses. The study skills course taught students effective outlining and concept mapping in hopes to make significant improvements in study habits. Results indicated that, despite statistically significant improvements in student study habits, only 23% of the students reported using outlines while studying and even fewer utilized concept maps. Although the students enrolled in the supplemental study course showed significantly improved exam scores compared to students not enrolled in the supplemental study course, the improvement could not confidently be attributed to changes in study behavior. However, Hoskins et al. noted that only 17% of the cohort volunteered to enroll in the study course, and those who volunteered did not sufficiently represent those high-risk students in need of study behavior changes.

Buchwitz et al. (2012) reported results from a pre-major course series, *Biology Fellows Program* (BFP) originally designed to increase the success of culturally diverse undergraduates in biosciences. All recruited participants were required to take three 10-week courses that aimed to help students think and write like a scientist, test and practice metacognitive learning strategies, and build a supportive bioscience learning community. One of the most important things students enrolled in the program valued was learning active studying, which involved connecting ideas and analyzing figures and graphs. In addition, academic performance was compared to students with similar academic and demographic backgrounds who did not participate in the BFP and statistically significant higher grades in the BFP participants were noted.

Unlike the previous two studies, Micari and Light (2009) employed qualitative methods through the lens of phenomenography to identify variations in learning experiences of participants enrolled in a STEM learning program entitled, *Gateway Science Workshop* (GSW). These workshops ran in conjunction with regular STEM courses including biology. Participation in GSW was voluntary and involved small group learning led by peer-facilitators trained to guide students through productive problem-solving. Findings revealed three contrasting approaches to learning within GSW: (A) Reliance- thinking about getting through the course, (B) Engagement – thinking about engaging with the material, and (C) Independence – thinking about how to learn. Each approach was characterized by two key dimensions: (1) learning intentions and (2) learning constraints.

Authors later discussed how these themes and dimensions corresponded with the characteristics of surface, deep, and strategic approaches to learning, respectively. One major finding revealed that students enrolled in the GSW program demonstrated an awareness of the possible variation in approaches to learning, which was noted as a successful learning attribute in and of itself. For example, students who identified with a reliance approach recognized the distinction between a state of anxiety and one of confidence. Likewise, students expressing an engagement approach recognized the distinction between passively taking in large amounts of information and creating new meaning based on novel situations. Micari and Light (2009) admitted that these findings cannot be empirically attributed to the GSW experience; however substantial evidence suggests that changes in learning environments can contribute to changes in students' approaches to learning.

Two important themes that emerged from these studies were the importance of modeling effective study strategies at the undergraduate level and the need to carefully consider recruitment strategies for institutional interventions. All three studies included courses that provided examples of evidence-based strategies for effective approaches to learning. Numerous studies in this field indicate that the majority of students do not enter college knowing how to effectively study for high-cognitive level science courses (Hoskins et al., 2017). Often undergraduate courses are taught at a fast pace and leave little room for introducing effective learning strategies. Buchwitz et al. (2012) found that providing students with an opportunity to test out study strategies exposed them to a variety of learning strategies in a low-pressure environment. Micari and Light (2009) also highlighted the importance of creating learning environments that foster the effective adoption of various approaches to learning.

Another factor to consider when designing and implementing a study skills invention is what audience to target and how to recruit them. A number of institutions target at-risk students, typically comprised of low-income, first-generation, or underrepresented minority students. Although literature supports gains in academic performance for high-risks students, pre-entry characteristics may not always serve as predictors of academic success (Kritzinger et al., 2018). In addition, students who typically volunteer for such interventions may not be those who most need the help.

Classroom-level factors

By far the most studies analyzed the influence of course-related factors on student approaches to learning biology. However, as described in the methods, these studies spanned such a variety of course related factors, that it was important to group the course-level studies into subcategories, based on the focal aspect of the course in the study. Out of the 34 reviewed studies, 19 studies looked at how students' approaches to learning changed in response to a modified course curriculum (Balasooriya et al., 2009; Belzer et al., 2003; Gouvea et al., 2019; Kieser et al., 2006; Quinnell et al., 2012; Quinnell et al., 2018; Stanton et al., 2015; Walker et al., 2010) or specific courses activities (course unit: Metzger et al., 2018; Smith et al., 2019; course topic: Quinn & Stein, 2013; Tomanek & Montplaisir, 2004; Quinn, 2011; course task: Hazel et al., 2002). Additional studies at the course level either provided descriptions of commonly used approaches to learning in the context of biological sciences (Dye et al., 2017; Hora & Oleson, 2017; Kritizinger et al., 2018; Knight & Smith, 2010; Sebesta & Speth, 2017) or reported correlations between students' approaches to learning and their learning outcomes (Davidson et al., 2019; Geller et al., 2018; Milner, 2013; Rhodes & Rozell, 2017).

Overall, the major findings from the course-level analyzes include: (1) favorable learning contexts did not necessarily result in changes in student approaches to learning (Learning Context), (2) there were low associations between surface approaches and poor student outcomes (Learning Outcomes), (3) there was a large percentage of mixed learning approaches in student samples (Mixed Approaches). Major examples of each finding are outlined below.

Learning Contexts Did Not Always Change SAL - General education literature supports the context-dependent nature of student approaches to learning, in that, how students approach learning depends on the level of cognitive demand required to complete the task at hand within a particular environment. In other words, the more a course promotes deep learning through activities or assessment measures, the more likely students are to use deep approaches to learning. Based on this premise, several studies conducted research in course contexts which embodied what Balasooriya et al. (2009) referred to as deep-enhancing features to promote deep learning. Deep-enhancing features included more student-centered course activities and assessments that required deep learning for students to be successful. Several studies (n = 8) measured student approaches before and after participating in a course with deep-enhancing features. Findings from these studies indicated that favorable learning context did not necessarily result in changes in students' approaches to learning (Balasooriya et al., 2009; Cuthbert, 2005; Quinn, 2011).

For example, Balasooriya et al. (2009) described a cross-over phenomenon to explain how, given the same context, some students shifted from deep to surface approaches to learning, while others shifted from surface to deep approaches from the beginning to the end of the semester. When these results were graphed, the lines representing students shifting from deep to surface and surface to deep, crossed over each other. This is important because it was predicted that students who initially adopted deep approaches to learning would maintain this approach throughout the semester given consistent course context factors. However, some students who used deep approaches early in the semester shifted to more undesirable approaches by the end of the semester. Quinnell et al. (2012) found a different pattern because they did not see any shift in students' approaches to learning in the course context they designed. They reported that 52% of the students' approaches to learning remained the same after one semester, and the majority of the students started out as surface or disengaged (low scores for surface and deep). These findings suggested that a course designed with a favorable learning context did not necessarily result in changes to student approaches to learning indicating how course-independent factors could also influence students' approaches to learning. In other words, despite participating in a course with deep-enhancing features, some studies find that students persist with surface level approaches to learning biology. However, when the hypothesized links between course design and student learning are not supported, it is important to consider how the intended design compared to the implemented design. In another study where the learning context did not change students' approaches to learning, Walker et al. (2010) thoroughly reviewed the course curriculum and found that the intentions to implement deep features into the lecture did not occur in practice. The course focused on content coverage and administered reproductive assessments that rewarded the acquisition of facts. This conclusion was evident in the small but significant correlation of more surface approaches with higher final grades.

This literature indicates that, despite attempts to create such environments, the majority of students continued to use surface level approaches to study biology. Prosser and Trigwell (1998) suggested that “changing the learning context may be insufficient to promote deep approaches because of variations in students’ perceptions of their learning situations” (p. 107). This warrants the notion that students persist with surface approaches because they may prefer learning environments characterized by features conducive to surface learning. This also put into question how well the course curriculum promotes deep learning when students are able to do well on exams using surface-level approaches.

Quinn (2011) noted that “inducing deep approaches is difficult, perhaps because of the profound influence of the student’s personal situations, cultural values, and other student-specific characteristics” (p. 118). Balasooriya et al. (2009) also noted that the persistence of either deep or surface approaches suggested that not all students’ approaches are context-dependent, and these unintended results may stem from the complex interactions between context-based factors and factors related to the students themselves. These findings suggest that more thorough investigation is needed in examining factors outside of course curriculum that influence how students approach learning.

Low Association Between Surface Approaches and Poor Learning Outcomes- Several studies identified strong associations between deep approaches to learning and positive learning outcomes as well as between surface approaches to learning and negative learning outcomes (e.g., Davidson et al., 2019; Geller et al., 2018; Milner, 2013; Rhodes & Rozell, 2017). However, Quinn and Stein's (2013) mixed method study found high associations between deep approaches and high outcome but low associations between surface approaches and low outcomes. These researchers compared scores from the *Study Process Questionnaire* with student outcomes using the Structure of Observed Learning Outcomes (SOLO) model, and found high SOLO outcomes associated with students who implemented deep approaches and no association with surface approaches for high or low SOLO outcomes. They did however discover a high association with restricted learning approaches (low scores on surface and deep approaches) and low SOLO outcomes. Additionally, Quinn and Stein (2013) noted that the self-described approaches that students reported during interviews aligned more with previous literature, in that surface approaches to learning mostly associated with low SOLO outcomes. This suggested misalignment between the quantitative and qualitative results.

Rytkonen et al. (2012) recognized that organized /strategic studying correlated with positive learning outcomes and academic progression and that deep approaches did not correlate with either. They also suggested that deep approaches may be less typical in science students due to the pedagogical culture or norms of the discipline. For example, English majors scored higher on items measuring deep approaches to learning compared to biochemistry and chemistry students. It was argued that science teachers were more likely to report more teacher-focused approaches to teaching, which may not encourage deep approaches to learning as opposed to in the humanities. Entwistle (2009) and Ylijoki (2000) note that the role of teaching and learning vary in different disciplines due to discipline-specific norms, values, aims, and problems. The results from Rytkonen et al. (2012) highlighted the disciplinary influence on how students approached learning.

The idea that deep and surface approaches to learning would look different across disciplines is not novel (Ramsden, 1988). This idea aligns with Marton and Säljö's (1976a) theory of the context-dependent nature of approaches to learning. Case and Marshall (2009) highlighted that with some science tasks, "a deep approach may initially demand a narrow focus on details, which taken on its own might appear to be a surface approach" (p. 17). In fact, some researchers have redefined characteristics of deep and surface approaches to learning within particular disciplines. Previously, Case and Marshall (2002) identified two approaches to learning specifically for engineering, a *procedural* deep approach, and an *algorithmic* surface approach to learning engineering. This literature suggests that student learning outcomes reflect how well students align their approaches with the nature of the task, and the nature of the task is dictated by the norms and practices of that particular discipline.

Mixed Approaches Were Prevalent- The majority of reviewed studies noted the predominance of surface approaches in pre-measures, while fewer post-measures reported students persisting surface level approaches to learning. This aligns with previous research on student approaches to learning in introductory undergraduate courses. However, several studies reported the academic success of students adopting mixed approaches (high surface approach and high deep approach scores).

Most quantitative studies reported these findings utilizing cluster analysis, grouping students with similar learning scores. For example, Quinnell et al. (2012, 2018) labeled one cluster group as dissonant, which made up 37% of the students surveyed.

Students categorized as dissonant used aspects, or mixes, of both deep and surface approaches to learning (Quinn, 2011). The terms *disintegrated*, and *incoherent* have also been used in literature to describe mixed approaches to learning. Other studies used semi-structured interviews to elicit students' study intentions, revealing that most students intend to first understand and then to memorize to achieve high scores on exams (Quinn, 2011; Quinn & Stein, 2013; Tomanek & Montplaisir, 2004). These studies supported the use of mixed-research methodologies to better understand such complex constructs as student approaches to learning. During interviews, students were able to elaborate on specific strategies they used, why they used them, and what course-related factors influenced their decisions on how to study. Findings from these studies support previous literature that question the appropriateness of dichotomizing deep and surface approaches to learning (Cuthbert, 2005; Tickle, 2000).

Student-level factors

The articles within this review commonly studied the relationship between student approaches to learning biology and students' epistemic beliefs, conceptions of learning, perceptions of the learning environment, and gender. A detailed review of findings from each relationship is outlined below.

Epistemic Beliefs- Three studies examined the relationship between student approaches to learning biology and students' epistemic beliefs towards biology. Epistemic beliefs refer to "learners' beliefs about the nature of knowledge and the nature of knowing" (Lee et al., 2016, p. 2327). Additional studies outside this review, have shown that epistemic beliefs can predict student behaviors and achievement and may shift depending on the discipline or context (Conley et al., 2004; Tsai 1998, 1999).

Two studies in Taiwan (Lee et al., 2016; Lin et al., 2012) analyzed responses from the *Epistemic Beliefs in Biology* survey (Lin et al., 2012) consisting of four dimensions: (1) multiple sources of biological knowledge, (2) uncertainty or tentative nature of biology knowledge, (3) development or changing of biological knowledge, and (4) justification of biological knowledge and how learners view experiments. Both studies highlighted the correlation between students who justified their knowledge with evidence and deep approaches to learning. Both studies revealed students whose beliefs about biological knowledge aligned with a single right answer were more likely to have surface motives and approaches to learning. However, one study (Lee et al., 2016) also revealed that belief of uncertainty, meaning students believed that biological knowledge is not always certain, negatively predicted deep strategies, which challenges the traditional assumption that students with more epistemic sophistication tend to adopt deeper approaches to learning. Both studies (Lee et al., 2016; Lin et al., 2012) noted the traditional focus on students learning declarative knowledge of Taiwan biology instructors and frequent mixed approaches of Taiwanese students encouraged by parents and instructors.

Watters and Watters (2007) collected 10 Australian students' responses towards epistemic beliefs via semi-structured interviews. These researchers examined student beliefs about learning. Most students articulated beliefs that learning involves memorization and/or understanding. The students who adopted more deep approaches believed learning to involve memorization, understanding, and application. However, two students with deep approaches believed learning relies on memorization only. Also, there were no obvious patterns between student beliefs, approaches, and achievement, despite researchers concluding that beliefs influenced approaches. For example, two high achieving students viewed learning as sense-making and relationships, while one of those students adopted deep approaches the other student adopted both surface and deep approaches to learning. Another high achieving student expressed using strategies that relied on memorization during the interview, scored highest on the quantitative deep approaches scale, and held a relational view of knowledge. Most students, however, described using surface level strategies during the interview but acknowledged that these strategies were ineffective. These students tended to rely on previous beliefs about studying and learning to drive their study behaviors.

All three studies (Lee et al., 2016; Lin et al., 2012; Watters & Watters, 2007) highlighted that the majority of students held less sophisticated epistemic beliefs about biology and surface motives and strategies after instruction. Authors attributed these results to instructional methods and academic expectations that aligned with surface level approaches. All three studies collected survey data on student approaches at one time point in the academic year. However, none of the studies adequately justified the time point chosen or examined changes in students' approaches to learning. The two Taiwanese studies (Lee et al., 2016; Lin et al., 2012) surveyed students across 10 different universities outside a specific course context. Therefore, the approaches and epistemic beliefs they reported described the student predispositions towards approaches to learning biology. The Australian (Watters & Watters, 2007) study was bound by the context of a biochemistry course; however, the survey was administered during the second semester of the students' first year and did not give specific account for the effect courses taken within the first semester had on learning strategies or beliefs about biological knowledge. All three studies concluded a moderate relationship between epistemic beliefs and student approaches to learning biology. Those relationships that contradicted hypothesized relationships were credited to unique cultural traditions within social and academic context.

Conceptions of Learning- Six studies examined the relationship between students' approaches to learning biology and their conceptions of learning biology (Chiou et al., 2012; Lee et al., 2016; Minasian-Batmanian et al., 2005, 2006; Quinnell et al., 2012; Quinnell et al., 2018). "A conception of learning refers to an individual's understanding or belief about learning" (Chiou et al., 2012, p. 168). Within these seven studies, student conceptions of learning were defined in two different ways and measured using validated inventories or researcher generated questionnaires.

The two studies from Taiwan (Chiou et al., 2012; Lee et al., 2016) explored relationships using the *Conceptions of Learning Biology/Science* survey (Chiou et al., 2012/ Lee et al., 2008), which consisted of reproductive-oriented (low-level) conceptions (e. g., memorizing, testing, and calculating) and constructive-oriented (high-level) conceptions (e. g., increasing one's knowledge, applying and understanding, and seeing in a new way). The remaining four studies from Australia (Minasian-Batmanian et al., 2005, 2006; Quinnell et al., 2012; Quinnell et al., 2018) operationalized student conceptions as either fragmented (a collection of facts) or cohesive (a holistic view). The two most recent studies (Quinnell et al., 2012; Quinnell et al., 2018) used *The Conception of Biology Questionnaire* (Crawford et al., 1998) to collect data and the earlier studies use a researcher-generated questionnaire with an open-ended question to collect data (e.g., What do you think biochemistry is about?).

Finding from the Taiwanese studies (Chiou et al., 2012; Lee et al., 2016) supported the hypothesis that conceptions of learning biology predicted approaches to learning biology, in that students who held constructive-oriented conceptions tended to have deep motives and adopt deep approaches. Likewise, students holding reproductive-oriented conceptions tended to have surface motives and approaches. However, contradictory results (Chiou et al., 2012) indicated that low-level conceptions of *calculating and practicing* had significant effects on deep motives, and high-level conceptions of increasing one's knowledge only had an effect on surface motives for learning. These researchers suggested that items that could be perceived by students as both reproductive and/or constructive might explain some of the contradictory results. These researchers also discussed that in-depth qualitative data would have been useful to help explain contradictory results.

Findings from the Australian studies (Minasian-Batmanian et al., 2005, 2006; Quinnell et al., 2012; Quinnell et al., 2018) also found an overall positive relationship between fragmented conceptions (a collection of facts) and surface approaches, and students with more comprehensive conceptions and deep approaches to learning. However, over half of the students who demonstrated a cohesive conception (a holistic view) still intended to adopt surface approaches to learning when studying for the course (Minasian-Batmanian et al., 2005, 2006). Researchers hypothesized that these results were due to lack of prior knowledge about the subject and years of participating in a school system where surface approaches are highly successful.

Quinnell, et al., (2012) and Quinnell et al., (2018) took a different approach to studying how students' conceptions of learning related to students' approaches to learning by constructing learner profiles that combined the constructs from *The Conception of Biology Questionnaire* and the *Study Process Questionnaire.* These researchers used results from a cluster analysis to characterize groups of students based on an "intersecting suite of student attributes" (Quinnell et al., 2012, p. 1056), that consisted of students approaches to and conceptions of learning biology. These studies compared how the conceptions of learning and the approaches to learning of first-year biology students changed over one semester. They found that approximately 52% of the students did not change their profiles from the start to the end of the semester, and of those 60% of the students' whose learner profiles were either disengaged (low scores on all sub-scales) or dissonant (high scores on all scales) did not change. After an examination of mean scores, students, on average, who did change their approaches to learning showed significant shifts towards more surface and less deep approaches to studying biology. These researchers noted that one semester may not be a sufficient amount of time to expect change towards a more desirable learner profile as well as to see the impact of the curriculum on the large percentage of students retaining surface approaches to learning.

Student Perceptions. Three studies explored the relationship between student approaches to learning and their perceptions of their learning environment (Hazel et al., 2002; Quinnell et al., 2018; and Rytkonen et al., 2012). All three studies showed statistically significant correlations between student learning environment perceptions and their approaches to learning biology. These studies indicate that students who tend to adopt more surface approaches to learning also perceive the environment to be less supportive of deep approaches. The opposite correlation resulted for students who adopted deep approaches, in that they perceived the same environment as more supportive of deep approaches. Across all three studies students held mixed perceptions of the same learning environment. In addition, Hazel et al. (2002) noted that knowing that students respond differently to the same context and that these differences are associated with differences in the quality of their learning, future research and practices should focus on increased student awareness of course requirements early in the semester. In addition, future research should examine the alignment between faculty expectations and student conceptions of learning.

Gender. Three studies examined gender differences among student approaches to learning (Belzer et al., 2003; Chiou et al., 2012; Lin et al., 2012). All three quantitative studies noted statistically significant differences between male and female students' approaches and /or pre-post content knowledge assessments. However, the two studies that used the *Approaches to Learning Biology* inventory reported contradictory results. Lin et al. (2012) reported male students adopting significantly more surface learning motives. Female student tended to hold a less mature view on source- and certainty-related epistemic views (beliefs about the nature of biological knowledge) and adopt more surface strategies. However, Chiou et al. 2012 reported that women scored higher on surface motives and that men held less sophisticated conceptions of learning biology than women. Both articles attributed the increased surface motive score to students fearing poor performance on exams regardless if they identified as male or female. Although these studies focused on gender as an influencing factor, results suggested that the increased surface motives scores could be addressed within the learning environment by attempting to reduce exam anxiety.

Belzer et al. (2003) examined gains in content knowledge after participation in a *Concepts of Biology* course designed to respond to perceived weaknesses in introductory students' study skills, critical thinking skills, self-esteem, and biological content knowledge. They measured changes in pre- to post-course content knowledge scores and motivation scores on the *Motivated Strategies for Learning Questionnaire* (MSLQ). Men scored significantly higher than women on pre- and post-course content knowledge assessments, and pre-course motivation. There were no gender differences in motivation scores post-course.

Studies identifying gender differences were based on statistically significant differences and lacked exploration into the educational context in which these differences may have manifested. Chiou et al. (2012) admitted that future research directions should explore the potential factors that influence gender differences such as disciplinary or societal norms and cultures that perpetuate traditional gender roles.

Implications for Research and Practice

This systematic literature review provided a descriptive landscape of how students approached learning biology at the post-secondary level, factors that influenced student approaches to learning, and the methodologies utilized to capture such descriptions. There are three key considerations for future research and practice directions: (1) a broader consideration for the influence of socio-cultural factors on student approaches to learning, (2) an increase of mixed methods approaches for exploring the complex nuances of the student learning experience, and (3) unpacking what it means to learn deeply in the biological sciences and how assessment should align with this desired approach to student learning.

Broader Consideration for the Influence of Socio-cultural Factors

Complexities associated with the student learning experience often require a more comprehensive exploration of the impact factors external to the academic system have on students' study behaviors. Several studies within this systematic review contributed results that were contradictory to their hypothesis, to factors external to the learning environment (e.g., Balasooriya et al., 2009; Geller et al., 2018; Hazel et al., 2002; Lin et al., 2012; Quinn, 2011; Quinn & Stein, 2013; Quinnell et al., 2018). Quinn and Stein (2013) reiterated that learning approaches are relational, and the traditional characteristics studied with Biggs (1987) 3P model, which is widely used in higher education research, are drawn solely from within the academic system (i.e., learning context, prior understanding, and perceptions of learning environment). Quinn and Stein (2013) recognized that the academic system interacts with the broader social system that is shaped by encounters with family, friends, peers, and colleagues.

Likewise, Balasooriya et al. (2009) hypothesized that the unexpected responses of students using deep approaches to learning shifting to surface-level approaches after instructional changes may arise from complex interactions between contextual and student factors identified through student interviews. Quinn (2011) also acknowledged the difficulties associated with inducing deep approaches, highlighting the limit to which student perceptions and approaches to learning can be *changed* by instructors and administrators without a broader consideration for the "powerful influence of student characteristics such as age, their life experience, and their prior knowledge" (p. 118). Quinn and Stein (2013) emphasized that behavioral choices of individuals, like how much time to invest in understanding a biological concept, relates to a range of broader socio-cultural aspects of the individuals' experiences. This acknowledgment positions higher education within an overarching community and societal system (Biggs, 1993; Quinn, 2011) that enables educational researchers to broaden the perspective in which they conduct exploratory and explanatory SAL studies. Thus, future studies on SAL in undergraduate biology need to explore the impact that socio-cultural factors, such as students, cultural (i.e., race, gender, ethnic, religious, social class), and disciplinary (i.e., science, mathematics) identities, have on how students choose to approach learning. Such socio-cultural considerations could potentially illuminate hidden factors that impact the student learning experience.

Increase of Mixed Methods Studies

By far, the majority of the studies in this review collected data utilizing only quantitative measures by administering a survey or questionnaire ($N = 15$). These studies provide a descriptive account of what approaches students adopted within a specific context. However, this methodology provides a limited perspective to understanding the complexities of the SAL construct as a whole. Lee et al. (2016) utilized quantitative measures to verify the theorized model, but admitted the future use of qualitative or mixed methods are "better for capturing the nuances of contextual information" (p. 2341). Quinn and Stein (2013) found that "the expected relationship between surface approaches and poor SOLO outcomes emerged more clearly from the interviews" (p. 629) and was not expressed in survey responses alone Walker et al. (2010) referenced Ertl and Wright (2008) in their decision to expand their methodological approach in future research.

> "Ertl and Wright (2008) argue that thus far the use of inventory studies has been limited in term of its ability to achieve change or improvement of students' experiences of learning in higher education. They recommend that the evidence base for using these studies should be extended through longitudinal evaluation studies that take account the students' learning contexts and wider socio-cultural settings" (Walker et al., 2010, p. 720).

Many studies represented in this review admitted to the limitations in collecting only quantitative data to explore the construct of SAL, which suggested the need to pair quantitative descriptions with rich qualitative explanations. Future research on SAL should use mixed-methodological approaches to increase the breath, depth, and consistency of research findings by maximizing the affordances of both quantitative and qualitative data (Warfa, 2016). Findings from this study also suggested that the current SAL instruments may not adequately capture SAL in both culturally diverse and discipline-specific context, therefore mixed-methodologies could also provide a better understanding of cultural and disciplinary influences for the development of new SAL instruments.

Curriculum and instruction for deep approaches to learning biology.

Biology education initiatives push for more opportunities for students to learn biology by performing aspects of the practices and discourse of biologist (Ford, 2015).

Students who incorporate key elements of learning science such as asking meaningful questions, constructing scientific explanations, and reflecting on their learning process during their study approaches, are more likely to have positive learning outcomes (Chin & Brown, 2000; Tomanek & Montplasir, 2004; Watters & Watters, 2007). These elements are traditionally associated with deep approaches to learning. However, evidence from this review revealed that students who used surface approaches to learning sometimes achieved positive learning outcomes (Quinn & Stein, 2013) and deep approaches to learning did not always correlate to positive learning outcomes or academic progression (Rytkonen et al., 2012). These findings suggest (a) a need to support undergraduate biology instructors to take a "practice based" approach to biology education, and (b) a misalignment between educational goals and assessment methods.

Variations in what is accepted by disciplinary experts, like biology faculty, as productive approaches to learning is arguably an underexamined area of research (Case & Marshall, 2009). What is unique about how we should learn science and more specifically biology, that translates to how we should teach and study biology? If our science learning goals are for students to think like scientists, how can these goals be reflected in our undergraduate instructional practices, to the extent that we also model effective ways to understand or study course material. Science is both a body of knowledge and a process (Derry, 1999), that is socially constructed and continually critiqued. With this understanding, more departmental support for post-secondary biology instructors is needed to increase their understanding of what it means to learn deeply in biology and support for designing courses that are aligned with these goals. By taking a more practice-based approach to teaching and learning, biology instructors could provide opportunities for students to integrate rich domain-specific knowledge with prior knowledge while simultaneously engaging in authentic scientific practices. Further research is needed to better understand how we can support post-secondary educators in understanding pedagogies that align with the practices of biologist.

However, as post-secondary educators take up a practice-based perspective for biology education, assessment methods will need to change as well. Even in an exemplary classroom that fosters deep approaches to learning, students will continue to use surface approaches to learning if those approaches reward them on assessments. Scouller (1998) similarly argued that…

> "If academic staff genuinely want their students to be analytical and critical thinkers and able to apply their learning to novel situations and transfer their learning to solve real problems….then assessment methods should firstly, encourage the development of such abilities, and secondly, provide students with the opportunity to demonstrate that they have developed these higher order abilities" (Scouller, 1998, p. 469).

Surface level strategies are no longer surface if they align with assessment intentions. This means that if the assessment method only requires students to recall definitions or vocabulary, then an appropriate study method would be rote memorization. In this instance, we cannot fault the student for using the most appropriate study strategy that would yield optimal results. To support this argument, Stranger-Hall (2012) investigated the effects two multiple-choice formatted exams (one multiple-choice only [MC] and one Multiple-choice + short answer questions [MC + SA]) had on introductory science students' development of high-level thinking skills. Results showed that student in the MC + SA section reported significantly more cognitively active learning behaviors (deep approaches to learning) than students in the MC section. Examples of cognitively active learning behavior include “I drew my own flow charts or diagrams” vs. a cognitively passive learning behavior, “I read the assigned text.”. The MC-only exam seemed to undermine instructor efforts to develop critical-thinking skill throughout the semester.

Future research in both discipline-specific characterizations of deep and surface approaches to learning and assessment alignment will push biology education initiatives further towards educational goals. With this research one can better understand how to model effective strategies and design more effective discipline-specific study interventions, which will ultimately increase persistence and retention efforts for science majors.

Study Limitations

There are two main limitations to the review. First, it is limited by the specific focus of analysis. This review is focused only on undergraduate biology student approaches to learning, acknowledging that there is other informative literature within other disciplines (e. g., chemistry, physics, engineering, mathematics, etc.) and at different academic levels (e.g., K-12, and graduate students). This review focused on undergraduate biology students given the distinct context of post-secondary learning and unique demands of introductory major courses.

In addition, this review aimed to examine findings related to how selected studies measured student approaches and the factors that influenced adoption. There are other important findings included in this body of literature that can contribute to our understanding of the construct of student approaches to learning not addressed in this study. This review is limited by the fact that it only includes studies that have been published in journals and did not consider important contributions of unpublished works (e.g., doctoral dissertations and conference presentations).

Conclusions

One common goal of higher education is developing students to become disciplinary experts (Sebesta & Speth, 2017). With this goal, comes the collective responsibility of multiple instructors, academic advisors, and institutional level administrators to support students in the process of becoming expert learners (Kritizinger et al., 2018; Sebesta & Speth, 2017). Specifically, within the context of biology education, disciplinary experts aim to foster biological thinking as opposed to students just temporarily memorizing a collection of facts (Gouvea et al., 2019), which directly relates to how instructors approach teaching and students approach learning biology. This systematic literature review serves to provide a descriptive landscape of how students approach learning biology at the post-secondary level, and the methodologies utilized to capture such descriptions. Findings and implications from this review encourage the adoption of methodological approaches, pedagogical strategies, and institutional interventions that broadly consider the myriad of factors that play a significant role in achieving the aforementioned goals of developing disciplinary experts.

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CHAPTER III: STUDY 1

EXAMINING UNDERGRADUATE STUDENTS' APPROACHES TO LEARNING INTRODUCTORY BIOLOGY

Understanding how students approach learning in culturally diverse, large lecture undergraduate biology classrooms is advantageous for optimizing the teaching-learning experience. Student Approaches to Learning (SAL) refers to how students engage with academic material. SAL are known to have a direct impact on student learning outcomes in discipline-specific contexts (Davidson et al., 2019; Geller et al., 2018; Marton & Säljö, 1976; Milner, 2014; Rhodes & Rozell, 2017). For decades, undergraduate biology educators have made efforts toward assisting students in their development of deep approaches to learning science (American Association for the Advancement of Science, (AAAS), 2011; Buchwitz et al., 2012; Handelsman et al., 2004; McGuire, 2006; Tomanek & Montplasir, 2004). Several studies have explored the construct of SAL in general, across a wide variety of academic disciplines (e. g., Trigwell et al., 2012; Beyaztaş & Senemoğlu, 2015) or measured students of a specific discipline with a generic approach to learning inventory (e.g., Kieser et al., 2006; Quinn & Stein, 2013; Quinnell et al., 2018; Watters & Watters, 2007). Findings from such studies are argued by researchers to abandon the context-dependent nature of the construct itself (Asikainen & Gijbels, 2017). However, measuring SAL at the post-secondary level within a discipline-specific context has often proved to be inconsistent due to the context-dependent nature of the SAL. In this light, this study aims to examine how students approach learning in the context of an introductory biology course utilizing a discipline-specific inventory.

To achieve this goal, this study used the *Approaches to Learning Biology (ALB)* inventory, developed by Chiou, Liang, and Tsai (2012) to capture how entry-level biology students approach learning. Although discipline-specific, the ALB survey has traditionally been used to measure SAL from students in Asian countries. Therefore, there is a need to explore the portability of this instrument to more heterogeneous sub-cultures, such as those found in America. This study explores if demographic or course context distinctions exist among a sample of introductory biology students, in regard to how they approach learning biology. In addition, this study adds to our practical understanding of how we as biology educators can enhance the teaching-learning experience through the promotion of deep approaches to learning.

Student Approaches to Learning

When students approach learning in educational settings, they can use deep-level or surface-level approaches or a combination of the two, referred to as mixed approaches to learning (Biggs, 2001). A deep approach to learning is based on a students' intrinsic motivations to understand the intentions of the tasks (Asikainen & Gijbels, 2017; Biggs, 2001). Students using deep approaches to learning aim to make meaningful connections between prior knowledge and new domain-specific knowledge (Chin & Brown, 2000; Kember, 2004; Richardson, 1994) which lead to positive learning outcomes (Ferla et al., 2009; Vermunt & Vermetten, 2004).

In contrast, students using surface approaches to learning share motives and intentions that are extrinsic to the true intentions of the tasks. Such surface motives are often driven by getting good grades or passing a test (Asikainen & Gijbels, 2017; Biggs, 2001). Students using surface approaches invest little time and effort into understanding the task, most commonly engaging in rote learning or selective memorizing without understanding (Biggs, 2001). Surface approaches are linked with negative student outcomes (Biggs, 1987, 2001).

This dichotomous perspective of student learning, with deep approaches linked to positive outcomes and surface approaches linked to negative outcomes, has been critiqued as oversimplifying some of the nuances and subtleties in students' learning experiences (Barnett, 1990; Case & Marshall, 2004, 2009; Volet & Chalmers, 1992). However, as Kieser et al. (2005) articulated below, the concept of deep and surface learning provides great insight into the relationship between student learning and teaching practices.

> "Although it is widely accepted that the concept of deep and surface learning cannot fully represent students' approaches to learning /studying, it does appear to describe an aspect of this complex phenomenon that is qualitatively important when we seek to understand variation in both student learning and teaching practice. Limited representation is understandable when researchers attempt to characterize any complex phenomenon using dichotomies, yet the deep and surface metaphor has a relationship to student-learning outcomes and has also proved invaluable as a model for teachers seeking to improve their practice" (Kieser et al., 2005, p. 150).

With this recognition, this study explores how the concept of deep and surface learning is expressed by entry-level biology students in efforts to: (1) identify patterns associated with learning approaches within the context of undergraduate biology and (2) provide recommendations for fostering deep approaches given such patterns.

Student Approaches to Learning Biology

Learning biology can be described as a generative process that requires students to actively integrate prior knowledge and domain knowledge (Chin & Brown, 2000). Successful integration involves "activities or methods used by an individual to encode information into long-term memory in the category of experiences that produce changes in mental representations" (McNulty et al., 2012, p. 1). This means that learning strategies that involve changes in mental representations or connections between prior and new knowledge are more effective in terms of relevant retrieval of information. Such strategies are characterized as deep approaches to learning. Recent biology education initiatives note that students who incorporate key elements of learning science such as asking meaningful questions, constructing scientific explanations, and reflecting on their learning process into their study approaches, are likely to have positive learning outcomes (Chin & Brown, 2000; Tomanek & Montplasir, 2004; Watters & Watters, 2007).

To capture the construct of SAL with validity, the measurement instrument must align with the nature of the construct itself. SAL describes the strategies students utilize for learning and the intent driving the choice of that strategy. These learning strategies and motives are defined within contextual boundaries, therefore should carry the assumption that students may utilize different approaches within different learning contexts (Biggs, 1987; Lee et al., 2016).

In efforts to align research with the context-dependent nature of SAL, scholars have argued that SAL should not only be examined within a task-specific context, but also within a discipline-specific context (Case & Marshall, 2009). Early scholars, such as Ramsden (1988) theorized that deep and surface approaches would have very different manifestations in different academic disciplines. Researchers have thus explored the construct of SAL in particular science disciplinary context, (e.g., biology: Hazel et al., 2002; Tomanek and Montplasir, 2004; Watters & Watters, 2007; engineering: Case & Marshall, 2004; chemistry: Sinapuelas & Stacy, 2015; physics: Prosser et al., 2000). This study adds to this body of discipline-specific literature with a context intentionally situated in an introductory biology course focused on the specific task of studying for the midterm exam.

Research Questions

RQ1: What demographic and course context patterns emerge from undergraduate biology student scores on the approaches to learning biology scale?

RQ2: What is the relationship between student approaches to learning biology survey scores and student learning outcomes?

Methodology

Research Design

This study used a cross-sectional survey research design to examine patterns associated with how introductory students approach learning biology at a single crucial point in time during an introductory biology course. To account for the context-dependent nature of the SAL construct, surveys were administered 3-4 days after midterm examinations to provide a point of reference for students while they completed the survey.

Study Context

Participants

This study took place in a large public university located in the Southeastern United States. Criterion-based sampling (Patton, 2015) was utilized to recruit all students enrolled in six introductory-level General Biology I course sections (N = 512). After consent, n = 140 students completed the survey yielding a survey response-rate of 27%. Participants ages ranged from 18 to 23 years. Demographic and course specific data were collected, including participants' self-identified gender, ethnicity, course section, and instructor. All demographic data are consolidated in Table 3.1. In addition, the number of participants taught by each individual instructor are depicted in Table 3.1.

Table 3. 1 Demographic and Course Context Data of All Participants (n = 140)

Gender		Ethnicity		Course Section & Instructor	
Male	37	African American/ Black	25	S-1- Dr. Williams	48
		Asian	8	S-2- Dr. Ernest	30
Female	102	Caucasian	73	S-3- Dr. Boyd	13
		Hispanic/Latino	10	S-4- Dr. Roland	15
		Middle Eastern	11	S-5- Dr. Boyd	10
Other	1	Mixed (2 or more)	10	S-6- Dr. Williams	24
		Other	3		

Course Context

Course Information- General biology I is the first of a two-part introductory biology sequence designed to introduce biological principles at the molecular and cellular scale to biology majors, minors, and other science-oriented students. Course pre-requisites include passing college algebra with a C or better or a MATH ACT score of 19 or higher. This course can fulfill general education requirements for natural sciences; however, the course also fulfills requirements for biology majors. This course is paired with a weekly laboratory component.

Instructors- For the fall of 2019, six sections of general biology I were taught by four instructors. The pseudonyms for the instructors include Dr. Williams, Dr. Ernest, Dr. Boyd, and Dr. Roland. All instructors held prior experiences teaching both upper division and introductory courses. All instructors, except for Dr. Williams, had teaching experience exceeding 20+ years. Dr. Williams had taught biological sciences for 8 years.

Course Structure -Major course structures were held consistent by each instructor with minor variations in pedagogical strategies. Each course was comprised of four units including molecular biology, cell function, genetics, and evolution. All unit materials and topics closely aligned with the layout of the assigned course textbook. All course sections included four unit examinations, use of in-class student response systems (i.e., clickers), consistently provided resources (e.g., study guides, textbook reading assignments, and practice quizzes), and a comprehensive final examination. Each examination was comprised of multiple choice and short essay questions.

Data Collection

Instrument

All students enrolled in general biology I were given the opportunity to complete the *Approaches to Learning Biology* (ALB) survey (Chiou et al., 2012). Surveys were administered electronically directly after mid-term exams. Both the principal investigator and course instructor introduced the research participation opportunity and then student consent was obtained in person.

The ALB survey was developed and validated by Chiou et al. (2012) who added biology specific terminology to replace the general science terminology of Lee et al.'s (2008) and Liang et al.'s (2010) *Approaches to Learning Science* questionnaire. These original measures were rooted in findings from a phenomenographic study that took place in Taiwan and was designed with sensitivity to Taiwanese culture for learning biology. Chiou et al. obtained content validity through expert review. They also conducted a pilot study consisting of 150 university biology students that examined the psychometric stability of the subscales and items via exploratory and confirmatory factor analysis. Modifications from the pilot study resulted in four subscales and 26 total items that align with Biggs et al.'s (2001) deep and surface approaches to learning.

Scale items are scored based on a 7- point Likert scale (1 = *strongly agree*, 4 = *neutral* , and 7 = *strongly disagree*). The subscales were designed to capture both predispositions and process components of approaches to learning. Predispositions describe approaches students are likely to adopt given a certain context, whereas the process components refer to the actual approach students adopted within a certain context. Depicted in Table 3.2 are definitions of each of the four subscales with corresponding sample items. Definitions were taken directly from Chiou et al. (2012, p.175).

This scale was chosen for two main reasons. First, the items of this scale are discipline specific. This instrument meets the goal of capturing student approaches to learning biology. After extensive review of related literature (see Chapter 2), there were no other validated instruments that measured approaches to learning biology in a discipline-specific context. Second, given that this scale was designed with sensitivity toward Taiwanese culture, administering it to American students will speak to the generalizability of this discipline-specific instrument to other cultures (Richardson, 2004).

Table 3. 2 Definitions of Four Subscales and Sample Items from *Approaches to Learning Biology* Scale.

Subscale	Definition	Sample Items
Deep Motive	Students show their intrinsic motivation while learning biology, such as learning biology driven by their curiosity and own interest.	(1) I come to biology class with questions in my mind that I want to be answered.
		(2) I find that I continually go over my biology class work in my mind even whenever I am not in biology class.
		(3) I like to work on biology topics by myself so that I can form my own conclusions and feel satisfied.
Deep Strategy	Students utilize more meaningful strategies to learn biology, such as making connections and coherent understanding.	(1) I try to find the relationship between the contents of what I have learned in biology subjects
		(2) I try to relate new material to what I already know about the topic when I am studying biology.
		(3) I try to understand the meaning of the contents I have read in biology textbooks.
Surface Motive	Students possess extrinsic motivation to learn biology, such as learning biology for course grades or others' expectations.	(1) I want to get a good achievement in biology subject so that I can get a better job in the future.
		(2) I worry that my performance in biology class may not satisfy my teacher's expectations.
		(3) I want to do well in biology subjects so I can please my family and the teacher.
Surface Strategy	Students use more rote-like strategies (such as remembering or narrowing targets) to learn biology.	(1) I see no point in learning biology materials that are not likely to be on the examinations.
		(2) When learning biology, I try to memorize the content again and again till I remember it very well.
		(3) As long as I feel I am doing well enough to pass the examination, I devote as little time as I can to studying biology subjects. There are many more interesting things to do with my time.

Note. Information retrieved from Chiou et al. (2012, p.175).

Faculty Interviews

The instructors from each course section were interviewed to provide an accurate depiction of the course structure. Each instructor participated in a 30-minute semi-structured interview. The interview protocol was designed to elicit the instructors' intentionality surrounding overall course structure, assessment, and student study supports. For exact questions included in the instructors' interview protocol, see Appendix C. To triangulate data collected from the interviews, I conducted informal class observations, and collected course syllabi. Over a two-week period (one week before mid-term exams and one week after mid-term exams), I attended each of the six general biology courses and observed how each instructor taught course topics. I documented any procedural components that occurred routinely each class session, as well as unique exam preparation and debriefing of pedagogical strategies. Both the course observations and course syllabi provided additional course-specific inquiries to reference during semi-structured interviews. For example, after observing Dr. Williams pass out extra credit vouchers to students who answered questions during class, interview questions were tailored to inquire as to why they choose this pedagogical practice.

Student Learning Outcomes

Course grades for each consenting student participant were provided by the corresponding instructor at the conclusion of the fall semester. All student information was de-identified during the collection of course grades. Course grades included four unit exam grades, a comprehensive final exam grade, and a final overall course grade. Each exam score reflected points earned out of a maximum possibility of 150 points. All final course grades were collected as letter grades and later converted to discrete and ordinal numerical representation for the purpose of analysis in this study (i.e., 1=F, 2=D, 3=C, 4=B, 5=A). Final grades were not chosen as an indicator of students' overall academic achievement but as one means of evaluating desired learning outcomes in an attempt to compare academic behaviors (Wang et al., 2013).

Data Analysis

To answer research question 1, the PI first reverse-coded the raw ALB data and then converted student responses to Rasch person-measures. Reverse coding the rating scale, allowed for data to be interpreted as higher numbers representing more agreement and lower numbers representing more disagreement. The Rasch measures were used to conduct two exploratory statistical analyzes: 1) a series of one-way ANOVAs to compare students across each ALB construct (Deep Motive, Deep Strategy, Surface Motives, and Surface Strategies, and 2) a two-step cluster analysis to examine if there were groups of students with similar approaches to learning biology across the four constructs.

These four ALB constructs are described in more detail below. To answer research question 2, the PI conducted a correlational analysis to determine the relationship between students' survey responses and their learning outcomes. A detailed description of data transformation and statistical analysis is provided below.

ALB Instrument

Rasch Measurement Conversion

Raw data from the ALB were converted from the original rating scale (1 = strongly disagree, 7= strongly agree) and then to Rasch measurements. Rasch analysis addresses the assumption that the score of "strongly agree" is the same distance away from "agree" as the distance "strongly disagree" is away from "disagree" on the Likert scale. Since the rating scale is ordinal, "computing means based upon the items answered (in an effort to consider missing data) often results in different means for the same persons as a function of items included in calculating those means" (Boone, et al., 2014, p. 30). For this reason, raw scores were converted into Rasch measurement to resolve the unequal interval problem before conducting parametric statistical analysis.

Univariate ANOVA

To reveal patterns associated with student demographic and course content variables to student approaches to learning, the PI conducted a series of one-way ANOVAs. These analyzes compared differences in ALB sub-variable scores (e.g., Deep Motive, Deep Strategy, Surface Motive, Surface Strategy) between groups based on gender (male, female), ethnicity (i.e., African American, Asian, Caucasian, Hispanic/ Latino, Middle Eastern, Mixed two or more, and other), course section (S1-S6), and instructors (i.e., Dr. Williams, Dr. Ernest, Dr. Boyd, and Dr. Roland).

Two-Step Cluster Analysis- Determine homogenous groups

The ALB scale is designed to distinguish the extent in which students agree with items associated with deep and/or surface level approaches. It is hypothesized that student responses from the ALB scale will reveal at least three homogenous student groups, one group that tends to agree more with surface level approaches to learning, one group that agrees more with deep approaches to learning, and one group the agrees with mixed-approaches to learning. To identify quantitatively-determined homogenous groups of cases within the ALB scale results, the PI ran a Two-Step Cluster analysis. Results from this analysis were used to answer research question 1 with regard to what patterns emerged along student approaches to learning variables. This analysis also supported the purposeful sampling of students holding contrasting approaches for the larger study.

Student Learning Outcomes

Correlational Matrix

I ran a correlation test to compare the relationship between ALB sub-variables (i.e., Deep Motive, Deep Strategy, Surface Motive, Surface Strategy) and student learning outcomes (i.e., four-unit exams, a comprehensive final exam, and final course grade). Results from this correlation analysis will be used to answer question 2.

Findings/ Results

Rasch Model Assumptions and Reliability

To verify that Rasch model assumptions of one-dimensionality were met and to assess reliability, three properties of the instrument were examined: (1) dimensionality, (2) item and person reliability, and (3) item fit.

Dimensionality

A principal component analysis (PCA) of Rasch residuals was conducted to examine response pattern dimensionality. Each ALB sub-variable (Deep Motive, Deep Strategy, Surface Motive, Surface Strategy) was treated as an individual trait; therefore, the items associated with a sub-variable should all reflect the trait in question. If the group of items being analyzed is one-dimensional, then the residuals should lack structure, in that they cannot be separated into more than one dimension. Rasch residuals with an eigenvalue <2 is said to be one dimensional. Each ALB sub-variable had an eigenvalue of the first contrast less than 2 except Deep Motive (2.068), suggesting that a unidimensional model captured an acceptable proportion of the variance in the dataset (Sbeglia & Nehm, 2018). The eigenvalues for each ALB sub-variable are found within Table 3.3.

Item and person reliability

For Rasch measures, calculating item and person reliability is conceptually similar to calculating Cronbach's Alpha values for raw data sets. Two methods were used to calculate reliability. The Expected A Posteriori/Plausible Value reliability (EAP/PV) index estimates if the order of item agreement/disagreement could be replicated in a different population within a similar context. In addition, the Weighted Maximum Likelihood Estimation (WLE) person separation index was generated, which estimates if the order of person agreement could be replicated with a different set of items of similar difficulty (Bond & Fox 2001). Reliability values of greater than 0.70 are considered acceptable (Grigg & Manderson 2016; Yang et al., 2017). The overall EAP/PV item separations were high for each ALB sub-variable, while WLE person separation reliabilities were greater than 0.70, except Surface Motive (0.54). All item and person reliability values are presented in Table 3.3.

Item fit

The fit of the items to the model was calculated by analyzing the mean squares fit statistics for each item (MNSQ). Acceptable MNSQ scores typically range from 0.7 to 1.3 logits, but a less conservative range of 0.5–1.5 logits is also used (Wright & Linacre, 1994). “High MNSQ scores indicate that the data underfit the model and that items are poorly measuring the respondents for whom they are targeted” (Sbeglia & Nehm, 2018, p. 4). ALB survey items had MNSQ fit statistics within the acceptable range. All MNSQ infit and outfit values for each ALB survey item are depicted in Table 3.4.

Table 3. 3 Results from Principal Component Analysis Testing Dimensionality and Item and Person Separation Reliabilities for the ALB scale.

ALB Sub-Variable	**PCA of Rasch residuals Eigenvalue (unexplained variance) of the first contrast**	**EAP/PV item separation**	**WLE person separation**
Deep Motive	2.0628	.99	.75
Deep Strategy	1.6398	.93	.70
Surface Motive	1.9815	.96	.54
Surface Strategy	1.9168	.98	.71

Note: EAP/PV: expected a posteriori/plausible value reliability; ALB: *Approaches to Learning Biology* scale; WLE: weighted maximum likelihood estimation.

Table 3. 4 Item Fit Statistics of the ALB Scale

	Item	**MNSQ (INFIT)**	**MNSQ (OUTFIT)**
Deep Motive	Q1	.94	.96
	Q5	.92	.82
	Q9	.62	.62
	Q13	.83	.85
	Q17	1.02	1.28
	Q21	.93	.95
	Q25	1.37	1.35
	Q27	1.35	1.44
Deep Strategy	Q2	1.22	1.34
	Q6	1.02	1.10
	Q10	.67	.62
	Q14	.93	.90
	Q18	1.18	.99
	Q22	.95	.98
Surface Motive	Q3	1.03	.98
	Q7	.85	.77
	Q11	.87	.95
	Q15	.98	.89
	Q19	1.08	1.06
	Q23	1.28	1.22
Surface Strategy	Q4	.94	1.02
	Q8	.94	1.08
	Q12	.80	.84
	Q16	1.00	1.04
	Q20	1.05	1.02
	Q24	1.26	1.46
	Q26	.99	1.00

Note: The fit statistics reported here are from separate unidimensional Rasch models for each item set. All values were within the conservative MNSQ range of 0.50-1.50. ALB: Approaches to Learning Biology survey

Research Question 1 : What demographic and course context patterns emerge from undergraduate biology student scores on the approaches to learning biology survey?

Univariate ANOVA

After assumptions for homogeneity of variance and normality were assessed and deemed met, the PI ran a univariate ANOVA for each of the four ALB sub-outcome variables (deep motive, deep strategy, surface motive, surface strategy) to determine if there were any significant differences between outcome scores when grouped by student demographic and course context variables. No significant differences were found between outcome scores on groupings by gender, ethnicity, course section, or instructor in regard to deep motive, deep strategy, surface motive, and surface strategy scores.

Two-step Cluster Analysis

The two-step cluster analysis revealed two distinct clusters within the sample as determined by ALB sub-variable scores. Results, depicted in Table 3.5, indicated that participants within Cluster 1 tend to agree more with deep approaches to learning biology and participants within Cluster 2 tend to agree more with surface approaches to learning biology.

Table 3. 5 Results from Two-Step Cluster Analysis Including Sub-Variable Means for Each Cluster.

Cluster	**Sub- Variable Means**			
	Deep Strategy	Deep Motives	Surface Strategy	Surface Motives
1 (*N* = 67)	67.65	58.69	46.76	63.14
2 (*N* = 73)	52.31	49.51	53.98	70.87

A chi-square test of homogeneity was performed to determine if there were any statistical differences in the distribution of demographic indicators between each cluster. Demographic indicators included Gender (Male, Female, & Other), Ethnicity (African American, Asian, Caucasian, Hispanic/Latino, Middle Eastern, Mixed, & Other), and Course Section (Sections 1-6). Results indicated no significant differences between Cluster 1 and Cluster 2, with regard to Gender, ($x^2 = 1.46$, df = 2, $n = 140$, $p = 0.48$), Ethnicity, ($x^2 = 4.68$, df = 6, $n = 140$, $p = 0.59$), or Course Section, ($x^2 = 1.12$, df = 5, $n = 140$, $p = 0.95$). This indicates that the likelihood of a student being grouped into Cluster 1 or Cluster 2 is not significantly related to their gender, ethnic backgrounds, or the section of general biology in which they were enrolled. Depicted in Table 3.6 are frequency counts for each cluster based on gender and ethnicity.

Results also indicated patterns associated with distinct items between each cluster for the ALB sub-variables. Depicted in Figure 3.1 are the overlapping histograms that compare participants' response scores for each of the four ALB sub-variables. The overlap shows a range of common scores shared by both Cluster 1 and Cluster 2. Deep Motives, Deep Strategy, and Surface Strategy scores shared qualitatively similar patterns with overlapping scores ranging from low-to-mid 40s to scores in the low-to-mid 60s. However, students within Cluster 1 agreed more with Deep Motive and Deep Strategy items, with some students scoring into the upper 80s / 100. Cluster 1 participants also disagreed more with Surface Strategy items, with some students reporting scores as low as the 20s. Contrasting patterns on responses to Surface Strategies were found for students within Cluster 2.

Table 3. 6 Frequency Counts for Resulting Cluster 1 and Cluster 2 Based on Gender and Ethnicity.

	Cluster 1 (N = 67)		**Cluster 2 (N = 73)**	
	Male	Female	Male	Female
General	16	51	21	52
African- American	1	8	3	13
Asian	1	2	1	4
Caucasian	8	26	12	26
Hispanic/ Latino	2	4	1	3
Middle Eastern	2	4	2	3
2 or more/ Other	2	6	2	3

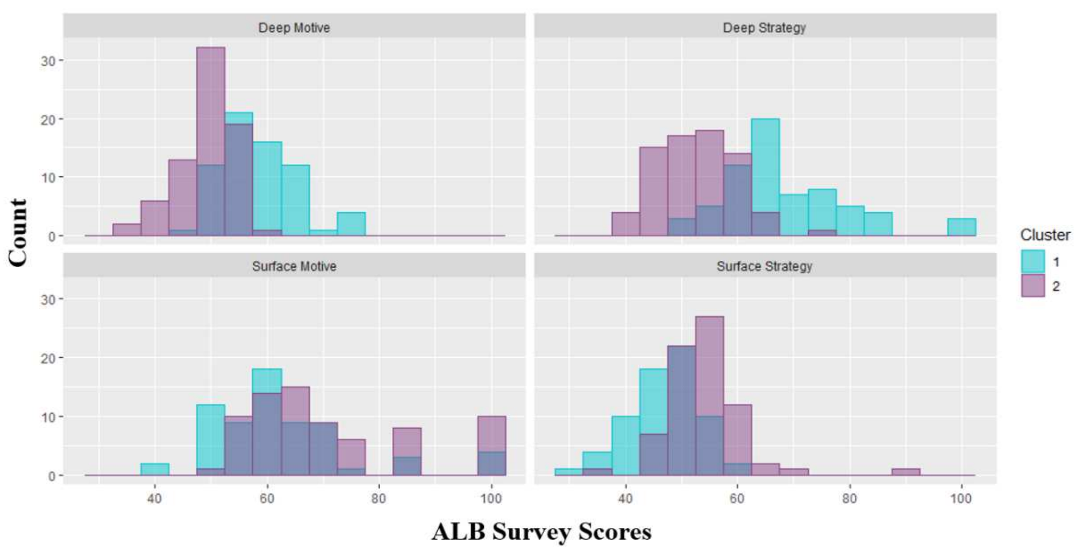


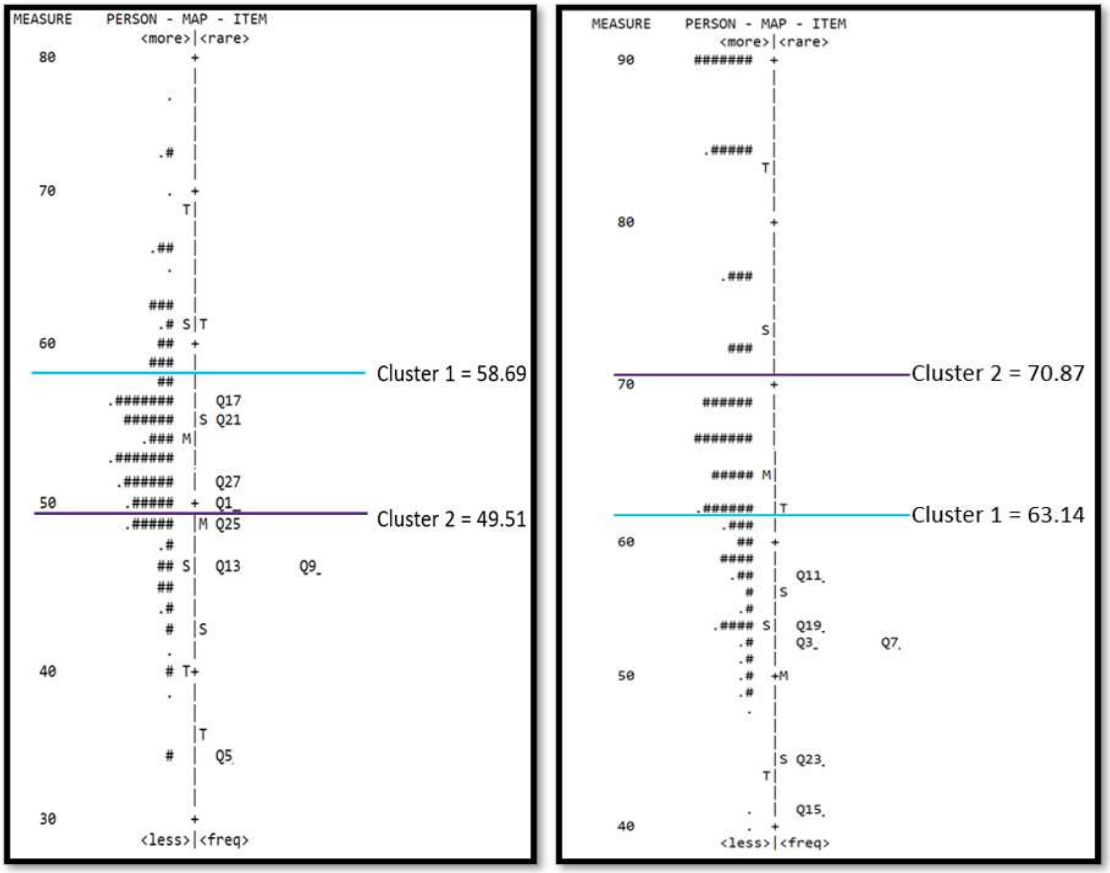
Figure 3. 1. Overlapping Histograms of Cluster 1 and Cluster 2 Frequencies. Overlapping histograms displaying the frequency of ALB survey scores comparing Cluster 1 and Cluster 2 responses for each ALB sub variable (e.g., Deep Motive, Deep Strategy, Surface Motive, Surface Strategy).

Interestingly, both Cluster 1 and Cluster 2 shared the most overlap for responses on Surface Motive items, with common scores ranging from the upper 40s all the way to 100. The only distinction between the two clusters was that more students in Cluster 1 disagreed with Surface Motive items, resulting in scores in the upper 30s. This indicates that regardless if students tended to agree more with items associated with Deep Strategy or Surface Strategies, students in both clusters still held surface motivations towards learning biology.

To look at these results from a more fine-grained perspective, a person-item Wright map was generated for each ALB sub-variable to reveal the specific scale items that were easier for students to agree with for each cluster as well as the items that distinguished each cluster from one another. Depicted in Figures 3.2 and 3.3, are person-item Wright maps, with a frequency of students on the left-side of each serrated-line and item-numbers for each sub-variable on the right. Each person count and item placement correspond to the 0-100 transformed Rasch measure scale on the far left. Items further to the bottom of each Wright map (less/freq.) indicate statements most easily agreed with by all students. Items close to the top of each Wright map (more/rare) indicate statements that were difficult for most students to agree with. For example, for the sub-variable Deep Motive, item #5 (Q5) which states '*I feel that biology topics can be highly interesting once I get into them'* was easy for the majority of the students to agree with. In contrast, item # 17 (Q17) which states ' *I spend a lot of my free time finding out more about interesting topics which were discussed in biology class'* was a statement that most students found it difficult to agree with. This speaks to the approaches to learning characteristics of the students who associated more with Deep Motives, in that they went beyond an interest in biology topics to enact learning outside of class that deepened and developed their interests.

The cluster mean values are shown on each Wright map to identify items that distinguished the two clusters. Depicted in Table 3.7 are the items that fell in between each cluster mean as demonstrated by the Wright map. For example, only one item landed in between the cluster means for Deep Strategy: item #6 (Q6). Q6 states *'I like constructing theories to fit odd things together when I am learning biology topics'* which also serves as the item most students found it very difficult to agree with. The mean value of Cluster 1 is far above Q6 indicating students in Cluster 1 found it easier to agree with Q6, whereas students in Cluster 2 found it harder to agree with Q6. This information provides insight into the distinct strategies utilized by students who identify more or less with deep and surface strategies.

It is also important to note that no items distinguished Cluster 1 and Cluster 2 for Surface Motive sub-variable items. This finding aligns with the great amount of overlap in survey responses between each cluster for Surface Motive (Figure 3.1). Despite students gravitating towards deep or surface strategies, most students shared similar agreement in statements like Q15 *'I want to get a good grade in biology class so that I can get a better job in the future'* and Q3 *'I am discouraged by a poor grade on biology tests and worry about how I will do on the next text.* All of the six items associated with Surface Motive were positioned towards the bottom of the Wright map, indicating that they were easier for all participants to agree with. However, Cluster 2 students did have a slightly higher cluster mean (*M* = 70.87) as compared to Cluster 2 students (*M* = 63.14) for Surface Motive.



Deep Motive Surface Motive

Figure 3. 2 Person-Item Wright maps for ALB variables Deep Motive and Surface Motive. Each Wright map displays Rasch person measure scores (*N* = 140) left of double-dashed line and 8-items for Deep Motive and 6-items for Surface Motive to the right. Person measures range from more agreement (top) to less agreement (bottom). Items are indicated by the corresponding survey question (e.g., Q1 = Survey question 1) ranging from frequent (top) to rare (bottom). M = mean, S = 1 Standard deviation from mean, T = 2 standard deviations from mean. Each '#' in the person column represent 2 people and each '.' is 1 person. The cluster mean value for Cluster 1 (teal) and Cluster 2 (purple) overlay each Wright map.

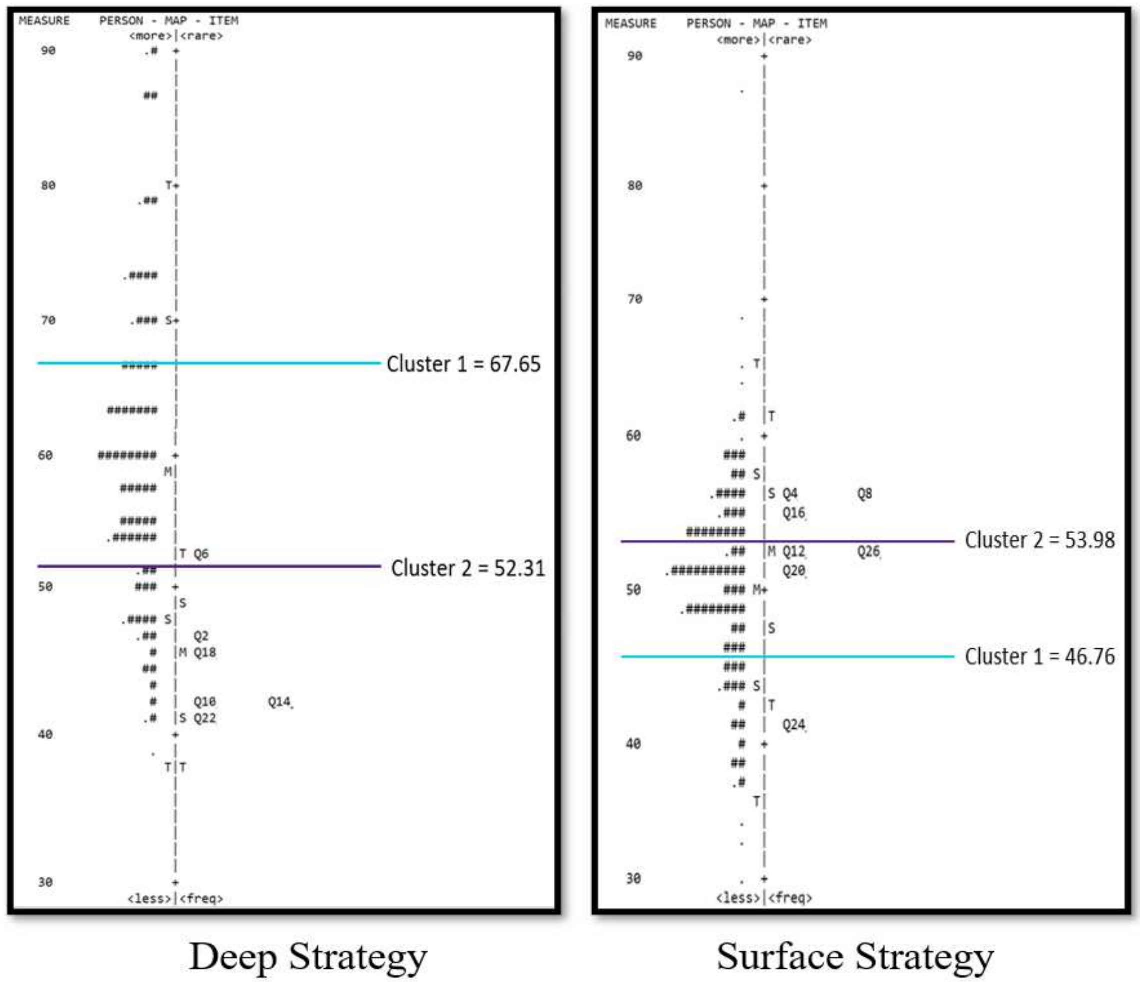


Figure 3. 3 Person-Item Wright maps for ALB variables Deep Strategy & Surface Strategy. Each Wright map displays Rasch person measure scores (N= 140) left of double-dashed line and 6-items for Deep Strategy and 7-items for Surface Strategy to the right. Person measures range from more agreement (top) to less agreement (bottom). Items are indicated by the corresponding survey question (e.g., Q1 = Survey question 1) ranging from frequent (top) to rare (bottom). M = mean, S = 1 Standard deviation from mean, T = 2 standard deviations from mean. Each '#' in the person column represent 2 people and each '.' is 1 person. The cluster mean value for Cluster 1 (teal) and Cluster 2 (purple) overlay each Wright map.

Table 3. 7 ALB Scale Item between Cluster 1 and Cluster 2 by Sub-Variable

Sub-Variable	**Question #**	**Item**
Deep Motive	Q1	I find that at times studying biology makes me feel really happy and satisfied
	Q27	I like to work on biology topics by myself so that I can form my own conclusions and feel satisfied.
	Q21	I come to biology class with questions in my mind that I want to be answered.
	Q17	I spend a lot of my free time finding out more about interesting topics which were discussed in biology class.
Deep Strategy	Q6	I like constructing theories to fit odd things together when I am learning biology topics.
Surface Strategy	Q20	I find the best way to pass biology examinations is to try to remember the answers to likely questions.
	Q12	I generally will restrict my study to what is required as I think it is unnecessary to do anything extra in learning a biology topic.
	Q26	I find that memorizing the most important content makes me get high scores in the examinations instead of understanding it.

Research Question 2: What is the relationship between student approaches to learning biology scale scores and student learning outcomes?

Correlational Matrix

After running a correlational analysis comparing the relationship between ALB sub-variables and student learning outcomes, the following relationships emerged (Figures 3.4 and 3.5). Results indicated that both Deep Motives and Deep Strategy variables were positively correlated to student learning outcomes. This means that as scores for sub-variables Deep Motives and Deep Strategies increased (indicating more agreement with these items), student exam and course grades also increased.

In contrast, both surface motive and surface strategies were negatively correlated to student learning outcomes. This means that as scores for sub-variables Surface Motives and Surface Strategies increased (indicating more agreement), student exam and course grades decreased. Results from this correlational analysis revealed overall positive correlations between deep approaches to learning biology and student learning outcomes, as well as negative correlations between surface approaches to learning biology and student learning outcomes. Depicted in Figure 3.4 are the correlation coefficients that reveal both the direction and degree of relationship. Depicted in Figure 3.5 are the p-values associated with each correlation.

Analysis revealed that each ALB sub-variable was significantly correlated with Exam 2 scores [D_M & Exam 2 *(r = 0.35, p =.000),* D_S & Exam 2 *(r = 0.33, p =0.01),* S_M & Exam 2 *(r = -0.37, p =.000),* and S_S & Exam 2 *(r =- 0.35, p =.000)*]. These results aligned with the intentional effort to collect survey data directly after students completed their midterm exam (Exam 2) to provide context for their responses.

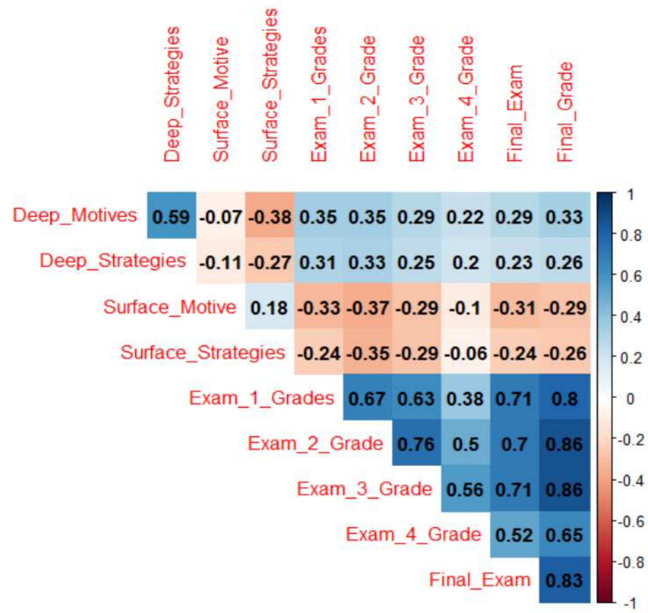


Figure 3. 4 Correlation Matrix of Correlation Coefficients of relationship between ALB variables and student learning outcomes.

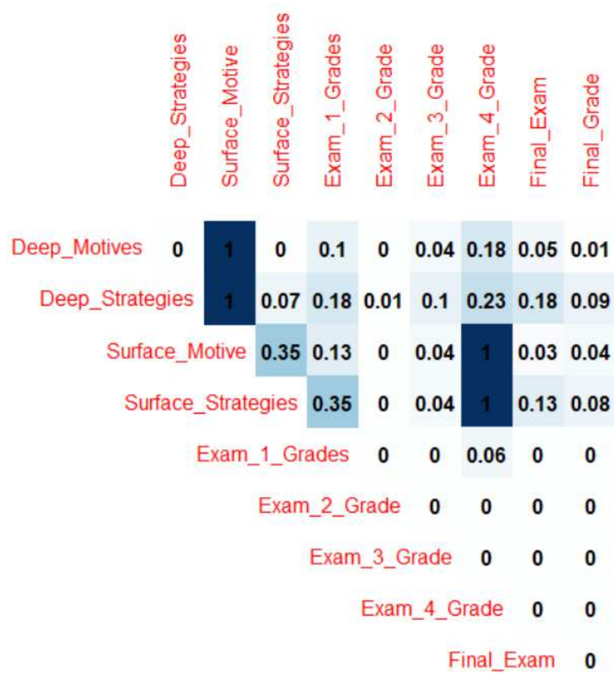


Figure 3. 5 Correlation Matrix of *p*-values of relationship between ALB variables and student learning outcomes.

Discussion

This study captured how students approached learning in the discipline-specific context of introductory undergraduate biology. First, with the aim of revealing patterns associated with ALB scale results, and demographic and course context variables, univariate ANOVAs revealed that students' approaches to learning biology were not significantly related to student gender, ethnic background, or course section/ instructor. These findings indicate that, in this study, student choice to adopt a deep or surface approach to learning is not related to their gender or ethnicity. However, significant gender differences were found in the work of Choiu et al. (2012), who used the same ALB instrument. It was found that the female students scored significantly higher on the Surface Motive factor ($t = 2.18$, $p < 0.05$) and significantly lower on the Surface Strategy factor ($t = -3.00$, $p < 0.05$) than the male students. No significant differences were found between Deep Motive and Deep Strategy scores.

Although these are important findings to consider, this study differed from that of Choiu et al. (2012) in that they surveyed biology majors across 10 different institutions with a wide range of biology course backgrounds. While those findings provide an insight into students' pre-dispositions towards how they would approach learning unattached to a specific task, this study examined how students approach studying for a midterm exam within the same introductory biology course, adhering to the context-dependent nature of SAL. This distinction could explain the differences in results.

With regard to ethnic and course context differences in SAL, it is well established that contextual factors (e. g., teaching/learning environment, course design, assessment procedures) and personal factors (e.g., students' perceptions of learning environment, prior knowledge, identity) heavily influence how students go about learning course material (Laird et al., 2008; Zeegers & Martin, 2001). However, in the case of this study, it was not anticipated that a students' ethnic background should predict how they approach learning biology. This notion is now supported by evidence elucidated from this study. It is important however for future research to further investigate how personal factors unique to individual students relate to or impact their study behaviors within a discipline-specific context. Future research on the role personal factors play on SAL offers a boarder scope in which to understand the student learning experience and could potentially illuminate unexamined influencers.

As for course context, despite collecting data from six different course sections of general biology I, each of the four instructors modeled similar pedagogical practices across each section. This conclusion was based on course observations and faculty interviews, that identified similar course structure and assessment practices. Admittedly, an understanding that learning environment significantly influences SAL is known (e.g., Biggs, 2001); however, course context/ instructor did not have a qualitatively significant relationship to students' ALB due to the similarities discussed above.

Findings from this study also confirmed the previously established relationship between SAL and learning outcomes (e.g., Davidson et al., 2019; Geller et al., 2018; Marton & Säljö, 1976; Milner, 2013; Rhodes & Rozell, 2017). The correlational analysis revealed that deep and surface sub-variables were inversely related to student learning outcomes. Although, this finding may not seem novel, it holds merit in that these findings were assessed using a discipline-specific inventory. Correlation patterns also revealed that each ALB sub-variable was significantly correlated with Exam 2 scores. These results aligned with the intentional effort to collect survey data directly after students completed their midterm exam (Exam 2) to provide context for their responses.

Lastly, findings from the two-step cluster analysis revealed two noteworthy patterns. First, overlapping histograms (Figure 3.1) showed predictable patterns for sub-variables of Deep Motives, Deep Strategies, and Surface Strategies, in that there was little overlap between the two clusters of students. However, Surface Motive measures showed large overlap between clusters with cluster means of 63.14 (Cluster 1) and 70.87 (Cluster 2). The two-step cluster analysis revealed two clusters of homogenous groups of students, one tending to agree more with deep approaches to learning (Cluster 1) and the other agreeing more with surface approaches to learning (Cluster 2). These findings aligned with the proposed dichotomous nature of the SAL construct. The fact that sub-variable Surface Motive showed large overlap, revealed that both students who agreed more with Deep Strategies and those that agreed more with Surface Strategies held similar surface motivations towards learning biology.

For example, students from Cluster 1 and Cluster 2 tended to agree with item #19 *"I want to do well in biology subjects so I can please my family and the teacher."* or item# 15 *"I want to get a good grade in biology class so that I can get a better job in the future."* These finding contradicts theoretical-based claims that suggest students who adapt Deep Strategies hold Deep Motives and students who adopt Surface Strategies hold Surface Motives (e.g., Choiu et al., 2012). However, from a practical perspective, it is understandable that students who implement Deep Strategies can hold both Deep and Surface Motivations for wanting to understand the course material.

Findings from the two-step cluster analysis also revealed the specific survey items that distinguished Cluster 1 and Cluster 2. This type of analysis is novel in that, cluster analysis are traditionally used in SAL research to identify learner profiles in the context of undergraduate biology (e.g., Balasooriya et al., 2009; Hazel et al., 2002; Quin & Stein 2013; Quinnell et al. 2018; Quinnell et al., 2012). These SAL learner profiles are usually compiled in conjunction with other student learning variables like students' epistemic beliefs, conceptions of learning, or perceptions of the learning environment. Results from these studies revealed pre-post semester changes in learner profiles as well as new categories of students as trending towards *Dissonance* (high scores for both Deep and Surface approaches to learning) or *Disinterested* (low scores for both Deep and Surface approaches to learning). These findings are important contributions to discipline-specific SAL research.

This study went a step further and identified specific survey items that most distinguished students tending towards deep approaches from those of surface approaches. Depicted in Table 3.7 are items that distinguish Cluster 1 from Cluster 2 for each sub-variable. There are no distinguishing items for sub-variable Surface Motive, which is expected given the large overlap between cluster scores. These items can be used to evaluate pedagogical practices that may foster the development of deep approaches to learning for entry-level biology students. For example, Q17 for Deep Motives states "*I spend a lot of my free time finding out more about interesting topics* *which were discussed in biology class."* This statement demonstrates that students who hold deep motives beyond an interest in biology topics to actions outside of class that deepen and develop their interests. Instructors could potentially encourage deep motivations towards biology by creating assignments/projects open to students' natural interests and curiosities towards biology.

Another example is Q6 for Deep Strategy: *"I like constructing theories to fit odd things together when I am learning biology topics."* Agreement with this statement suggests that students who implement deep strategies constructed meaningful connections with biological concepts that may seem not to relate to each other at first glance. This strategy may not be apparent to all students. Dye and Stanton (2017) argued that students may be evaluating approaches to learning for the first time in college and therefore would benefit greatly from instructors modeling desired behaviors. Other researchers studying undergraduate biology students' study behaviors agreed that modeling desired behaviors of active, metacognitive learning strategies, and engagement in learning communities promotes the use of deep approaches to learning (Buchwitz et al., 2012; Davidson et al., 2019; Dye & Stanton, 2017; Rhodes & Rozell, 2017; Tomanek & Montplaisir, 2004). Other distinguishing scale items potentially hold similar value in enhancing the teaching-learning environment of post-secondary introductory biology courses.

Study Limitations

There are two main limitations for this study. First, the survey response-rate represented only 27% of the available introductory biology student population. Acceptable survey response rates range in educational research higher rates above 50% are desired and could lead to more generalizable inferences for similar populations (Saleh & Bista, 2017). Within this study there were several factors that could influence response rate, one being that students were asked to complete surveys online outside of class as opposed to during class.

The second limitation is that the person reliability value for Surface Motive (0.54) was below the acceptable value of 0.70. This suggests that if given a different set of items of similar difficulty, the person agreement may not be replicated. The Surface Motive variable also revealed the most overlap of agreement between Cluster #1 and Cluster #2, suggesting both groups found Surface Motive items easy to agree. However, the person-item Wright map for Surface Motive revealed most items were towards the bottom of the map, not aligned with most of the participants. This bares to question if the items representing Surface Motive precisely measured the sampled group. Considering these two limitations, future work would benefit from an increased sample size to confirm similar trends and ability for Surface Motive items to accurately measure demographically diverse student populations.

Conclusion

Examining how students approach learning introductory biology illuminate factors that help researchers disentangle some of the complexities associated with understanding the teaching-learning experience. Findings from this study add to discipline-specific SAL literature aimed both at adding to the descriptive landscape of how students approach learning, and correlational research aimed at identifying relationships between SAL and learning outcomes. Future research directions seek to add to this base by exploring discipline-specific factors that may impact student study decisions, as well as their science identity.

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CHAPTER IV: STUDY 2

APPROACHES TO LEARNING BIOLOGY OF WOMEN OF COLOR: THE INTERSECTIONALITY OF RACE, GENDER, AND SCIENCE IDENTITY

Despite steady growth in national diversity, women of color (WOC) continue to struggle in accessing higher education and persisting to graduation in STEM as compared to their White counterparts (Banks & Dohy, 2019; Espinosa, 2011; Johnson et al., 2011; Ong et al., 2011; Palmer et al., 2011). This leads to representations of WOC in STEM fields that are disproportionate to the U. S. population (National Academy of Sciences, 2007). To explain such underrepresentation of women of color in science, research has historically focused on differences in measurable student outcomes, such as scores on standardized tests of this group of students (Banks & Dohy, 2019). However, standardized measures often do not take cultural validity into account (Solano□Flores & Nelson□Barber, 2001). Research findings overwhelmingly demonstrate that women of color, among other underrepresented groups, do not persist in science due to social or interpersonal factors (Brown, 2000; Carlone & Johnson, 2007; Ong et al., 2011; Ong et al., 2018 ; Valenzuela, 2006; Varma, 2002; Varma et al., 2006), not because they are less talented, competent, or interested than those people who do persist in science (Tobias, 1990; Trujillo & Tanner, 2014; Seymour & Hewitt, 1997).

Because women of color are part of racial, ethnic, and gender minority groups, persistence in science for WOC often consists of navigating experiences of exclusion, isolation, and lack of belonging (Johnson, 2011). WOC often find themselves as the only one that looks like them in various post-secondary science spaces. Such isolating experiences are shown to impact the development of WOCs' science identity, which is hypothesized to be key to student persistence and retention in science (Trujillo & Tanner, 2014).

From a resource-based perspective, several studies have illuminated how underrepresented minorities, including WOC, have been successful in science by authoring new identities, balancing competing identities, and continually developing their science identities amidst the sometimes hostile terrain of science (e.g., Banks & Dohy, 2019; Brown et al., 2016; Byars-Winston et al., 2016**;** Chang et al., 2014; Espinosa, 2011; Hurtado et al., 2010; Johnson et al., 2011; Palmer et al., 2011). Studies that examined how WOC succeed in science took a resource-based perspective in understanding persistence. Although such studies are informative at a broad and macroscopic level, there is a need for microscopic or detailed examinations of how cultural and social factors (e.g., identity) affect women of colors' day-to-day academic decisions that have a direct impact on academic achievement, such as the approaches they draw on to study for their science classes. Such studies are essential to understand, from a resource-based perspective, how women of color successfully navigate through the STEM pipeline and can possibly illuminate more practical aspects of the path for women of color that follow.

To address this need, this study examined how undergraduate women of color experience the phenomenon of studying introductory biology through the lens of science identity and intersectionality. This phenomenon includes both how students conceptualize what studying is (conceptions of studying) and how they actually go about studying (approaches to learning). How WOC conceptualize and approach learning biology directly relates to successful academic performance, which increases their overall successful navigation as a science major. It is well documented that students' approaches to learning are strongly influenced by both contextual factors (e.g., teaching/learning environment, course design, assessment procedures) and personal factors (e.g., students' perceptions of the learning environment, student identity) (Zeegers & Martin, 2001; Laird et al., 2008). Such contextual and personal factors are said to be unique to the discipline of study due to the fact that, "different disciplines have different cultures that have different norms, values, aims, and problems and the role of teaching and learning vary in different academic environments" (Rytkönen et al., 2012, p. 253). For this reason, it is imperative to examine factors that influence how WOC approach learning at the discipline-specific level (e.g., Biology).

In an attempt to sort through some of the complexities associated with student learning experiences in biology, this study first explores demographic and course context distinctions in approaches to learning biology of a diverse sample of introductory biology students. The work then takes a closer look at how the science and cultural identities of selected WOC impact how they experience the phenomenon of studying introductory biology. This study defines women of color as Black/African American, Latina/Hispanic, Native American/ American Indian, Asian, Middle Eastern, Native Hawaiian / Pacific Islander, and multiracial women, recognizing that although WOC may share common experiences related to their race/ethnicity or gender, each racial and ethnic group also holds unique cultural experiences that contribute to their academic experiences.

Conceptual Framework

Conceptions of Studying

At the undergraduate level, the act of studying outside of class time is consistently expected by instructors, yet often ill-defined as to what activities constitute studying. For some, studying is task-oriented in that it implies completing a task either during or outside of class, while for others it may include attending class. Robbins et al. (2004) defined studying as "those activities necessary to organize and complete schoolwork tasks and to prepare for and take tests" (p. 264), while Anderson and Armbruster (1980) stated that "studying involves reading in preparation for performing a criterion task" (p. 1). Other scholars define studying in terms of one's ability to concentrate, hours spent studying, and scheduling regular review sessions (Noin, & Hudson, 2010). All of these definitions are constructed from the perspective of the researcher and not the students actually engaging in that act itself which leaves the question open as to how students might define studying.

Recent studies have examined how undergraduate science students define studying to highlight the need for consistency in how studying is conceptualized in higher education. For example, Johnson and Gallagher (2019) centered their study on categorizing how undergraduate anatomy and physiology students defined such terms as studying, learning, and memorization. They found that students defined studying in four distinct ways: (1) studying as a process, (2) studying as a use of time, (3) studying as an action leading to an extrinsic act (e.g., taking a test), and (4) studying as an action leading to an intrinsic act (e.g., memorization or understanding course material). In addition, studies in similar contexts of undergraduate science acknowledged the need to address the assumption that students, researchers, and instructors share a common definition of what is meant to study (e.g., Hora & Oleson, 2017). These studies also call for a need of solidifying a common definition of studying in future research.

Academic agreement on a common definition of studying is one step in the direction of helping students carry out this activity efficiently. Hora and Oleson (2017) proposed that researchers and educators alike adopt a multidimensional perspective to how they think about the act of studying. After exploring STEM undergraduates' study habits, they argued that "conceptions of the act of 'studying' extend beyond a focus on discrete, decontextualized factors such as hours spent studying or the use of specific strategies" (p. 15). Thus, educators, instructional designers, and administrators should think more strategically about how to foster effective study habits by considering student perceptions of studying and how these lead to student behaviors like cue-seeking, resource acquisition, and distraction management in shaping their study habits (Hora & Oleson, 2017). More importantly, WOC might have intra-cultural perceptions of what it means to study that differ from their instructors or other students. The next section considers how student approaches to learning are correlated to student learning outcomes.

Student Approaches to Learning and Student Learning Outcomes

It is well known that how students study course material directly influences their learning outcomes. Recent studies have identified strong associations between deep approaches to learning and positive learning outcomes, and between surface approaches to learning and negative learning outcomes within the context of undergraduate biology. (e.g., Davidson et al., 2019; Geller et al., 2018; Milner, 2014; Rhodes & Rozell; 2017). Deep approaches to learning are based on a perceived need and driven by intrinsic motivations to understand the intentions of the tasks (Asikainen & Gijbels, 2017; Biggs, 2001). Students who adopt deep approaches are said to search for inherent meaning of the tasks, make tasks meaningful to their own experiences or the real world, integrate aspects of parts of task into a whole, and form hypotheses or theorize about the tasks (Kember et al., 2004; Richardson, 1994). Students using deep approaches engage in appropriate learning activities, where appropriateness is measured based on alignment with the instructor's intentions of the task. Research indicates that deep approaches are synonymous with independent high-quality, meaningful learning, which eventually leads to a deeper understanding and positive learning outcomes (Ferla et al., 2009; Vermunt & Vermetten, 2004).

In contrast, surface approaches to learning are based on motives and intentions that are extrinsic to the real purpose of the task, typically driven by fear of failure or keeping out of trouble (Asikainen & Gijbels, 2017; Biggs, 2001). Students using surface approaches invest little time and effort in understanding the task. Students inappropriately engage in low-cognitive level activities with tasks that are designed to promote high-cognitive activities. Most commonly, rote learning or selective memorizing without understanding is a surface approach to learning with the goal to quickly gain enough information to satisfy learning goals. Surface approaches are commonly linked with negative student outcomes (Biggs, 1987, 2001). However, rote learning is not always classified as a surface approach. Students who use verbatim recall when it is required to understand are not using surface approaches (Biggs, 2001). For example, if a course assessment requires students to recall definitions or vocabulary, an appropriate study strategy would be to match the vocabulary terms with the definitions. However, if a course assessment requires a student to explain how two biological concepts are related, then it would be inappropriate for a student to only memorize terms to recall on the exam.

Learning biology is said to be a generative process that requires students to actively integrate prior knowledge and domain knowledge to form meaningful new connections. Chin and Brown (2000) emphasized that the development of rich domain-specific conceptual knowledge depends on the successful integration of prior and new knowledge. Successful integration involves “activities or methods used by an individual to encode information into long-term memory in the category of experiences that produce changes in mental representations” (McNulty et al., 2012, p. 1). This means that learning strategies that involve changes in mental representations or connections between prior and new knowledge are more effective in terms of relevant retrieval of information. Such strategies are characterized as deep approaches to learning. Recent biology education initiatives describe how students who incorporate key elements of learning science, such as asking meaningful questions, constructing scientific explanations, and reflecting on their learning process into their study approaches, are more likely to have positive learning outcomes (Chin & Brown, 2000; Tomanek & Montplasir, 2004; Watters & Watters, 2007).

Given the direct link between how a student approaches learning and the student’s learning outcomes, it is important to investigate factors that influence students’ decisions to adopt deep verses surface approaches to learning. Students are encouraged throughout post-secondary education to utilize deep approaches to maximize positive learning outcomes; however, there are many contextual factors that influence the likelihood of students adopting deep approaches (e.g., teaching/learning environment, course design, assessment procedures). For example, students may adopt different approaches to learning within different disciplinary contexts (Asikainen & Gijbels, 2017). Current biology education reform initiatives encourage instructors to shift away from instruction that emphasizes surface approaches to learning and, instead, design classroom environments that foster deep approaches to learning (Laird et al., 2008). Despite efforts to promote deep approaches to learning, a large number of undergraduate students use inappropriate, surface-level approaches that are related to negative student learning outcomes (Balasooriya et al., 2009; McNulty et al., 2012; Quinn, 2011; Quinnell et al., 2012; Walker et al., 2010). Quinn (2011) also noted that "inducing deep approaches is difficult, perhaps because of the profound influence of the student's personal situations, cultural values, and other student-specific characteristics" (p. 118). Based on this research, it is important to examine how factors outside of the academic system, such as students' personal factors, may play a key role in how students decide to approach learning.

Personal factors (e.g., students' perceptions of the learning environment and socio-cultural factors) heavily influence how students go about learning the course material (Laird et al., 2008; Zeegers & Martin, 2001), yet they are often ignored in efforts to enhance persistence in science (Winston et al., 2016). Balasooriya et al. (2009) noted that the persistence of either deep or surface approaches may stem from the complex interactions between context factors and student factors. Biggs (2001) argued that "the events involved in teaching and learning form an interactive system, where outcomes cannot be satisfactorily accounted for by any one set of factors, within or without the learner's skin" (Biggs, 2001, p. 74).

For these reasons, it is imperative that future research not only more thoroughly consider the interaction between academic context and personal factors, but the myriad of personal factors that make up the identity of each student. As students enter college, they bring with them multiple identities that influence their academic decisions. In addition, as students experience discipline-specific learning environments (e.g., the science classroom), they author new identities that continue to shape their learning experience and ultimately their academic success. This study takes a novel perspective in attempting to illuminate personal factors the impact the academic decisions of women of color on the microscopic level of understanding how they approach learning introductory biology.

Science Identity

Identity is a complex construct that is often conceptualized as having both socially constructed (e.g., race, ethnicity, gender identity) and experiential (e.g., perceptions of lived experiences) components (Le et al., 2019). These components are rooted in social psychological theories embedded in the works of Holland et al. (1998), Gee (2000), and Lave (1991). Holland et al. (1998) conceptualized identity as a sense-making process of determining who a person is via internal dialogue and sociocultural participation. While Gee (2000) defines identity as "being recognized as a certain 'kind of person,' in a given context" that varies across space, place, and time (p. 99). Lastly, Lave (1991) argued that "relations between subjects and objects in the world are shaped by their cultural and historical circumstances" (p. 81) concluding that identities are socially constructed, influenced by the roles individual assume and the activities they engage in with peers and more knowledgeable others (Morton & Parson, 2018).

It is with this same fundamental perspective that I use the theoretical lens of identity to understand how the socially constructed identities of race and gender influence the science learning experiences of WOC. Over the years, contributions from identity-based research have grown in significance in the field of science education because it offers an ontological approach to learning (Avraamidou, 2020; Wenger, 1998). Wenger (1998) expressed that "learning transforms who we are and what we can do, it is an experience of identity" (p. 215). From this perspective, researchers in science education have used the construct of identity to study students' science identities with the goal of contributing to an "understanding of how science identity might serve in making science learning meaningful and purposeful" (Avraamidou, 2020, p. 326).

In recent years, several studies have added to the evidence that supports the key role science identity plays in student persistence and retention in the sciences, especially for women of color (e.g., Andersen & Ward, 2014; Aschbacher et al., 2010; Carlone & Johnson, 2007; Calabrese Barton & Yang, 2000; Chinn, 2002; Gilmartin et al., 2007; Hazari et al., 2013; Olitsky, 2007). Not only does science identity impact students' willingness to persist in science, but it is also said to impact their overall classroom experiences (Eddy et al., 2015). Evidence suggests that students who leave the sciences are just as talented or competent as those who persist in science (Tobias, 1990; Seymour and Hewitt, 1997). However, "those who leave appear to reject the culture of science, in particular the culture of undergraduate science classrooms, and as a result, choose not to adopt a professional identity within this scientific culture" (Trujillo & Tanner, 2014, p. 12). Therefore, it is imperative that WOC's science identity development be considered when examining factors related to persistence and retention in science.

In summary, science education research has embraced science identity as an analytical lens because it can be used to answer questions about the kinds of people promoted and marginalized by science teaching and learning. If science is viewed as a community of practice (Lave & Wenger, 1991; Wenger, 1998), it positions the process of learning science as a socialization of students into the norms and discourse practices of science (Brown, 2004; Kelly, 2007; Varelas et al., 2005; Warren et al., 1994). With this notion, entering science majors are aspiring members that must be enculturated into this community (Carlone & Johnson, 2007). It is imperative to understand "how neophytes affiliate with, become alienated from, and/or negotiate the cultural norms within these communities" (Carlone & Johnson, 2007, p.1189). In addition, science identity frameworks allow researchers to understand emerging identities and the ways students come to see science as a set of experiences, skills, knowledge, and beliefs worthy (or unworthy) of their participation (Carlone & Johnson, 2007). This body of literature helps to unpack areas of science education that traditionally place science practices as narrowly defined tasks or as a finished body of knowledge, an attribute that does not always appeal to a broad range of students (Calabrese Barton, 1998; Eisenhart & Finkel, 1998; Gilbert & Yerrick, 2000).

Science Identity from an Asset Perspective

To combat the narrow perspective of what science is and what is valued in science, I use the lens of science identity to illuminate assets that WOC bring into the science community that uniquely derive from their socially constructed identities of race and gender. Barriers to academic success for WOC are often presented as the absence of static factors such as parental support, strong pre-college science experiences, teacher encouragement, or financial support (Brown, 2002; Buzzetto-More et al., 2010; Charleston, 2012; Russel & Atwater, 2005). Although such literature provides a starting place to understanding how women of color can successfully persist in science, such explanations position the students "as a passive recipient of her life's conditions with little consideration for how she might creatively position herself within and against those conditions" (Carlone & Johnson, 2007, p. 1188). Examining women of color's science identity accounts for individual agency and illuminates how they author new identities, balance competing identities, and continually develop their science identities amidst societal structures that constrain individual possibilities (Brickhouse, 2000; Carlone & Johnson, 2007; Johnson et al., 2011).

To provide a concrete foundation on which to build this analysis, I frame the construct of science identity within the three-dimensional model developed by Carlone and Johnson (2007), which emphasized the interplay of *competence*, *performance*, and *recognition* within the development of WOC's science identity. Theoretically, a person who has a strong science identity, is *competent*, demonstrating meaningful knowledge and understanding of science content. They also have developed skills to *perform* their competence in scientific practices (i.e., use of scientific tools and language). Lastly, they are *recognized* by themselves and others as a *science person* (Carlone & Johnson, 2007).

Carlone and Johnson (2007) emphasized the component of *recognition* as being most impactful in the successful development of the science identity for WOC. For WOC, science identity is shaped by the magnitude in which they view themselves as a part of the science community and how they are viewed by others as a scientist within the community (Carlone & Johnson, 2007). Critical experiences along their path of science education influence this recognition component of their science identity development and these experiences mutually impact their identity as WOC. I acknowledge the importance of all three components of the science identity model; however this study will only focus on the Recognition component as it relates to its impact on the academic behaviors of WOC.

This model for science identity carries the assumption that one's gender, racial, and ethnic identities affect one's science identity. Although several impactful studies have examined science engagement through the lens of science identity (e.g., Danielsson, 2012; Gonsalves, 2014; Trujillo &Tanner, 2014), few have accounted for how other identities may be of influence in science (non) participation (Avraamidou, 2020). This study recognizes that WOC hold multiple identities that are central to their social positioning and science identity development, and therefore argues that their science identities should be examined in conjunction with other mutually constructed identities through the lens of intersectionality.

Intersectionality

One of the salient characteristics of science identity is that it is relational to multiple other identities, such as gender identity, religious identity, and ethnic identity (Avraamidou, 2020). To fully consider the role multiple identities play in shaping participants' science identity and their academic decisions, this study leverages the concept of intersectionality as both a conceptual framework and a methodological tool.

The term *intersectionality* was first coined by Kimberle Crenshaw (1989) as a response to U.S. anti-discrimination laws inadequately recognizing the struggles and marginalization of Black women. Rooted in Black feminism, Intersectionality "contends that the experiences of Black women and girls illuminate a particular understanding of their position in relation to sexism, class oppression, racism, and other systems of domination" (Haynes et al., 2020, p. 3). Since these early studies, intersectionality scholarship has crossed cultural and disciplinary contexts, specifically the educational affordances of considering the multiple identities a person holds in research (Lyons et al., 2016).

This study is not focused on women who also happen to be people of color or people of color who also happen to be women. Based on the construct of intersectionality, the gender and racial/ethnic identities of WOC are mutually constructed and cannot be separated. Intersectionality provides a guide to study the personal/cognitive factors that interact with environmental factors to influence approaches to learning biology, which may help us understand attrition and persistence in science of students who live at the intersection of race/ethnicity and gender. Previous studies have described how successful women of color authored new identities, balanced competing identities, and continually developed their science identities (Johnson et al., 2011). Yet, for WOC, science identity may at times be in conflict with other cultural identities. Therefore, in terms of intersectionality, it is necessary to understand how science identity intersects with race/ethnic and gender identity.

This study provides a unique approach to exploring the multiple identities of WOC in science, in that it goes beyond telling the narratives of the participants to connecting their experiences to academic behaviors and learning outcomes. In efforts to increase the persistence of WOC past the introductory stage of their academic science journey, this study is carefully designed to examine cultural and social factors that play an impactful role in how these women navigate the day to day task of studying biology.

Research Questions

Q1: How do undergraduate students approach learning biology in the context of introductory biology?

Q2: How do women of color experience the phenomenon of studying introductory biology as it relates to their conceptualizations of studying, approaches to learning biology, and their learning outcomes?

Q3: How do the intersecting identities of science, race/ethnicity, and gender of women of color shape how they experience the phenomenon of studying introductory biology?

Research's Positionality

As the principal investigator, I recognize my position as a woman of color and a researcher. I identify as an African American female, with a professional background in science education and student success at the higher education level. Within my professional career, I have worked with several undergraduate biology students along various stages of their academic journey to identify barriers and bridges to their academic success. Commonly revealed, adapting effective study strategies in the context of rigorous science courses, emerged as a critical factor in students' academic achievement.

Personally, as a member of a group historically underrepresented in academia, I hold similar experiences as the participants in that I too have had to balance competing cultural identities, religious identities, and science identities to successfully establish my recognition in the science community. Therefore, my epistemological positionality is aligned with the goal of the study, as I am interested in empowering WOC to embrace all facets of who they are in their pursuit to learn science, as well as to illuminate the complex connections between students' multiple identities and their learning experiences. With the full understanding that my science learning experiences are not identical to those of the participants, I remained attentive to the lived experiences of the participants and structured a research design grounded in phenomenology to minimized my own subjectivity.

Methodology

Research Design

To explore how the intersectionality of race, ethnicity, gender and science identities impact how WOC approach learning biology, I used the participant-selection variant of the explanatory sequential mixed methods research design. Mixed methods are necessary to develop a rich understanding of a small number of participants, while simultaneously generalizing understandings by including a large number of students from diverse backgrounds at the study site. In accordance with the participant-selection variant of the explanatory sequential research design (Creswell & Plano Clark, 2018), I collected data in two phases, placing priority on the qualitative phase (Phase 2). The purpose of the initial quantitative phase (Phase 1) was to capture approaches to learning across a large, diverse sample of students (Research Question 1) and to identify and purposefully select the most valid participants to answer Research Questions 2 and 3.

Within the qualitative portion of Phase 2, I used phenomenological methods to examine how the cultural and social factors embodied by women of color shape their learning experience, specifically their study approaches. Phenomenology is a methodology that seeks to explain how the learner has come to experience a particular phenomenon, in this case studying biology in an educational context. "Phenomenology tries to show how our words, concepts, and theories always shape (distort) and give structure to our experiences as we live them" (Adams &Van Manen, 2008, p. 616-617). In other words, this type of method relies on the collection of personal descriptions of variations in understanding the same phenomena and seeks to identify why these understandings may vary (e.g., Ashworth & Lucas, 1998; Wright & Osman, 2018).

Study Context

Participants

This study took place in a large public university located in the Southeastern United States. Within Phase 1, I used criterion-based sampling (Patton, 2015) to recruit all participants enrolled in one of six introductory-level general biology I courses. After consent, 140 participants volunteered to complete the *Approaches to Learning Biology* (ALB) survey for Phase 1 of the research study. Participants ages ranged from 18 to 23 years. Within Phase 2, I used maximum variation sampling to select a sub-group (n =10) from the homogenous groups identified in Phase 1. This sampling technique revealed a diverse array of women of color that held different perspectives of the central phenomenon of approaches to learning biology (Creswell & Plano Clark, 2018). Criteria for selection included (1) completion of *ALB* survey from Phase I, (2) be a declared biology major, and (3) self-identify as a woman of color (e.g., Blacks or African Americans, Hispanics or Latinos, American Indian or Alaska Natives, or Asian).

Course Information

General biology I is the first of a two-part introductory biology sequence designed to introduce biological principles at the molecular and cellular scale to biology majors, minors, and other science-oriented students. Course pre-requisites include passing college algebra with a C or better or a Math ACT score of 19 or higher. This course can fulfill general education requirements for natural sciences; however, the course also fulfills requirements for biology majors. This course is paired with a weekly laboratory component.

Major course structures were held consistent by each instructor with minor variations in pedagogical strategies. Each course was comprised of four units including molecular biology, cell function, genetics, and evolution. All unit materials and topics closely align with the layout of the assigned course textbook. All courses included four unit examinations, use of in-class student response systems (e.g., clickers), provided supplemental resources (e.g., study guides, textbook reading assignments, and practice quizzes), and a comprehensive final examination. Each examination was comprised of multiple choice and short essay questions.

Data Collection

Phase 1- Instrument

All students enrolled in general biology I were given the opportunity to complete the *Approaches to Learning Biology* (ALB) scale (Chiou et al., 2012). Surveys were administered electronically directly after mid-term exams to provide specific context to survey questions. Both the principal investigator and course instructor introduced the research participation opportunity before student consent was obtained. Demographic and course specific data were collected with survey responses including participants' self-identified gender, ethnicity, course section, and instructor name. (See CHAPTER III, Table 3.1 for specific demographic data).

The ALB scale consists of four subscales and 26 total items that represent Biggs et al.'s (2001) deep and surface approaches to learning. Scale items are scored based on a 7-point Likert scale (1 = *strongly agree*, 4 = *neutral*, and 7 = *strongly disagree*). The items were reverse coded and converted to Rasch person measures ranging from 0-100 before conducting data analysis. The subscales were designed to capture both predispositions and process components of approaches to learning. Predispositions describe approaches students are likely to adopt given a certain context, whereas the process components refer to the actual approach students adopted within a certain context. The four subscales include two subscale that describe deep approaches to learning; Deep Motives and Deep Strategies and two subscales that describe surface approaches to learning; Surface Motives and Surface Strategies. (See CHAPTER III, Table 3.2 for definitions of each of the four subscales).

Phase 2- Semi-Structured Interviews

I conducted a series of two semi-structured interviews to elicit participants' studying experiences in the course and how those studying experiences are mediated through the intersection of their racial, ethnic, gender, and science identities. The first interview took place a week after students from each course section completed midterm examinations. Given the context-dependent nature of how students approach learning, it was imperative that participants have a recent study context to reflect on and reference when describing their approaches to learning biology.

All interview questions regarding how the participants approached learning biology referenced the common context of their midterm examination. The second interviews took place after the general biology I course concluded. The second interview served as a follow-up interview to elicit participants' reflections on how they approached learning introductory biology and factors they felt contributed to their academic decisions. Each interview lasted, on average, one hour. In addition, all interviews were audio-recorded with the permission of the participants and were subsequently transcribed verbatim. A detailed description of the interview protocol design is discussed below.

To understand factors that influenced how WOC approach learning introductory biology, the interview questions targeted six main topics over the span of two separate interviews. The topics included, (1) Conceptions of Studying, (2) Current Approaches to Learning, (3) Science Identity, (4) Cultural Identity, (5) Cultural and Social factors of WOC and (6) General Study factors of WOC. Questions on topics 1, 2, and 6 addressed components of the students' approaches to learning theory and were intended to elicit how participants conceptualized studying in general and how they approached learning in the context of their introductory biology class. Questions on topic 4 provided insight into the intersection of participants' cultural identities (e.g., gender, race, ethnicity), while questions on topic 5 extended these understandings to the context of the undergraduate biology community. Questions on topic 3 were specific to how participants recognized themselves as science people and how they perceived they were recognized by others as science people. Sample interview questions are provided in Table 4.1 as they correspond to each topic. Interview questions were originally structured around exploring the identities of race and gender. However, the research questions were constructed with the intent to leave space for multiple influencing identities to emerge.

In order to obtain item face validity, prior to conducting the research, the interview questions were piloted with four WOC. These WOC were studying biology, but they were not potential participants in this study. The pilot interviews were conducted to verify if the interview questions elicited experiences and perceptions as intended. Current interview questions reflect a revised version of the interview protocol.

Table 4. 1 Six Interview Discussion Topics and the Corresponding Interview Questions.

	Topic	Sample Questions
Interview #1	Conceptions of Studying	What does the term studying mean to you?
		What is the goal of studying?
		How did you learn how to study?
		Is there more than one way to study? If so, how do you know when to study a specific way?
	Current Approaches to Learning	Think back to this past exam in your BIOL 1110 course. Walk me through how you prepared for this exam.
		Did you use any course materials to aid in your studying process? If so, what did you use?
		Does how you actually studied for the exam match how you think you should have studied for the exam?
	Science Identity	Do you see yourself as a science person?
		What characteristics makes you a science person or not?
		Is being a science person an important reflection of who you are? Explain why or why not.
		Are you recognized by others as a science person? If so, who recognizes you as a science person?
		Do you value one person's perspective over another regarding recognizing you as a science person? If so, who and why?
		How does having more people with your cultural background make you feel more or less like a science person?
	Cultural Identities	Tell me more about your family and the role they played in your decision to become a biology major.
		Describe significant members of your family perceptions of people who major in biology/science. Do you agree or disagree with these perceptions?
		Did any of these significant people in your life ever give you studying advice? If so, what did they say?
		Do you ever feel pressure to study or learn a certain way from your family/friends? If so,

		explain how this influences how you study currently.
Interview #2	Cultural & Social Influencers	What is it like being a woman of color majoring in biology at this university?
		Are there instances in science class where you experience subtle forms of racism? Please elaborate.
		To what extent do you believe that your success or failure in your attempt to achieve a science degree represents all other __ science majors?
		To what extent do you believe that your prestige in your scientific major is solely related to your achievements in your major?
		As a woman of color, do you feel like others see you as a legitimate member of your biology major?
		What is the extent to which you feel you can relate to other students in your major?
	General Study Influencers	Did other students or faculty give you advice on how to study throughout the semester? What advice did they give you? Did you use this advice? Why or why not?
		What factors inside and outside of class do you think made the most impact of how you studied for BIOL 1110?

Data Analysis

A sequential mixed-method research design (SMMA) (Onwuegbuzie & Teddlie, 2003; Tashakkori & Teddlie, 1998) was used to structure the analysis of student responses. The SMMA was carried out in 4 stages, modified from the Onwuegbuzie and Teddlia (2003) seven stage mixed-method analysis framework. Stage 1 consisted of the quantitative data analysis of survey responses through data reduction and construction of data display. Results from Stage 1 were used to purposefully select participants for semi-structured interviews.

Stage 2 consisted of qualitative data analysis of interview responses through data reduction, analytic memoing, and construction of data displays. Both the data displays from Stage 1 and 2 were consolidated, compared, and integrated in Stage 3. Results from the Stage 3 analysis were used to select contrasting cases through maximum variation sampling. Stage 4 consisted of a comparative case study analysis by referencing the integrated data from Stage 3. Depicted in Figure 4.1 is a detailed overview of the four stages. Following is a detailed description of each of the 4 stages of the sequential mixed-method analysis.

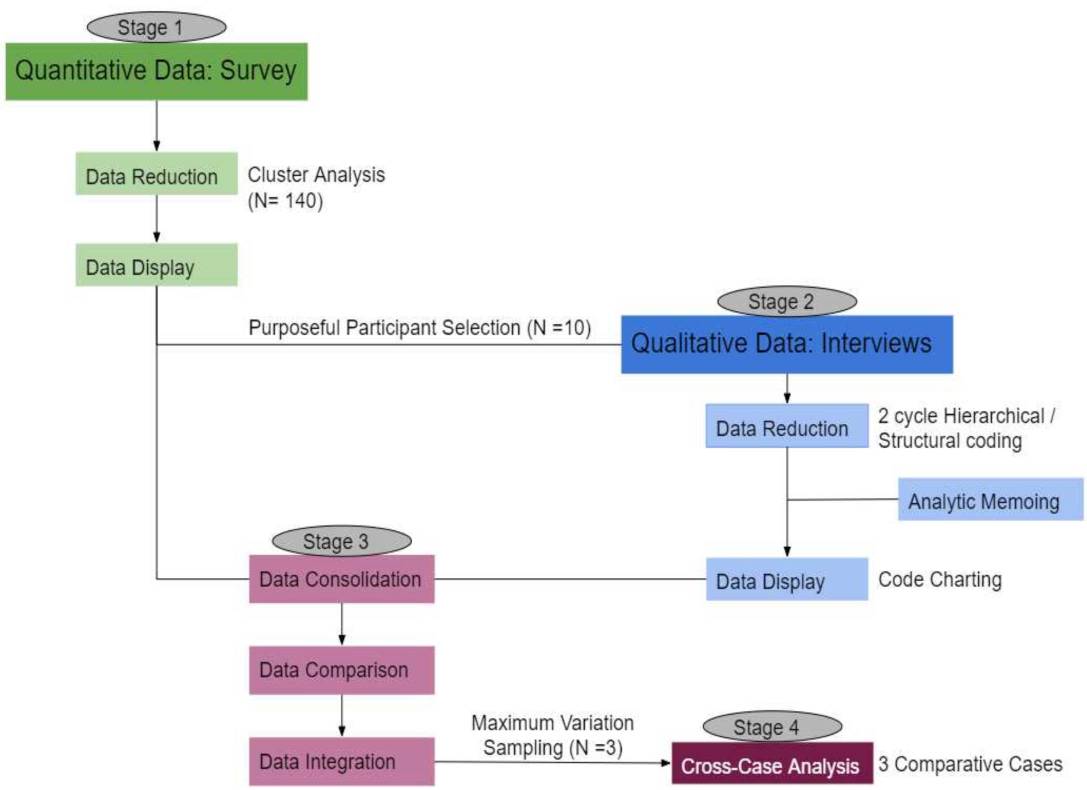

Figure 4. 1 Overview of Four-Stage Sequential Mixed-Method Analysis.

Stage I- Quantitative Data Analysis

The ALB scale is designed to distinguish the extent to which students agree with items associated with deep and/or surface level approaches to learning. The survey data were reduced by conducting a Two-Step cluster analysis. In this study, the Two-Step cluster analysis was used to identify homogenous groups of cases within the ALB scale results. These homogenous groups consisted of students who held similar levels of agreement toward each of survey item representing the four ALB sub-variables (e.g., Deep Motives, Deep Strategies, Surface Motives, Surface Strategies). Results from this analysis were used to answer research question 1 with regard to the emerged patterns of student demographic and course content variables. This analysis also supported the purposeful sampling of students holding contrasting approaches. Depicted in Table 4.2 are the demographic descriptions of each cluster including ethnicity and gender.

Table 4. 2 Demographic Descriptions of Ethnicity and Gender for Cluster 1 and Cluster 2

	Cluster 1 (N = 67)		**Cluster 2 (N = 73)**	
	Male	Female	Male	Female
General	16	51	21	52
African- American	1	8	3	13
Asian	1	2	1	4
Caucasian	8	26	12	26
Hispanic/ Latino	2	4	1	3
Middle Eastern	2	4	2	3
2 or more/ Other	2	6	2	3

Stage 2- Qualitative Data Analysis

The second stage involved a thematic analysis of participants' interview responses, that incorporated both inductive and deductive reasoning. The goal of this analytic method was to understand how purposefully selected women of color experienced the phenomenon of studying introductory biology and how their mutually constructed identities shaped their experiences. In keeping with phenomenological analysis, I first attempted to suspend preconceptions to minimize bias towards the phenomenon (e.g., *epoche*) by bringing awareness to personal perspectives and assumptions regarding the investigated phenomenon (Patton, 2015).

Each transcript was divided into four focal areas consistent with the interview protocol and research questions. The four areas of focus were, (a) Conceptualizations of Studying, (b) Approaches to Learning Biology, (c) Science Identities, and (d) Cultural Identities. Next, the content within each focal area was sorted and organized through the process of phenomenological reduction (Onwuegbuzie & Teddlie, 2003; Patton, 2015).

The data reduction process was carried out through a series of two-cycled structural and hierarchical coding schemes. Within the first cycle, the responses from each participant regarding a specific focal area were extracted and compiled. Preliminary codes were established based on similar responses. Preliminary codes and descriptions were reassigned to each participant in a narrative format. Each narrative was sent to the respective participant to confirm accuracy through member's checking.

Within the second cycle, comments from the participants' check were combined with the preliminary codes and collapsed to form more salient categories. Codes were then organized in a hierarchical structure allowing for different levels of granularity within the coding scheme (Saldana, 2016). One main code may also include multiple embedded sub-codes that provided a more detailed account of the phenomenon. Throughout each cycle of coding, the researcher's ideas were recorded and developed through analytic memoing. Lastly, the hierarchical data was visually displayed in tables through the act of code charting (Saldana, 2016). Each chart included all main codes and sub-codes for a specific focal area and were summarized in preparation for comparative analysis.

Stage 3- Mixed-Method Data Integration

Within Stage 3, summarized data displays from Stage 1 and Stage 2 were consolidated, compared, and integrated to reveal thematic patterns across all selected participants. Learning outcome data were added to ALB scale results and the qualitative comparative analysis to determine relationships between how the participants experienced the phenomenon and their academic achievement. Learning outcome data consisted of the participants' scores on 4 unit examinations, one comprehensive final examination, and their final course grade. Integrated results were used to select participants for the comparative case study analysis (Stage 4) through maximum variation sampling (Creswell & Plano Clark, 2018).

Stage 4- Comparative Case Analysis

Following data integration, contrasting cases were identified in accordance with case study sampling approaches used by other scholars studying complex phenomena among underrepresented populations (McGee & Bently, 2017; Yin, 1998). Each case was carefully examined to determine first how they experienced the phenomenon of studying introductory biology and second how their science and multiple other identities shaped this experience. A combined framework of science identity (Carlone & Johnson, 2007), and an intersectionality analysis (Collins & Bilge, 2016) was used as an analytical framework. To do so, a combination of inductive and deductive open coding techniques was used through a line-by-line analysis (Straus & Corbin, 1990). More narrowly, the science identity framework provided the structure to explore the role of recognition on science identity development. Codes for recognition were modified from codes previously established for examining physics identity recognition (Avraamidou, in press). Codes related to recognition included: (a) sources of recognition (e.g., father, mother, grandparents, siblings, social community); (b) type of recognition (e.g., explicit, implicit); (c) time/place where it occurred (e.g., high school in Dubai); and (d) impact of recognition on both science identity development and approaches to learning biology (e.g., resources or barriers).

The theory of intersectionality was used as an analytic lens to examine the intersections and negotiations of multiple identities the participants held throughout their science education journey and which served either as a bridge or barrier to their recognition (Avraamidou, 2020). This lens was also used to examine the role these multiple identities played in how the participants currently studied and how they developed their current approaches to learning. Examples of such codes included: (a) gender, race, science identity; (b) gender, social class, and science identity; (c) race, social class, science teacher identity; (d) gender, social class, and religious identity. Results from this comparative case analysis were written highlighting critical instances that showcase the experiences of each WOC.

Trustworthiness

In attempts to establish trustworthiness and to minimize subjectivity, I used the criteria prescribed by Lincoln and Guba (1986): credibility, transferability, dependability, and confirmability. To establish credibility, I used triangulation strategies through (a) a collection of multiple sources of data used for the same purpose (i.e., ALB scale, different interviews, student artifacts), (b) thick- rich descriptions of findings, and (c) members check by participants. To address transferability, informal course observations in addition to direct participant descriptions were used to provide detailed contextual information for readers to make appropriate transfer. Issues of dependability were addressed through in-depth descriptions of the research design, data collection, and data analysis. Lastly, in an attempt to achieve confirmability, I consulted external peer researchers to review interpretations of the data.

Findings/Results

Q1: How do undergraduate students approach learning biology in the context of introductory biology?

The two-step cluster analysis revealed two distinct clusters in which common ALB sub-variable scores were grouped. Each cluster consisted of mean values for each sub-variable of the ALB scale. Results, depicted in Table 4.3, indicated that participants within Cluster 1 tend to agree more with deep approaches to learning biology and participants within Cluster 2 tend to agree more with surface approaches to learning biology.

Table 4. 3 Results from two-step cluster analysis including sub-variable means for each cluster.

Cluster	Sub- Variable Means			
	Deep Strategy	Deep Motives	Surface Strategy	Surface Motives
1 (N= 67)	67.65	58.69	46.76	63.14
2 (N= 73)	52.31	49.51	53.98	70.87

As reported elsewhere (CHAPTER III), a chi-square test of homogeneity was performed to determine whether the frequency counts were distributed equally across each cluster for gender (male, female, & other), ethnicity (African American, Asian, Caucasian, Hispanic/Latino, Middle Eastern, Mixed, & Other), and course section (Sections 1-6). Results indicated no significant differences between Cluster 1 and Cluster 2, with regard to gender, (x^2 = 1.46, df = 2, n = 140, p = 0.48), ethnicity, (x^2 = 4.68, df = 6, n = 140, p = 0.59), or course section, (x^2 = 1.12, df = 5, n = 140, p = 0.95). This indicates that the likelihood of a student being grouped into Cluster 1 or Cluster 2 is not significantly related to their gender, ethnic backgrounds, or the section of introductory biology in which they were enrolled.

A total of 10 WOC, five from each cluster, were purposefully selected and invited to participate in semi-structured interviews. Diversity in ethnic background and approaches to learning were considered during the selection process. Depicted in Table 4.4 are student demographics including self-identified ethnicities, academic classification, academic major, and the number of university level science courses completed for the sample. To better understand how each of the 10 participants situate within the two resulting clusters, overlapping histograms are presented in Figure 4.2 showcasing each participants' ALB scale scores.

Table 4. 4 Demographic Variables for Selected 10 Women of Color

Pseudonym	***Ethnicity***	***Classification***	***Major***	***Prior College Science Courses***
Kiara	African American	Junior	Exercise Science	2
Destiny	African American	Sophomore	Forensic Science	1
Jasmine	African American	Freshmen	Forensic Science	0
Aniyah	African American	Freshmen	General Biology	Dual Enrollment
Helen	Asian	Freshman	Biology	0
Lucy	Asian American	Junior	Computer Science	1
Sofia	Mexican	Freshmen	Animal Science	0
Isabella	Hispanic	Freshmen	Computer Science	0
Adriana	Latina	Transfer	Biology	1 semester
Ashaki	Middle Eastern	Freshmen	Biochemistry	0

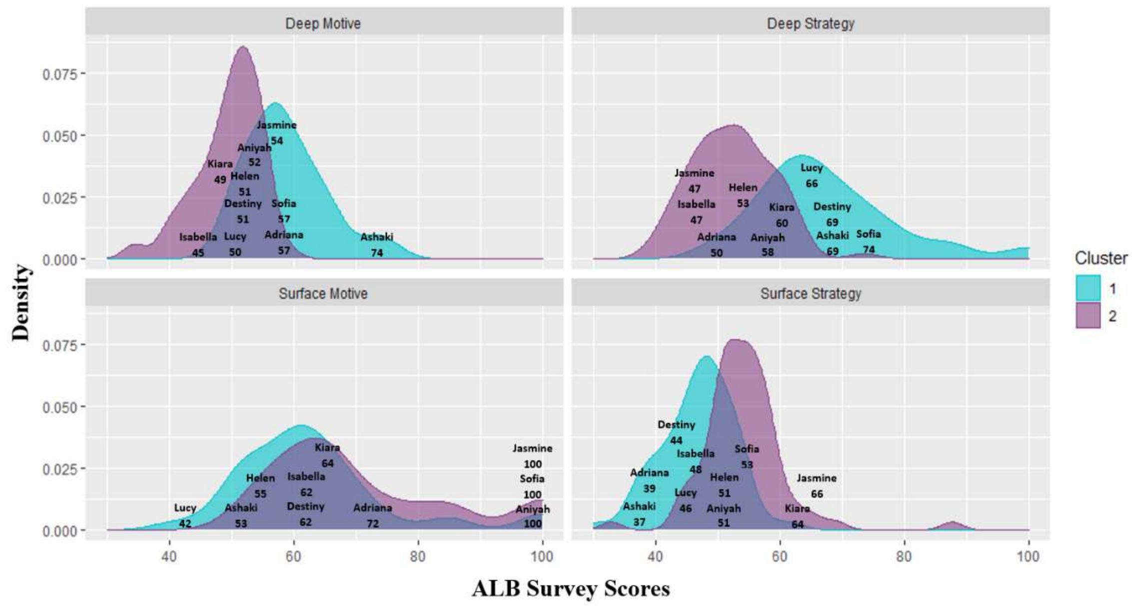

Figure 4. 2 Overlapping Density Plots for Cluster 1 and 2 Including Selected 10 Women of Color ALB Scale Scores

Q2: How do women of color experience the phenomenon of studying introductory biology as it relates to their conceptualizations of studying, approaches to learning biology, and their learning outcomes?

The Phenomenon

In alignment with the phenomenological methodology, I examined interview responses from the perspective of understanding how each WOC experienced the phenomenon of studying undergraduate biology and how their mutually constructed identities impacted their experiences. The original components of this phenomenon included how the participants conceptualized studying and how they approached studying in the context of their introductory biology course, in alignment with the interview protocol.

After initial analysis of the interview responses, the construct of metacognitive regulation emerged as a critical component that related to not only how each WOC approached learning but their learning outcomes as well. For this reason, the phenomenon described within the findings below includes the three components of Conceptions of Studying, Approaches to Learning, and Metacognitive Regulation. Due to the recent addition of this component, a brief explanation the construct of metacognitive regulation and how it is used in this study as an analytic lens is provided below.

Metacognitive regulation is how learners regulate their thinking for the purpose of learning, and it involves the skills of planning, monitoring, and evaluating learning goals (Stanton et al., 2019). Strong metacognitive skills are associated with positive impacts on learning and achievement (Stanton et al., 2019). Based on the continuum for introductory biology students' metacognitive regulation proposed by Stanton et al. (2015), participants were categorized according to how they reflected on the effectiveness of their current study strategies and their willingness to make necessary adjustments to these strategies following feedback.

Findings revealed that introductory biology students identified with one of the four proposed categories; (1) Not Engaging- Students are unwilling to reflect and adjust approaches to learning, (2) Struggling- Students are willing to reflect and adjust, but do not know what to, (3) Emerging- Students know what to do to adjust their studying, but may not follow through, and (4) Developing- Students follow through with study adjustments in order to enhance learning. These four categories were used to categorize the metacognitive regulatory behaviors described by each WOC.

Overview of Results

To address how each WOC experienced the phenomenon of studying introductory biology, each construct (i.e., Conceptions of Studying and Approaches to Learning) was isolated, thematized, and condensed into a hierarchical coding chart. Below is a detailed explanation of each of the resulting codes and the corresponding coding chart.

Conceptions of Studying

Participants' conceptions of studying were comprised of their definitions, goals, and motivations of studying. The four *a priori* themes for how biology students defined studying that were first developed from Johnson and Gallagher (2019) were used for the initial coding process (i.e., (1) Studying as a process, (2) Studying as a use of time, (3) Studying as an action leading to an extrinsic act [e.g., taking a test], and (4) Studying as an action leading to an intrinsic act [e.g., memorization or understanding disciplinary content]). These a priori themes were condensed and modified to better represent the essence of the participants' responses, resulting in three main themes, Process, Product, and Context, which will be further elaborated below.

Participants who conceptualized studying as a process specifically described the actions involved in their studying. Participants discussed what they were doing when they are studying whether it be *reviewing personal notes*, *testing themselves*, or *making connections* with the course material. For example, Isabella's response was *"I guess just going over notes and just really understanding it and being able to maybe explain it to somebody".* Isabella's response reflected studying as the process of *reviewing personal notes*.

Isabella's response also reflected a pattern that I noticed with many participants in that she reflected elements of both Process and Product. This dual conceptualization is also evident in the previous quote when Isabella refers to her desired outcome of 'understanding' the material (a Product). Participants who conceptualized studying based on their desired intrinsic or extrinsic outcome were coded within the Product category. Another example is Destiny's response *"I guess I would define studying is like memorizing and I guess, I guess just memorization".* Destiny's response was coded as a Product with the intrinsic outcome of memorization.

Lastly, some participants indicated that their conceptualizations of studying were contextually bound by describing the study environment they felt was required for successful study practice. These comments were coded as Context. For example, Lucy's response was "*I think it's anything that's not directly assigned to be turned in"* which described studying as something other than graded work. Lucy's description places parameters around what comprises as studying, in which it must be in the context of a non-assignment. In another example, Ashaki emphasized the importance of being alone while she studied in her definition; *"I think that studying basically means that you locking yourself [in a room], being isolated and just focusing on a book and that's it focusing on something that you just need to understand and explain".* It is also important to note that several participants stated that they would study differently for a different discipline, meaning that their definitions of studying were discipline-specific. These responses were also coded with the category of Context. All three main codes, corresponding sub-codes, and examples are depicted in Table 4.5.

Table 4. 5 The Hierarchical Coding Chart for Conception of Studying Introductory Biology.

Conceptualization of Studying	**Process** of Studying	Organization	Space
			Time
		Reading Prepared Text	e.g., PPT slides, textbook
		Reviewing Personal Notes	e.g., handwritten, typed
		Explaining Concept to self	
		Testing Self	e.g., quizzing, flashcards
		Assimilation of Knowledge	
		Making Connections	e.g., analyzes
	Product of Studying	Extrinsic	Immediate (e.g., good test/course grades)
			Future (e.g., Better oneself, career goals)
		Intrinsic	Memorization
			Understand
			Learn
			Knowledge gain
		Evidence of Intrinsic Outcome	Application -Near- transfer (e.g., current course) -Far-Transfer (e.g., real life)
			Explanation to others
	Context of Studying	Discipline-dependent	e.g., strategy/definition changes with subject.
		Outside of class work	e.g., not an assignment
		Individual	e.g., must study in isolation
		Group	e.g., must study in groups

Approaches to Learning

In alignment with the approaches to learning theory, participants' approaches to learning biology were categorized based on strategies and motives. Each strategy and motive was further broken down into contrasting categories of deep and surface. Participants were asked to describe exactly how they studied for their Introductory Biology midterm exam and what motivated them while they studied. Results for the motive component were consolidated within the Conceptions of Studying table, however examples of both strategies and motive responses will be provided below.

Participant's strategies were themed as *Self-Generated* strategies (e.g., note-taking, self-quizzing, etc.) or strategies using *Provided Resources* (e.g., PowerPoint slides, textbook, study guides). These strategies were categorized as deep-level or surface-level based on how the participant engaged in each activity. For example, Adrianna was coded as utilizing deep strategies because she reorganized her personal notes and provided resources into a one-page study guide for each exam that she then used to quiz herself.

> **Adrianna**: *" by the end I always make a sheet like… that like… test three see… [showing an example to the Interviewer] so I put everything down that like from each uh … yeah each like concept chapter or whatever just and I barely look at the notebook. I just like put it down to see if I remember and then that's like a cheat sheet that you know and I'm not…. of course, I'm not gonna use [it for] the test but like it's for me to remember like everything broken down….this is how I organize myself."*

Some participants described both deep and surface-level engagement, which was categorized as a mixed approach. For example, Sofia described both reorganizing her personal notes in correlation to the provided PowerPoint slides as well as just 'looking over' her notes. Sofia also mentions drawing pictures and conducting independent research to gain a better understanding of the topic.

> **Sofia:** *"Well our professor ….he'll [post] like the PowerPoints so I usually go back on the PowerPoints and like look over stuff and also take notes so it's easy to like look at my notes and then look at whatever slide he was talking about and be able to understand it and if I don't then I just go on and research more about it. Sometimes [I] write down pictures or [I] draw some like sketches or sometimes [I] just write down like he asks us questions and [I] write down the answer".*

In addition, participants noted *Online Resources* that they used while studying (e.g., Khan Academy, Quizlet, Google Search). These online resources were not categorized by deep or surface level engagement codes, because it was difficult to determine how participants used these resources based on interview responses. For this reason, it was only documented if these resources were used or not. Participants often spoke about studying in regard to how they organized their space and time, as well as what prompted them to start/finish studying. These categorizes were coded as *Organization* and *Study Cues*, respectively. Each main code, sub-code and corresponding examples for strategies used to learn introductory biology are depicted in Table 4.6.

In addition to strategies, each participant was asked what motivated them while they studied. Responses were categorized as reflecting deep, surface, or mixed motives based on their drive to accomplish immediate extrinsic goals (e.g., passing the exam, getting good grades), desire to understand course material to better themselves in the future, or some blend of the two. For example, Kiara showed surface motives for studying while primarily focusing on obtaining certain grades in class. These grades were ultimately connected to her financial obligations to maintain her academic scholarship.

> **Kiara:** *"um this is a very tricky question. I wouldn't say I had like a motivation but it's like when I see like… when grades… when certain grades start coming in and I started seeing those grades [that's] what actually motivates me to like keep going. Like you need to study…. like you have to study…. so like ….also I just I know while I'm here I know why I'm here so it's not just to chill, relax, and have fun. It's also to get your grades and to keep on studying. And you know you had to have these scholarships, so I keep on pushing.*

Isabella on the other hand, expressed mixed motives for studying biology because she not only wants to do well in the class, but also to understand the material well enough to be informative for future endeavors.

> ***Isabella:*** *"I think it's to have actually learned from what I'm reading so not only to do good on my test but also like just have that information even though I might not use it because I'm a computer science major and I won't ever like need to know how DNA replicates. I at least… if somebody's talking about it I'm not completely uninformed about it and just kind of knowing what kind of what other people are talking about 'oh yeah I studied that back when I was in college' just something that I can come back to in my head and be like oh actually understood that and maybe I will have to know something like that down the road so it because science and computers you know…. doctors use computers. Computers are everywhere basically so I kind of maybe down the road I'll have to know something about how DNA works so I just kind of have to want to have a basic understanding of just basic things.*

Table 4. 6 The Hierarchical Coding Chart for the Strategy Component of Approaches to Learning Biology.

Strategies	Self-Generated Strategies	Note-Taking	**Deep-Level**	**Surface-Level**
			Correlate notes w/ provided resource	Highlight notes
			Create new reorganized notes- typed, cheat sheet, whiteboard	Read over notes
				Rewrite notes
		Quiz- Self	Answer questions in own words	Memorize Flashcards
		Explain to others	Teach content to others	
		Recorded Lectures	Listens to recorded lectures	
		Verbal Communication	Explains concepts out loud to self	
	Provided Resources	Study Guide, PowerPoint Slides, Textbook	Match content w/ personal notes	Reread
			Answer questions using other resources	Highlight
				Summarize
	Online Resources	Khan Academy, Independent Research, and/or Quizlet		
	Organization	Time (Frequency)	**Total Study Time before Exam**	**Duration of Study Event**
			Prior to lesson	< 1 hour
			≤ 1 day	1 hour
			1-6 days	> 1 hour
			≥ 1 week	
	Study Cues	**Start Studying**	**Done Studying**	
		Same as Frequency	Evidence of Intrinsic Outcome- I understand b/c I can now …	Time limit- I am done when time to take exam

Overarching Themes

Depicted in Figure 4.3 are the consolidated survey and interview results aligned with Stage 3 of the Sequential Mixed Methods analysis. Consolidated results consist of each participants' cluster assignment, Conceptions of Studying main code, ALB scale and interview results, as well as their learning outcomes for the midterm exam and final course grade.

Results present an overall alignment of ALB scale scores with ALB interview responses with the exception of three participants. Adriana's ALB scale results demonstrate cluster scores below the mean for the sub-variable Deep Strategy (Cluster 1 M = 67.65, Adriana's DS score = 49.99), and Deep Motive (Cluster 1 M = 58.69, Adriana's DM score = 57.04), and above the mean for Surface Motives (Cluster 1 M = 63.14, Adriana's SM score = 71.59). Adriana described using deep strategies and holding deep motive during her interview. Adriana described during her interview recently transitioning from surface approaches to learning to deep approaching to learning when she moved from Brazil to attend school in the U.S. As her motivations for success shifted so did her approaches to learning. However, this does not adequately explain why her survey responses did not align with her interview responses. The other two participants only had misalignment with two or fewer sub-variables: Kiara (Deep Strategy) and Destiny (Deep Strategy and Surface Strategy). With 7 out of the 10 participants' ALB scale results mirroring their interview responses, this speaks to the validity of the ALB instrument.

Consolidated results revealed two main trends across all 10 participants: (1) A strong relationship between participants' approaches to learning, metacognitive regulation, and learning outcomes, and (2) consistent conceptualization of studying as a Product, with sub-code variation aligned with participants' approaches to learning.

Strong relationships between approaches to learning, metacognitive regulation, and learning outcomes.

Participants that primarily utilized deep approaches and demonstrated follow through in developing metacognitive regulation had higher exam scores. Likewise, those participants that primarily utilized surface approaches and struggled to identify appropriate strategies had lower exam scores. Ashaki, Lucy, and Helen primarily utilized deep strategies and held mixed motives. They all expressed that their study strategies were effective and planned to continue to use them. Adriana also described her study effectiveness in a similar fashion, yet held deep strategies and deep motives to learning biology. All students with metacognitive regulations categorized as Developing, earned an "A" for their final course grade. In contrast, Kiara, Jasmine, and Destiny all described using surface level approaches, admitted that they knew their study strategies were not effective, but they did not know of more effective strategies to implement. All of these students struggled to regulate their approaches to learning and ended the semester with lower learning outcomes. The participants who held both mixed strategies and motives, Isabella, Aniyah, and Sofia, and knew of effective strategies but failed to follow through with implementation, yielded average grades.

Conceptualizing Studying as a Product

Consolidated results also showed that all 10 participants conceptualized studying according their desired outcomes or as a Product. However, it is important to note that there are descriptions within the product category that align with deep and surface level approaches to learning. For example, Adriana described studying as "*learning concepts like trying to understand concepts that you need to know for your profession or for your life*" which refers to understanding concepts for future goals. Whereas Destiny's response was "*I guess I would define studying is like memorizing and I guess I guess just memorization*". Both participants described products of studying, but on different processing levels. Patterns emerged within this variation with regard to how students approached learning. Participants who held deep approaches to learning defined studying according to the intrinsic outcome of understanding, whereas participants who held surface level approaches to learning described intrinsic outcomes of memorizing.

Table 4. 7: Consolidated ALB Scale and Interview Results for Selected 10 Women of Color

Participant Pseudonym	Cluster	Conceptualization of Studying			ALB Scale Results				ALB Interview Results		Metacognitive Regulation	Midterm Exam Grade	Final Course Grade
		Process	Product	Context	Deep Strategy	Surface Strategy	Deep Motives	Surface Motives	ALB: Strategies	ALB: Motives			
Ashaki	1				69.39	36.93	73.64	52.49	Deep	Mixed	Developing	A	A
Lucy	1				65.89	46.21	49.78	41.69	Deep	Mixed	Developing	A	A
Helen	2				53.36	50.83	51.42	55.14	Deep	Mixed	Developing	A	A
Adriana	1				49.99	38.63	57.04	71.59	Deep	Deep	Developing	B	A
Isabella	2				47.24	48.16	45.05	62.1	Mixed	Mixed	Emerging	C	B
Aniyah	2				57.58	50.83	52.27	100	Mixed	Mixed	Emerging	D	C
Sofia	1				73.53	53.39	57.04	100	Mixed	Mixed	Struggling	D	C
Kiara	2				60.06	64.36	48.99	63.77	Surface	Surface	Struggling	F	D
Jasmine	2				47.24	65.78	54.06	100	Surface	Surface	Struggling	D	F
Destiny	1				69.39	44.04	50.6	62.1	Surface	Surface	Struggling	F	F

Q3: How do the intersecting identities of science, race/ethnicity, and gender of women of color shape how they experience the phenomenon of studying introductory biology?

After comparing all 10 participants to determine how they experienced the phenomenon of studying undergraduate biology, this study examined how the multiple identities of three of these WOC impacted their study behaviors. Ashaki, Aniyah, and Jasmine were selected for a comparative case analysis based on four criteria; (a) they all identified as WOC in their interviews, (b) they were all freshmen, (c) they were all majoring in biology or a related science, (d) they displayed contrasting approaches to learning biology, metacognitive regulations, and learning outcomes.

Although the original intention of this study was to purposefully select 10 WOC from the participant pool for deeper qualitative analysis, interview responses revealed that not all selected participants identified as WOC. Participants were selected based on their responses to demographic survey questions such as to their self-identified gender identity (i.e., male, female, other) and ethnic identity (i.e., African American, Asian, Caucasian, Hispanic/Latino, Middle Eastern, Other). Participants who selected female and any non-Caucasian ethnicity were invited to participate in an interview. However, during the interview when asked “Do you identify as a woman of color?”, only 5 out of the 10 participants said yes (Destiny-African American, Jasmine-African American, Aniyah-African American/mixed, Sofia-Hispanic, and Ashaki-Middle Eastern). Interestingly, those participants who did not identify as a WOC, defined this label according to skin color and those who did identify as WOC described experiences that shaped their identity as a WOC. This finding revealed an implication for how socio-cultural researchers’ categorization of cultural identities may be unintentionally misaligned with that of the participants in the absence of personal interviews. Therefore, Ashaki, Aniyah, and Jasmine presented as interesting comparative cases based on their unique experiences as WOC beginning their post-secondary science education journeys.

Each case is organized according to first a brief description of their background, followed by how each participant experienced the phenomenon organized in a table, next their perceived science identities, and lastly critical instances that overlap their science identity and/or other multiple identities and their current study approaches. After each of the three cases are examined in-depth individually, a comparative analysis and discussion of common findings are presented.

Ashaki

Background: Ashaki identifies as a Middle Eastern, Muslim woman who shares dual citizenship in Dubai and America. Her citizenship is shared due to her mother being from Dubai and her father from America. Her parents currently reside in Dubai, while she and her two sisters attend college in America. Ashaki grew up in Dubai and traveled to America for her final years of high school in pursuit of a more rigorous college education. Ashaki's parents believed that Dubai provided a more challenging high school curriculum and America provided a more challenging college education, therefore each child moved to America to transition to college. Ashaki studied both English and Arabic from early childhood in preparation for this transition. Back in Dubai, her mother works as a high school biology teacher and her father is a chemical engineer. Ashaki aspires to be a doctor (neurologist) and is currently majoring in Biochemistry.

Table 4. 8 Ashaki and the Phenomenon

[Conceptions of Studying, Approaches to Learning Biology, and Metacognitive Regulations]

Construct	**Thematic Code**	**Sample Excerpts**
Conceptions of Studying	**Context-** Individual **Product**- Intrinsic-Understand **Process-** Explaining concept to self **Product**- Extrinsic -Immediate & Future	"*I think the studying basically means that you are …being isolated and just focusing on a book and that it is focusing on something that you just need to understand and explain …you need to explore that book you need to be alone…teach it to yourself "* *"I think seeing an A in my grade is like maybe… makes me happy you know"* *"I need to do good right now so that I can have a successful future."*
Approaches to Learning Biology	Deep Strategies	*"I study basically on the whiteboard. I explain it to myself. I think that you being your own teacher is the best thing. So, I talked to myself out loud also whenever you have friends that don't understand you can explain it to them so the more you explain it to your friend the more you sort of like remember it better to you and also when you say out loud you're sort of like speaking to yourself and so like although it might sound creepy you know but saying it out loud would actually make you memorize it because you're listening to it and you're speaking it at the same time …..like using them both which will allow you to basically, you know understand biology better."*
Meta-cognitive Regulation	**Developing-** Students follow through with study adjustments in order to enhance learning	*"I kept on working hard trying many different methods and the best thing that actually worked for me was a whiteboard"*

Perceived Science Identity- Ashaki identifies as a science person and as a scientist. Her current science identity is based on her high interests in science and her perceived competence in science. Ashaki grew up liking science and is fascinating by things like plants and the human body. She defined a science person based on how much individuals studied and worked hard to understand the material. She also mentioned that a science person has a certain discourse of hard words that make sense when explained to others. When asked did she see herself as a scientist, she replied,

> ***Ashaki:*** *"yeah I mean why can't I…you know. I see myself as a scientist. Like I'm telling stuff to other people that they don't know about. I might not like… got that information or I invented it, but I'm teaching it to other people too. Like I told my friends, whenever they don't understand it, I go and teach it to them or stuff like that. I find that also you can be a scientist you know anyone basically just knowing everything… when one person doesn't know nothing and you're telling them about that I think you can be a scientist."*

Ashaki identified as a scientist based on her role in explaining scientific knowledge to others that do not know that same knowledge. This relates to how she approaches learning biology, in that her primary study strategy involved explaining content to others. From Ashaki's descriptions, science is understood socially. Ashaki both learns science and displays her scientific knowledge through explanation, to herself and others. Although Ashaki perceived herself as a scientist, when asked did others perceive her as a scientist she stated, "*when [I] become a doctor I think [I'll] be recognized by them"*. She believed that she needed to achieve a certain title to be recognized by her family and close friends as a scientist.

Ashaki: Gender, Social Class, Family, Religion, Science Identity- Following are five instances that reflect the development of Ashaki's science identity through implicit or explicit recognition. These instances also reflect how Ashaki's science identity and other multiple identities shaped how she approached learning biology.

Instance #1

"…My mom is really smart"

Ashaki: "*My mom is also a teacher. She's a biology teacher and so that's why she also made me become interested in biology because she's a biology teacher and I always used to [see her] tutor her two students out of class and they used to come to our house while she's tutoring them and I used to see that… I sort of wanted to become a teacher too you know*…*when I was young she was my teacher for everything …My mom is really smart, so she knows like biology, chemistry, math, physics…. all of that. She actually wanted to become a doctor but she couldn't because her family was poor basically and they had eight kids and she was the head of the household so she had to do something at that time. It was expensive to become a doctor so she couldn't so she went and become a teacher to give her money for her siblings and everything….I always understood from her….she's the one who I believe introduced me to a whiteboard because she always used to take me to school with her when I was a little kid and so like I used to play on the white board."*

Throughout her interview, Ashaki consistently emphasized the positive impact her family had on her biology education pursuits, especially her mother. Ashaki credits her strong affinity towards and high competence in biology to her mother's profession as a high school biology teacher. This excerpt showcased an instance of implicit recognition by her mother demonstrating an effective way of learning biology through tutoring other students on the whiteboard. Ashaki's mother taught her and others by explaining biological concepts on the whiteboard, and Ashaki later emulated this study strategy. This was also an example of implicit recognition in that Ashaki's Mother recognized that she was capable of learning biology which over time increased her actual and perceived competence. This instance added to how Ashaki perceived her science identity.

This excerpt also highlights a part of Ashaki's social class identity. In Ashaki's eyes, her Mother was smart enough to become a doctor. However, her Mother grew up in a family that could not afford for her to go to medical school and her Mother had to obtain a teaching job to provide income for her family. This element of social class is echoed throughout Ashaki's interview by her parents pouring into her that education is a vehicle to achieve a higher social status. Ashaki mentioned numerous times that in her words, "*my studying impacts… the way I'm gonna become successful basically so I want to become a doctor because I want to help people out ….but I want to help people out and at the same time like get paid you know".* Ashaki held the idea that if she studies hard enough she will be successful in life.

Instance #2

"*... I used to be stupid at physics*"

Ashaki: *"As [I] grew up …..people would start to downgrade [me] for [my] grades... I used to be stupid at physics …. I used to be the only one in class who used to get a zero or like a really bad grade of [the]whole class… but people kept on pushing me. They kept laughing at me, that pushed me to do better because I knew myself; that I was better than that. I felt like people's negative comments saying that just because my mom is like a biology teacher and I'm just only good at biology because maybe like… she helped me to cheat my way through and then I'm just like no she never did. Like I had passion for biology because of my mom is biology teacher…..I believe if you tell yourself I'm stupid ….you will never succeed because you're telling your brain …'I'm stupid', so don't study but if you tell yourself 'I'm not stupid', 'I can do this', then you can do it. Because I believe that anything is possible, that impossible is possible. So, if you work hard then you can study and that's how I did. I kept on working hard trying many different methods and the best thing that actually worked for me was a whiteboard."*

Ashaki recalled explicit instances where she was recognized for low competence in physics, compared to a high competence in biology. Ashaki used this negativity to fuel her persistence in searching for a more effective way of learning physics. She credited her natural high competence in the subject of biology to her '*passion*' for the subject and because her mother was a biology teacher, suggesting that she was more motivated to learn biology. This instance also spoke to core principles that shaped how Ashaki perceived her science identity, and competence. Asahki took a lot of rigorous science courses in Dubai, where she said she attended a Cambridge School with a British curriculum. As displayed in this instance and others she mentioned, grades were seen as a currency for competence and success in science. High grades meant that you were competent in science. Ashaki worked hard now in college to get an "A" in her biology class because it related to high competence in science and ultimately a successful life. In addition, when asked where did she get this notion that "anything is possible" she referenced her relationship with God and strong belief that if she works hard enough she can achieve anything. This reflected internal representations of her religious identity.

Instance #3

"I used to be the only one …wearing the hijab"

Ashaki: "*I think when basically I go to my lectures, when I go to my classes, I'm the only one who wears a hijab. So I sort of like… I'm like 'wow it's really different'. It was the same thing in high school. I used to be also you know how in high school they usually gather like in the gym for like competitions on music and dance and stuff… like that so like I used to be the… only one from all my high school group who wore the hijab. Although there were other Muslims, they didn't wear the hijab…but when I go to college, here, it's just like basically some lectures that I'm the only one. I find in campus many people are also wear the hijab, like not only me."*

This excerpt highlighted the impact external representation of Ashaki's faith had on her perceptions of being the 'only one' in her whole high school and some college lectures wearing the hijab. Ashaki was that only student in her introductory biology class who wore a hijab. Ashaki recognized that these experiences of isolation were really different compared to growing up in Dubai. However, she felt that college was more diverse and accepting of her differences. Ashaki mentioned during her interview that as long as she was not harmed than she was ok with being different in college. This instance spoke to how Ashaki's religious identity coincided with biology education experiences, and how she negotiated this isolation by recognizing and being proud of her differences.

Instance #4

"I want more women to do that… it would make me proud of who I am"

Ashaki: *"it sort of like upsets me you know because it's usually like you always see men as doctors or you always see basically Americans who are doctors. You never see basically like people who are Muslims are also like in* [local University] *for example. But like nowadays you see that and when I saw that people who [are like] us on TED talk for example…. there was like one Muslim, a woman, who actually went and did that and I actually want also like more women to do that ….because you see men, Muslim men a lot doing that but I also want woman also to do that and I think that would basically make me proud of who I am you know. That also not only men can just do that, women can also do that so I believe that woman can also do anything too."*

Not only was Ashaki aware of the underrepresentation of Muslim women in her undergraduate science experience, but she also mentioned that she would like to see more Muslim women represented in the professional science arena more broadly. Despite coming from a family that encouraged the high achievement of women in STEM, Ashaki felt that seeing more Muslim women in science would make her feel proud of who she was and what she is capable of accomplishing. This instance highlighted the implicit recognition by others that she too could be a Muslim woman studying science. This instance also showed how Ashaki's gender and religious identity intersected, in her desire for more representation of Muslim women in the STEM field.

Instance #5

"…he offered me to do research…"

Ashaki: *"He's always like a good professor and he always makes things interesting and he offered me to do research so that's where I was like 'you know what let's try it'. ….He even told us that he wants to train us and you know he's told us that he wants students who have passion you know, we'll keep on with him forever yeah. So that's what I was just like you know what it's gonna be fun like these things. I've been doing it and it's actually fun you know. We do stuff that are fun and weird and we look under the microscope but it's like a different microscope, like you can see the bacteria clearly."*

During her follow-up interview, Ashaki mentioned that she got offered an opportunity to work in her introductory biology professor's research lab. She was not clear as to why he chose her, however she expressed that he wanted someone who was passionate and dedicated to working with him for multiple years. Ashaki was excited for this opportunity and stated that it would look good on her medical school application. She was able to articulate clearly the focus of the research lab. She also spoke to lab techniques that she had already learned from this experience which spoke to the performance component of her science identity development. This instance was an example of explicit recognition by someone Ashaki perceived to be a creditable member of the science community, her professor.

Overall, the mix of implicit and explicit instances of recognition served as resources in Ashaki's science development journey. Even in instances that appeared to be negative, Ashaki's religious identity, strong family ties, and aspiration to obtain a high social class pushed her to work hard and persist. Ashaki's approaches to learning biology were shaped by implicit moments of recognition by her mother, and experiences intersecting her class, gender, religious, and science identity. Ashaki's perceptions of herself as a scientist were later affirmed by a member of the science community.

Aniyah

Background: Aniyah's parental ethnic background is a mix of African American/ Native American (mother) and Costa Rican (father) decent. Aniyah's mother was a single parent by choice through fertility treatment, therefore Aniyah identifies socially as an African American being that she primarily grew up with her mother's side of the family. Aniyah's mother is an elementary school teacher. Aniyah grew up in what she referred to as a semi-liberal, semi-conservative household that upheld certain Catholic values. Aniyah grew stronger in her Catholic faith after attending a private Catholic grade school. Aniyah grew up in the southeastern United States, surrounded by a large external family unit. Aniyah aspires to be a biology teacher, with a major in General Biology and minors in Education and Spanish.

Table 4. 9 Aniyah and the Phenomenon

[Conceptions of Studying, Approaches to Learning Biology, and Metacognitive Regulations]

Construct	Thematic Code	Sample Excerpts
Conceptions of Studying	**Process-** Assimilation of knowledge **Product-** Intrinsic - Understand **Product -** Evidence of Intrinsic Outcome- Application **Context-** Discipline-dependent **Product-** Extrinsic - Future	*"studying to me is the act of breaking down knowledge and being able to connect it to the material at hand and just really not only like knowing it like comprehending it, understanding it, applying it ….because if I can apply it, then that means I know it because I can contextually connect it to the idea".* *" It depends on the class… with math it's working out a product, working out problems… I can't remember things. I might be able to work it out. In science, it's a little bit different. I pretty much like read about it."* *"you're here to get an education, you're here to learn… make something of yourself."*
Approaches to Learning Biology	Mixed Strategies	*"I'll actually go ahead and like look at the like Khan Academy lessons before class and like watch the videos and I'm pro at it, that when I get to class, I'm not as confused about what's going on.* *I kind of just go through and immerse myself in those [notes]. I'll go through and read all of them like highlight things. I'll make flashcards."* *"those are really important for me because in order for me to actually understand the information and be able to apply it, I need to understand it. So, I had to connect it to things or else I'm just gonna forget it all."*
Meta-cognitive Regulation	**Emerging-** Students know what to do to adjust their studying, but may not follow through	*" I was doing great until midterms and then what happened was everything started happening at once and I didn't plan for it like I should have."*

Perceived Science Identity- Aniyah recognized herself as a science person but not a scientist. She mostly identifies with the subject of biology because it aligns with how she thinks and makes sense of the world. She also has an affinity towards science that drives her curiosity about the environment.

Aniyah: "*I definitely see myself as a science person mostly because it's easier for me to see things statistically and factually and with evidence. And science just as always made sense to me in the terms of biology. Biology always made sense to me. Chemistry makes no sense to me but that's just because chemistry is like if science and math had a love child, that's really just what chemistry is for me and that doesn't make sense. But biology definitely makes sense because it's very… I'm very in tune with the environment like Earth and like things like that. So, being able to connect it to something that's relevant within my existence is very important so that's why I love science.*

Aniyah described a scientist as someone who has earned that title through formal educational training and contributions to the science community. She appreciates the work of scientists but does not see herself doing experimental work like "*drug testing*" or "*chemical work*". She is however, interested in understanding how "*people correlate with science*", and she described this interest as more humanities research. With this view, Aniyah aligned more with a science teacher identity, in that she does not doubt her capability to engage in scientific practices and understand scientific knowledge. Her passion for science, however, is connected to how she can relate science material to others.

Aniyah recognized that she was at the early stages in her academic career and being recognized by others as a scientist may be premature. *"I do acknowledge the fact that like I'm an undergrad and I don't know that much"* Aniyah added that studying science is different from studying other subjects by stating, "*for me science is really conversational so it's kind of just reading and articulating things about it"*. This speaks to how she approaches learning biology as it relates to her views of science as a discipline. Like Ashaki, Aniyah sees science as being understood and negotiated socially.

Aniyah: Gender, Social Class, Race, Ethnicity, Religion, Science Teacher Identity- Following are seven instances that reflect the development of Aniyah's science identity through implicit or explicit recognition. These instances also reflect how Aniyah's science identity and other multiple identities shaped how she approached learning biology.

Instance #1

"I would like, learn how to study from her."

Aniyah: *"I would probably say [the]person that influenced [how I study], I say definitely my high school biology teacher because I kind of saw the way she would remember things. It is very like task-oriented, a list oriented, kind of like a to-do list situation. So the way I would like learn how to study from her was she would write on everything she needed to do and then write like sub-notes about it and that kind of like really helps me because when I study and I do my notes now…. 'okay for the topic and then key points about it and then under those key points just kind of break it down'….I'll do that when I take notes and also when I study too because when it comes to studying for me I have to be able to break an idea down or else I'm kind of not grasp it completely. So, if we're talking about like Evolution again like…'okay what are the key points for the different types?' …'okay what about those types?'... 'well how do I know this?'... 'and how other people know this?'... 'and how did we all come to like this conclusion?' ...so kind of like remembering those small things."*

Aniyah described the implicit recognition from her high school teacher of effective ways to organize and study her biology content. This background resonates to how Aniyah first described her approaches to learning biology. She first painted a detailed picture of how she organized her time and space in coordination with how she organized her course materials. She described in detail how she organized her notebook and set reminders in her calendar for when she needed to start studying. Aniyah's high school biology teacher also served as representation of a women in science (she was not a WOC). When asked if she knew someone she would identify as a scientist, Aniyah identified her high school biology teacher. Aniyah recognized that her teachers held a Ph. D and referenced peer-reviewed literature during class. This experience helped shape Aniyah science teacher and gender identity through implicit recognition that she, as a woman, could achieve something similar.

This instance also reveals the influence her high school experiences had on the development of her science identity and how she comes to understand course material. Although Aniyah went to a predominantly white Catholic grade school (K-8th grade), she attended a public high school where she was enrolled in an International Baccalaureate (IB) program. Aniyah described her IB program as being culturally diverse and as providing a more challenging curriculum. Her IB program extended a traditional one-year biology course over the span of two years, offering a more in-depth perspective of the subject. It was in this program that she also took a Theory of Knowledge course, that taught how to examine different ways of knowing and how to recognize what it means to know something. These experiences resurfaced when she studied for introductory biology. She described in this instance how she expanded on the strategies she learned from her high school biology teacher, and tried to make connections with the course material. This highlights a high perceived competence in biology and implicit recognition that students with diverse background can be successful in advanced level science courses.

Instance #2

"…the world is gonna go on without me if I don't move with it."

Aniyah: "*What motivates me so yeah not failing… yeah no besides that. What motivates me to study is just knowing at the end of the day the world is gonna go on without me if I don't move with it. Like I have a very clear understanding that you're here to get an education. You're here to learn, make something of yourself, and if you don't do what you need to do then it's not gonna happen for you. You have to work for it and just some things may come easy, but you also have to put in the work and the dedication, and you know… earn it. So, if I really want my degree because I know I need a degree to be successful and what I want to do at least, and you know overall just build a comfortable life for myself right now. If that means passing this test… that's just one step towards my goal. I think it's important to know your goal and know what steps you have to take to get there and just be about it."*

Aniyah expressed mixed motivations behind her study strategies. In addition to wanting to understand the course material, she fears failing and acknowledges education is a vehicle to a comfortable life for herself. The success from passing a test, leads to a successful life. This is an example of how her social class identity shaped her motivations for studying and passing test. This instance also demonstrates what is known as projected agency (Avraamidou, 2020) in that she knows her goals and what it takes to achieve those goals.

Instance #3

"I definitely need to make sure that my I's are dotted and my T's are crossed"

Aniyah: "*I mean it makes me feel like I'm doing something right definitely but also it makes me kind of want to work harder because if someone's gonna be coming to me and asking you for help I definitely need to make sure that my I's are dotted and my T's are crossed and like I know what I'm talking about makes me kind of want to work harder."*

Here Aniyah responded to how she feels about her peers coming to her for help with biology content. She was explicitly recognized by her peers as being competent in biology, and Aniyah uses this recognition as a resource to push her to work harder and become someone worthy of seeking advice from. This instance adds to her perception of herself as a science teacher and the level of competence it takes to be viewed as proficient in science.

Instance #4

"I didn't want to enter a field that was so like controversial."

Aniyah: *"My upbringing kind of affected it [*my decision to be a biology major] *in a very funny way. It really actually deterred me because I didn't want to enter a field that was so like controversial in a way. So, coming from the background I've come from like religion is important and like science and religion haven't always seen eye to eye, but I know what's important to me and like those two things are important. I don't see why they can't fit. Also, I was just raised in a home that was very accepting of education and religion at the same time it was like they can find their place to coincide.*

Aniyah and her mother were both Episcopalians who later converted to the Catholic religion after Aniyah's experiences in grade school. In this instance, Aniyah expressed the internal tension between her semi-conservative Catholic values and her love for science. This tension originally deterred her from becoming a biology major, yet her supportive family background created a space where science and religion can co-exist. This instance provides an example of how Aniyah's science identity intersected with her religious identity and how Aniyah's family helped her negotiate how to pursue biology education and maintain her religious identity. Unlike Ashaki, Aniyah's religious tensions were internal, and were often unaware to key players in her science education journey.

Instance #5

"it's very much an independence in the sense of like survival."

Aniyah: "*Definitely my mom. We are very stubborn people but it's from a good place. It's funny so in my family, it's mostly male-dominated so the women… you gotta know how to hold your own. You have to know like when it's time to argue and it's not. If your point disagrees with theirs, you better come with the facts to back it up because we don't play games. So it's very much an independence in the sense of like survival…..I'm very independent. I want to be able to solve my own issues. So, I don't want to have to ask or depend on anyone else to do that for me but I know at the end of the day you gotta humble yourself and ask for help if you need it."*

This statement was a response to Aniyah being asked where she thinks her sense of independence came from. The pattern of independence echoed throughout Aniyah's interview. This pattern was first established by Aniyah's description of her mother and extended family. Her mother's choice to be a single parent instilled in Aniyah that success in life can be accomplished independently. Also, Aniyah described her extended family being majority males, requiring her and her mother to 'come with facts' if they ever disagreed with any man. In order to survive this family dynamic, Aniyah built a notion that she needed to be able to solve problems on her own and not ask anyone for help. This notion transitioned to how she approached learning biology, in that she rarely if ever felt ok to personally ask the professor for study strategies. This instance speaks to how Aniyah's gender-identity played a role in how she approached learning biology.

Instance #6

"I'm not gonna be your token."

Aniyah: "*I was at one of the science fairs and someone from a sorority approached like, it was a predominantly white sorority, they're like 'oh my gosh we would love to have someone you know of your ethnic background in our sorority' and I was like pause… what?... they were like 'yeah no we love science majors a bunch of us are science majors but we don't have any people of color' and I was like I'm not gonna be your token for anyone else…. even just because of the way you approach me in the situation. I don't like it you're making me very uncomfortable, I need you back up. I think that's when I got kind of defensive. I didn't say anything. I was kind of like okay thank you and I'll take your card but I'm not gonna do anything with it because the way you've presented yourself it's very uncomfortable and uneasy yeah."*

Experiences of *tokenism* is said to be very common with underrepresented minority groups (McGee & Bentley, 2017). The idea that the only reason a particular group extends membership to a person of color is to be able to say they now have a *diverse* group, not because of the assets the person brings to the group. As Aniyah told this story, it was not made clear until the end of the story what words she actually exchanged with the other women from the sorority. Aniyah expressed in the interview all of the things that she was thinking at the time, "*I'm not gonna be your token for anyone else"….* and*, "I don't like it you're making me very uncomfortable",* **and** *"I need you to back up".* However, she did not say any of this to the sorority women. Aniyah just said thank you and took the card and walked away. This speaks to an explicit low recognition of her science identity. The sorority women recognized Aniyah as a biology major, not based on her competence or performance, they were only interested in having a biology major who was also a person of color. The emotions attached to Aniyah's real response were internalized and never expressed to the sorority women.

This response pattern was highlighted in another instance Aniyah described during her interview. She recalled that she had a question in Chemistry class and the person sitting next to her said "*of course you do*". Aniyah said that she asked the person, "*what is that supposed to mean?*", despite feeling disrespected internally. Aniyah said that she sometimes has to filter her responses to instances of microaggression so that she does not fulfill the stereotype as "*the angry black women*". To overcome this stereotype, Aniyah often embodied the mindset that she could push through barriers of race and gender by working hard and applying herself.

Instance #7

"….starting the game at a disadvantage."

Aniyah: "….*definitely realizing that [you're] starting the game at a disadvantage. First of all, you're a woman, so people already are going to think less of you in terms of what they believe you can do as a whole academically or just in life. So, definitely especially people who have traditional values and I'm like well ….I acknowledge that I may be needed in a home one day but that's not today!.. I want to be able to adventure and explore and focus on my academics and be more than that. I feel also you're a person of color so definitely historically you've had a disadvantage but also the way that stereotypes and perceptions have been cultivated through those experiences of past and history you definitely have to fight against the grain and kind of realizing that just because you are in a place doesn't mean [you have] to stay there. So, you can definitely break their boundaries and break through the color lines if you, you know, work hard enough and believe in yourself and apply yourself.*

Aniyah was aware that women of color are often viewed through a stereotypical lens that sometimes undervalues their potential to succeed even before they have had a chance to demonstrate their abilities. In her words "*starting the game at a disadvantage*" means looking past the traditional gender roles and historical perceptions of people of color and letting your hard work and dedication speak for itself. This outlook resonated in how Aniyah approached learning and studying in the academic setting. Aniyah believed that even though she attends a predominately white university, she can still achieve academic success because everyone is graded on the same merit-based scale. Aniyah believed that her work ethic can break gender and color barriers. This is an example of how Aniyah's gender and race identity shaped her perception of her academic space, the university, and motivated her to persist in how hard she studied. This is an example of implicit recognition of how Aniyah's race and gender identity placed her in a position where she felt like she had to prove herself to overcome stereotypes. The cultural diversity, or lack thereof, of her university implicitly suggested that high competence was recognized as an avenue for overcoming inequities in higher education that are based on race and gender.

Overall, Aniyah described instances of implicit and explicit recognition that shaped both her perception of her academic environment and how she approached learning biology. Aniyah's strong biology background and experiences with her high school biology teacher shaped her perceived competence in science and provided implicit moments for Aniyah to emulate how to organize and study her biology course material. Throughout her interview, Aniyah exuded an attribute of independence, shaped by her gender-identity and family experiences, that echoed in how she approached learning biology. Aniyah often tried to figure things out on her own before seeking study help. She was aware of what she needed to do to accomplish her academic goals; however, towards the end of the semester, she abandoned her well-thought-out study plans and struggled to consistently implement effective learning strategies. Aniyah did however believe that if she continued to work hard, she would break through historical barriers created by racism and sexism in academia.

Jasmine

Background: Jasmine identified as an African American and is the oldest of eight sisters. While born and raised in the Southeastern United States, Jasmine was primarily influenced by her mother and grandmothers. Jasmine aspired to be a Forensic Scientist, after watching *CSI* with her grandmother over the years. Her mother was a special education teacher and father owned/managed a charter school (Jasmine expressed that she was not sure exactly what her father did). Jasmine attended a summer bridge program prior to starting her freshmen year.

Table 4. 10 Jasmine and the Phenomenon

[Conceptions of Studying , Approaches to Learning, Metacognitive Regulation].

Construct	**Thematic Code**	**Sample Excerpts**
Conceptions of Studying	**Process**- Explaining to self **Product**- Intrinsic-Understand **Process**- Making connections **Product-** Intrinsic-Knowledge gain **Product**- Intrinsic-Memorization **Context**- Discipline-dependent	*"well for me when I studied it's basically just like teaching myself in a way for me to understand …I'm big on connection to see who I had it all goes."* *"The goal…. if you can basically just recite what you just read or what you're trying to gain knowledge of you just basically like how you say a favorite song basically recited it get them talk about it."* ***Interviewer:*** *Would you say there is more than one way to study?* ***Jasmine:*** *"Yes, for different subjects to."*
Approaches to Learning Biology	Surface Strategies	*"And I studied or like I had to read the book and I had to use what's it called like sticky notes of each paragraph and like summarize it up at the end of* like *the big things and had to use like our class notes where he was really talking about; when he was just really going off. They always said like if he's always going into detail and going off, that's a hint. And so, I wrote everything he said down, and I just really did that and read my notes."* *"I just really just basically, just try to remember what I took out from most of the chapters basically."* *"I use flash cards or you use like real-world examples. That's my biggest thing…connecting it to me."* ***Interviewer:*** *Do you have an example in your head of something you've made a connection to?* ***Jasmine:*** *No once I take the test...its gone."*

Meta-cognitive Regulation	**Struggling-** Students are willing to reflect and adjust, but do not know what to do	***Jasmine:*** *"That's my thing. They really don't teach you how to study. They just say study…Like most school and family too. Like how do you study? Because I never knew.* ***Jasmine:*** *"So, it just basically like a [Freshmen Seminar course] and she was giving us all helpful tips too because I really didn't know.*

Perceived Science Identity- Jasmine conditionally identified as a science person and not as a scientist. When asked if she saw herself as a science person, her response was…

> **Jasmine:** "*oh I really don't know it depends. Like if I'm like… if I failed this semester and I'm not gonna do science anymore because I really push myself and studied hard and gave it my absolute all so if I failed and I'm just not gonna do science anymore."*

Jasmine believed that a science person had to be smart and determined. She emphasized that someone would have to be determined especially if it is hard for them to understand. Jasmine expressed that she loved science and that she felt that some science material is harder to understand than others. She stated that one topic, for example microbiology, may not be for her because it is hard to understand. Jasmine said that she is still exploring what subject she feels is right for her. When asked which biology topic she felt that she connected with the most, she responded, "*there's different subjects I do like, but I just haven't found the one that [I'm] like yeah this is for me yet."* Jasmine said that she liked studying about the human body. She felt that a scientist, however, consumed their thoughts and time with all things science as she stated that they *"live, eat, and sleep science".* When asked if she would say others perceived her as a science person, she stated, "*Yes to be funny, because I take biology and chemistry*." She specifically referenced her family members, like her grandfather, that would joke about her being a science person.

Jasmine: Gender, Social Class, Race, Ethnicity, Science Identity- Following are eight instances that reflect the development of Jasmine's science identity through implicit or explicit recognition. These instances also reflect how Jasmine's science identity and other multiple identities shaped how she approached learning biology.

Instance #1

"I would just love it…how they would just gather all the information…"

Jasmine*:* *"…and so my mom is a teacher and she would always say that in college she wanted to be a doctor. But she was saying that it was so hard that she had ended up switching to be a teacher. So, she'll always say dream big, dream big. And so, I will always watch like Criminal Minds, CSI Miami with my grandmother. And I would just love like it. The way… how they would just gather all the information…put all the… just them working in the lab. I would always google it and just real deal… just look and try to see what they were doing. So, I just love that. I always tell her like I want to do stuff like that."*

Jasmine's affinity towards forensic science grew from what she witnessed on fictional television shows. Jasmine fondly remembered watching episodes of criminal investigation shows with her grandmother. Jasmine mentioned in her interview that she asked her mother what the TV actors' occupation was called in real life, and her mother told her that they were forensic scientists. At that stage in her life, her mother and grandmother were supportive in her "*dreaming big*" and pursuing this profession. Jasmine started this excerpt off however, mentioning that her mother wanted to become a doctor, but ended up switching to become a teacher because it was too hard. This instance described both implicit and explicit moments of recognition, that played a role in Jasmine's perceived science identity. Jasmine's mother implicitly painted the picture that science is something "*hard*" and pursuing a science profession will be a hard task to accomplish. Jasmine's perceptions of herself as a science person were dependent on the internal and external recognition of high competence levels in science. Jasmine needed to pass her Biology class to view herself as a science person. She perceived science as being "*hard*" and "*difficult to understand*". This instance highlights that, at an early stage in her life before she attended college, she was explicitly recognized as being able to achieve whatever she was interested in doing. Jasmine knew she was interested in forensic science, to the point that she personally researched their practices and imagined herself doing similar things.

Instance #2

"…do I really want to do this because science is really hard?"

Jasmine: *"Oh, high school was really easy, yeah like it wasn't that …like that difficult. That's what made me love science today. But once I got to college, it was like I couldn't like I remember the stuff but it was like more in depth. So, it was kind of hard and it made me like want to change my major. Like 'do I really want to do this because science is really hard'. ….In high school, I was more like reading ….like if I read it and I like really understood it, like break it down to my own words for me to understand it I mean. It was like real good in high school but now it's like I had to do flashcards, makeup questions, cuz it's just so much more….. Yes, like his* [Intro Biology instructor] *questions are more like practical and I'm probably not used to the practical questions. We do really [more] explaining. Like in high school really didn't have to explain. We just had to say like, what happened and now you have to really know what's going on in detail."*

Jasmine's love for science was reinforced by her ability to be make good grades in her high school science classes. She felt that high school science was easy compared to college science classes. This comparison highlighted the different way she had to learn how to approach college biology. Jasmine said that she could just read course material in high school and *"understand"* it well enough to get a high score on a test. However, in college, she had to do flash cards and make up her own questions to answer more *"practical questions"*. Jasmine felt that college biology required more detailed explanations. This is an instance of implicit recognition in that, like Ashaki, grades are presented here as a currency to evaluate science competency. Jasmine associated her ability to understand science with whether or not she should pursue a science major. This instance also highlights that Jasmine was well aware that she must adjust the way she used to study for high school and find a study strategy that matches the requirements of introductory college biology.

Instance #3

"They really don't teach you how to study."

Interviewer: Who taught you how to study or how did you learn how to study?

Jasmine: *That's my thing. They really, really don't teach you how to study. They just say study. So, it was kind of hard."*

Interviewer: Who is they?

Jasmine: "*Like most ... like school and family too. Like go study, go study. Like how do you study? Because I never knew."*

Jasmine: "*So, it just basically like a* [Freshmen Seminar] *and she was giving us all helpful tips too because I really didn't know."*

Interviewer: What tips that you get in [Freshmen Seminar]?

Jasmine: "*Basically with the reading.... reading and using your own sticky notes about what are you reading; just taking out the main topics and, asking yourself questions. Then if your professor is like you know going off in a detail, that's a hint that that's probably one of the questions or subjects you got to talk about [study]. Just giving us hints like that."*

Here Jasmine revealed that she felt she was never really taught how to study. She placed this responsibility on her pre-college schooling and family for not adequately preparing her for how to effectively study for college level courses. Later in the interview, Jasmine stated that she was mostly told that she would have to write papers in college. After one semester in college, Jasmine deemed this an inaccurate representation of college course work. However, Jasmine did mention that she was currently receiving advice on how to study from her Freshmen Seminar class. Jasmine described later that she used these study tips to study for Exam 3 in her introductory biology course, after failing Exam 2. Jasmine also mentioned that at midsemester, her roommate helped her create a study guide for biology class that she planned to use for future studying. These instances showcased two important things. First, Jasmine recognized that she needed to adjust her approaches to learning biology. Second, that she was actively searching for more effective study strategies while she was taking the course. This is an example of someone who is struggling to metacognitively regulate their approaches to learning because they do not quite know what works yet. Jasmine did seek help and study advice, but unfortunately, she was not able to find an approach to learning biology that worked for her and ended up not passing introductory biology.

Instance #4

"a good experience …is gonna make me like …just push through it."

Jasmine: *"I really do like that [forensic science]. I really want to[do it]. Cuz like with the forensic science I want to join the FBI and I want to travel. Yeah, I really wanted to do that. And I'm trying to see if like is it just cuz I'm just having a rough semester or what? But I really wanted to get in some internships …. like just to see if like this is something that I really want to do. …I just went… I met with our Career Development [center]and I had to fill out the assessment and I've been going. So, it's like the little science meetings and she was saying they do have a little program but it is in the summer….You know I want to see like I feel like if I have a good experience with that [then] it's gonna make me like okay just push through it."*

Jasmine desperately wanted to experience what it would be like to engage in similar practices as a forensic scientist. She knew she was interested in this profession, but the more she struggled in introductory biology, the more uncertain she became that it was the right field for her. Jasmine took the initiative to seek out any opportunity that would help her with this uncertainty and ultimately let her know that the struggle was worth it. The representative from the Career Development Center explicitly recognized Jasmine as a forensic science major that could participate in a summer internship. This type of recognition gave Jasmine hope that, maybe if she did fail this class, she could just take it again. Earlier in the interview, Jasmine stated that she would not pursue science anymore if she did not pass introductory biology. However, as the interview went on Jasmine begin to open up more about her love for forensic science and the possibility of a summer internship. Her speech shifted from "*I just won't do science anymore*" to "*I will just have to take it again*". This shift represented another aspect of Jasmine's science identity development. Jasmine mostly evaluated her science identity based on her internal and external competence in science. However, when she spoke about the summer internship, she spoke of engaging in certain practices, or science performance, that would confirm that, indeed, she was a science person.

Instance #5

"I had the correct answer too."

Jasmine: *"I did [a Summer Bridge Program] and like a staff…. so I took college algebra in high school. So, I knew a little math I mean I can do a little math. And so, we were doing like some little pop quizzes or something, you know like a pop quiz and something in math. And you know a bunch of black people in the class[and] you know one white person. So, it was a math problem. Black people, 'uhhh math'. You know getting upset , you know regular black people. Of course, the little teacher she's white. So, of course everyone's like I don't know how to do it but I knew how to do it because I had the good math teacher so I could do it. And so she, the teacher was like what's the answer and of course the little white boy raised his hand. He says the correct answer and the teacher* *gon say 'yeah I knew you just knew it'. I had the correct answer too. I didn't do all the other stuff being extra."*

Here Jasmine described an instance of implicit low recognition that she was not as smart as the only white male in the room. Although this example was of a mathematics class, Jasmine recalled this incident as a response to how she has learned to navigate gender and race stereotypes being a science major. Jasmine felt that she was often judged based on her gender and race before given an opportunity to show her strengths. Jasmine was proud of the fact that she knew the answer to the mathematics problem. Earlier Jasmine had mentioned that she went from hating mathematics to "*kind of liking it again"* because a college algebra teacher worked with her to help her understand the course material. Jasmine used this as an example of how she could overcome "*hard*" or difficult to understand biology topics, regardless if she is recognized by others as being able to do so. Jasmine said that she does not let these types of incidents bother her, she just keeps going. This instance intersects Jasmine's race and gender identity with her perceptions of her science identity.

Instance #6

"They always been so negative."

Jasmine: *"I gotta toxic family. They're very negative…..Constantly saying that 'oh I'm not going to graduate' and stuff,…. dropout. So, that makes me constantly want to go back and do harder. Cause that why I said I didn't do good on exam two. [They are] constantly calling, sending texts, texting through my sisters phones. Stuff like that. It's just my mom and her momma, Nana. …Just saying I'm going up…here failing, gonna flunk out, gonna drop out on all this…. From the beginning, since the first day [of school]…. I have always done better than what they like think.. They always been so negative. So, they always made me like.. I'm gonna show you different. I'll show you wrong yeah. It's really just me doing this for them [younger sisters]. Showing them [younger sisters] that even though it was hard, struggling and all of that, I still made something. I feel like we don't have a lot. Yeah, it's not really a lot of inspiration."*

Earlier in the interview Jasmine spoke of fond memories of her and her paternal grandmother watching criminal investigation shows on television and her mother saying, *"dream big"*. As, Jasmine grew up she spoke of more negative experiences with her mother and maternal grandmother, Nana. Jasmine spoke of her mother and Nana taunting her in a sense, saying that she will not be successful in college. As Jasmine spoke about this negativity during the interview, tears rolled down her face. Jasmine was connected to every word her mother and Nana said to her, yet Jasmine always came to the conclusion that "*misery loves company"* in her words. Jasmine believed that her mother projected the hurt and shame she felt from not fulfilling her dreams to become a doctor on to Jasmine. This negativity was used as fuel to push Jasmine to work harder and prove to her littler sisters that the struggle was worth it. This served as an example of explicit low recognition, in that her mother and Nana did not recognize her as someone capable of obtaining a science degree and ultimately becoming a science professional. However, this experience served both as a bridge and a barrier to her science identity development and how she approached learning biology. Jasmine admitted that failing Exam 2 was a result of her listening to the negativity of her family. In this case, this explicit low recognition was a barrier. On the other hand, Jasmine's drive to succeed stemmed from her wanting to prove her family wrong and desire to provide inspiration to her younger sisters.

This also serves as an example of how Jasmine's social class identity and science identity played a role in how Jasmine approached learning biology. Jasmine spoke of the lack of inspiration from her family in that most of the family members that obtained college degrees became teachers. She spoke negatively about this popular choice of occupation, because she said they all hated being teachers. The rest of Jasmine's family did not finish college, including her father. In her perspective, Jasmine had to search for her own inspiration to work hard, pursue more effective study methods, and persist in her major. Jasmine felt that her family did not provide her and her sisters with a good example of how to achieve *"hard"* degrees, such as those in the science field. This perspective connects to how Jasmine positioned her instructors as a medium to learning course material. Jasmine spoke of her instructor as not making meaningful connections within class, and the fact that this hindered her from making connections when she studied on her own.

Instance #7

"I really don't even know women in science."

Jasmine: *"Like we don't talk about any.. I don't hear any information about any black people or women [in science]. So, it makes me want to be one. I'm like ok the first. I like that. Yeah. Like I don't.. really don't even know women in science. So, it is like okay make me want to do it."*

Jasmine: *"um just like give me a heads up about like.... what it's like.... what's really going on. You know behind the scenes….Like are the people racist and stuff? Like how's your job? You know so you know like the big meetings and stuff, like, how are they?"*

Jasmine recognized the underrepresentation of women in science, specifically women of color in her academic setting. She did not recall information presented in any of her science classes about women of color. When asked if she would like to know more women of color in science and what that would do for her, she responded with the practical response of "*just give me a heads up*". This suggests that Jasmine could see herself as a science professional and she wanted to know from those that have come before her what it was like. Jasmine wanted to know if they have experienced any racism or discrimination along the way, or what professional conferences were like. Jasmine called this a "*behind the scenes"* view of what it would be like to be a WOC in science in

America. This curiosity speaks to Jasmine's science, race, and gender identity, with the implicit recognition that, if other WOC have done this before her, then so could she, even if she did not know any WOC in science personally.

Overall, Jasmine experienced moments of implicit and explicit recognition that served as both resources and barriers to her science identity development. Despite Jasmine's lack of college science preparation and negative family dynamic, she demonstrated persistence in seeking help and advice on how to approach learning biology more effectively. Jasmine desired to participate in a summer internship to provide confirmation that she was in the right major and that the struggles would be worth it.

Cross Case Comparison- Ashaki, Aniyah, and Jasmine

Looking across all three cases, each participant faced both implicit and explicit moments of recognition that shaped how they perceived themselves as a science person and how they approached learning introductory biology. Three themes emerged from their experiences: (1) the idea of themselves holding a peripheral position as related to the science community, (2) the significance of perceived competence in science by themselves, and its effect on science identity development, and (3) persistence in a course regardless of prior science experiences.

Peripheral Position to the Science Community- All three women identified as a science person. This identity was based on their love for science or a particular science profession. When asked how they would characterize a science person, all but one out of the ten WOC interviewed described a science person as having an advanced interest in science. For Jasmine, this strong interest contributed to her persistence in finding a more effective study strategy for biology, despite her failing the second exam. Ashaki noted that her passion for the subject of biology was the reason for her high competence in introductory biology. Aniyah, held great interest in biology, and she highlighted that scientific thinking aligns with how she processes information in general.

All three participants described identifying as a science person as something accomplishable at their stage of educational experience. However, only Ashaki perceived herself as a scientist as a freshman. Although Aniyah described thinking like a scientist, she distinguished herself from that of a scientist based on the scientific practices and the subject of research. Aniyah felt that scientists are mostly involved in bench research, like drug and chemical testing. However, when asked who she recognized as a scientist, she mentioned her high school biology teacher, who obtained her Ph. D. Aniyah's perceptions of a scientist were linked to her high school biology teacher yet separated from her perceived science identity. With this, Aniyah exhibited more of a science teacher identity, in that she believed she was competent in science, but did not see herself engaging professionally in certain scientific practices. Similarly, Jasmine felt that being a scientist required an intense dedication of time and space, that she did not immediately identify with herself. Despite Jasmine passionately aspiring to be a forensic scientist, she did not associate herself with the practices of scientist.

These findings suggest a perceived peripheral position of themselves alongside the science community. As freshmen, only three of the ten WOC interviewed saw themselves as a scientist, however, all but two saw themselves as a science person. For these WOC, they believed that they were capable of learning biology content but had not yet gained enough experience with scientific practices to see themselves as a scientist. In this sense, they positioned themselves on the outside of the scientific community engaging in the content produced by the community. This peripheral perspective revealed the role perceived and actual competence played in perceived science identity at this academic stage.

Impact of Perceived Competence in Science- At the freshmen level, findings revealed that these WOC more often referenced their perceived competence in biology when describing their science identity. Jasmine initially stated that her identity as a science person was dependent on her passing introductory biology. Jasmine's identity in science was based on her perceived ability to understand the content and the affirmation of a *good* grade in biology class. Ashaki's science identity was based on her ability to explain hard content to others. Ashaki believed that scientists understood complex scientific knowledge and that they were able to easily break down these complexities to those who did not understand. Similarly, Aniyah often referenced her rigorous high school curriculum aiding in her ability to break down biological concepts in a meaningful and retainable way. Aniyah never doubted her ability to comprehend course material. She associated this same level of competence with that required of someone claiming to be a science person, stating that they had to be knowledgeable of scientific concepts.

All three WOC's experiences revealed an important finding that distinguishes this work from other science identity literature investigating WOC. The early work of Carlone and Johnson (2007) emphasized the important role that the Recognition component had on the development of 15 WOC's science identity development. These researchers studied high achieving WOC at advanced stages of their academic career into their early careers, where they found that different experiences of recognition of self and recognition by others within the science community served as a resource in the participants' persistence. Other studies have found similar findings through the examination of WOC at advanced academic and professional stages (e.g., Andersen & Ward, 2014; Aschbacher et al., 2010; Avraamidou, 2020 ; Carlone & Johnson, 2007; Calabrese Barton & Yang, 2000; Chinn, 2002; Gilmartin et al., 2007; Hazari et al., 2013; Olitsky, 2007). What this work did not address was instances of recognition at initial and gatekeeping stages of science identity development.

Adding to these findings, our work suggests that WOC at the freshmen level have not had many opportunities to be explicitly recognized within the scientific community, therefore their recognition of self is primarily based on their perceived competences in science and their performance in science courses. Freshmen WOC have not yet proved to the science community, and in some cases to themselves, that they are competent in science. In the cases of Ashaki and Aniyah and other WOC interviewed, previous and current science experiences had positioned grades as a currency to establishing "smartness" in science. Therefore, their perception of who constitutes a science person is heavily connected to how competence is formally assessed through testing in academic settings. Jasmine's perceived competence led her to question her pursuit as a forensic science major even before she engaged in the related scientific practices during a summer internship.

These findings suggest the benefit of incorporating multiple ways of defining and assessing science competence at the introductory stage, to aid in the development of students' science identities. Adapting effective study strategies contributed to the perceived competencies as freshmen. A student's use of deep approaches to learning often lead to higher student learning outcomes, which is recognized as high competence by both the student and the instructor. With this understanding, a single method for assessing competence, such as a multiple-choice exam, may not provide a holistic representation of a students' understanding and knowledge of the content. This limited representation and assessment of their knowledge could perhaps misguide students who are passionate about science and wish to pursue a science career. In the case of Jasmine, she struggled to find a strategy to effectively study for one method of assessment, which she viewed as the source of her science identity. Perhaps if provided other means of assessment, Jasmine could have had an opportunity to evaluate her science competence more holistically.

Persistence regardless of Science Experiences- Despite variations in each of the three WOC's prior science experiences and moments of implicit and explicit recognition, each woman found motivation to persist through the semester. Ashaki recalled moments of implicit low recognition by her high school physics peers, that motivated her to find more effective study strategies, which she eventually modified for her introductory biology course. Aniyah persevered through moments of microaggression, where her gender and race identity intersected with her science identity. These moments, although meant to suggest that because she was a woman of color in science she may not be as competent as her white counterparts, motivated Aniyah to push through historical boundaries and study harder. Jasmine described moments of explicit low recognition from her mother and grandmother, that stirred up an "*I am going to prove you wrong"* attitude which motivated her to keep searching for more effective ways to study.

This persistence emerged despite each participants' varied exposure and access to science-related resources, a concept which Archer et al. (2015) coined as *science capital*. Bourdieu (1977, 1984, 1986) originally conceptualizes capital as "the legitimate, valuable, and exchangeable resources in a society that can generate forms of social advantage within specific fields (e.g., education) for those who possess it" (Archer et al., 2015, p. 923). Therefore, science capital is thought to include science-related resources, such as scientific forms of cultural capital (e.g., scientific literacy, science dispositions), science-related behaviors and practices (e.g., science media consumption; visiting informal science learning environments, such as science museums), and science-related forms of social capital (e.g., parental scientific knowledge). Each of the three participants described varied high school experiences, parental scientific knowledge, and engagement with others they perceived to be a part of the science community, resulting in different amounts of science capital that could be used to their social and academic advantage.

In particular, Jasmine notably entered college with less science capital as compared to Ashaki and Aniyah, yet Jasmine still sought out help and advice that would aid her in implementing more effective study methods. Her genuine interest in forensic science and desire to elevate to a higher social class motivated her to continue. These are aspects of Jasmine's cultural identity, including social class, race, and gender that impacted her academic behaviors and ultimately her academic persistence. Yosso (2005) referred to this as cultural capital, which positions the array of cultural knowledge, skills, abilities and contacts possessed by socially marginalized groups as resources or capital used to persist toward academic achievement. Yosso noted that these cultural resources such as *aspirational capital, linguistic capital, navigational capital, or social capital,* often go unrecognized and unacknowledged in the field of education, yet can often explain how some students of color navigate certain academic spaces. Each of the three WOC used various amounts of their science and cultural capital to navigate introductory biology. Specifically, these science-related and culture-related resources helped each participant make decisions on which study strategies to try, how to organize course material, and which instructional cues to pay attention to in their approaches to learning biology.

Limitations of the Study

Limitations of this study include an unequal number of participants representing each race/ethnicity. Of the ten participants, four identified as African American, two as Asian American, one as Middle Eastern, and three identifying as either Hispanic, Latina, or Mexican. Acknowledging that although women of color may share common experiences related to their race/ethnicity or gender, each racial and ethnic group also holds unique cultural experiences that contribute to their academic experiences. With this stated, overall analysis across all 10 WOC maybe not adequately represent the unique cultural experiences of each ethnicity.

Future Implications

Broadly considering the findings from this work and how these findings relate to understanding how to enhance the student learning experiences of women of color, the following section provides future implications for practice, research, and theoretical applications.

Practice

Practical implications for this work include ways to enhance students' learning experiences at the freshmen level, and more specifically ways to incorporate and support the rich experiences of WOC, that encourage persistence and science identity development. First, this study revealed the strong trends associated with how the WOC approached learning biology, their metacognitive regulations, and their learning outcomes. These trends suggest the need to not only model effective learning and studying strategies but provide opportunities for students to evaluate those strategies within the learning environment. Research shows that students may be evaluating their approaches to learning for the first time in college (Dye & Stanton, 2017). Therefore, by modelling desired behaviors of active, metacognitive learning strategies, the instructor aids students with a wide range of academic backgrounds in locating an effective discipline-specific strategy (Davidson et al., 2019; Dye & Stanton, 2017; Rhodes & Rozell, 2017; Buchwitz et al., 2012; Tomanek & Montplaisir, 2004).

Recently, Stanton et al. (2019) compared the metacognitive regulatory skills of introductory and senior-level biology students. Findings from their work revealed that while introductory and senior-level students can evaluate if a strategy is effective or not, introductory students struggled to evaluate their overall study plan. This mirrors

Jasmine's experience in that she knew that her current strategies were not effective, yet she struggled to identify an overall plan that would help her study more appropriately. Although such struggles are not unique to WOC, when paired with other exclusion and isolation factors many students of color face, these struggles can seem amplified.

Findings also revealed the need to provide more opportunities for incoming freshmen to engage in scientific practices that approximate how biologists generate knowledge. Early engagement expands the opportunities for explicit recognition from others within the science community and provides multiple means for WOC to evaluate their perceived competencies in science. This study highlighted the important role perceived competencies played in WOC's self-recognition as science people, their academic behaviors, and ultimately their persistence in the course. Their perceived competency was primarily based on how well they performed on an exam and rarely based on how well they applied scientific knowledge to novel situations, which is more aligned with the reformed goals for post-secondary biology education (AAAS, 2011). For WOC like Ashaki, who was explicitly recognized by her family and later her introductory biology instructor for her passion and competence in biology, engagement in scientific practices reinforced her science identity. However, for WOC with similar science backgrounds as Jasmine, early engagement could perhaps provide a solid foundation in which they can develop their science identity. Jasmine longed to experience similar practices as a forensic scientist to determine if her persistence through traditional biology courses was worth it.

It is often argued that introductory laboratories are the space for students to engage in scientific practices. However, when describing their introductory laboratory experience, most of the participants emphasized that misalignment between lab and lecture, the procedural or cookbook experimental design, and/or the large quantity of content required for them to recall on the practicum. Their lab experience did provide them with experiences using scientific tools, such as a microscope. However, given the efforts to increase the persistence of WOC in science, early exposure to the authentic investigative practices of scientists could lead to more WOC seeing themselves as participants within the science community. To address the call to increase early exposure to authentic science experiences, biology faculty can leverage the growing number of programs aimed at involving undergraduate students in scientific research projects either in a laboratory or industrial setting (Krim et al., 2019). For example, undergraduate research experiences (UREs; Linn et al., 2015; National Academies of Sciences, Engineering, and Medicine [NASEM], 2017) and course-based undergraduate research experiences (CUREs; Corwin et al., 2015) are both opportunities for undergraduate students, especially WOC, to start to see themselves as scientists and increase their overall competence in science.

Lastly, all three WOC emphasized the lack of women of color in science represented in the academic setting as well as their larger communities. Few participants personally knew any WOC in science, and those who did described high school teachers or family members who majored in a science-related field. Seeing others who looked like them was critical in each WOC recognizing herself as a science person or scientist. Instructors have the opportunity to implicitly recognize the WOC in their classroom, by showcasing successful scientists who happened to be WOC. This positive representation will counteract more prominent stereotypical representations. Although increased positive representation of diversity in science is not directly associated with how WOC approach learning, increased representation is linked to science identity development, which directly impacts students' leaning experiences (Eddy et al., 2015).

Research

Future research endeavors are needed to further examine the role cultural capital plays in WOCs' day to day academic decisions, such as how they approach learning. It is understood the students of color bring unique cultural experiences in the academic space that are not always seen as valuable (Yosso, 2005). These cultural experiences are thought to aid students of color in persistence and academic success. Previous works captured evidence of science success by identifying sources of cultural and social support, such as family support, influences of religion, or altruism in science careers that were critical in the persistence of women of color in science (e.g., Ceglie & Settlage, 2016). A deeper look into how WOC leverage their cultural capital to make decisions about how to successfully approach learning is needed. For example, Ashaki's determination to persist through moments of low science recognition (i.e., her high school physics class) was rooted in her religious identity as a practicing Muslim. Likewise, Aniyah's independent perspective towards learning and life was shaped by her experiences as female in a male-dominated family. Also, Jasmine unknowingly tapped into what Yosso (2005) referred to as *aspirational capital,* in that her desires to provide an example of academic success to her younger sister pushed her to continuously seek study help.

From a different perspective, WOC can also leverage their cultural capital to construct unique ways to relate to and understand course material. For example, Adriana (one of the 10 participants in this study) leveraged her *linguistic capital* of being bi-lingual to understand the root words associated with scientific terminology she learned in introductory biology. WOC may have cultural or social experiences that they can tie into how they approach learning biology. Through further research on the impact of cultural capital on SAL, institutions and disciplinary departments can develop study interventions that empower students of diverse cultural backgrounds to leverage their cultural capital to meaningfully connect to course material.

Theory

From a theoretical perspective, the construct of SAL is conceptualized as a dichotomy of deep verses surface approaches to learning. I propose that the construct of SAL be conceptualized and operationalized as a continuum as opposed to a dichotomy. Evidence from this study, and others in the field, show that a portion of students implement approaches to learning that are consistent with both deep and surface approaches to learning, and in some cases inconsistent with both deep and surface approaches. Three out of the ten participants in this study held mixed strategies and motives toward learning biology that was representative in both quantitative and qualitative data sources. Other studies examining undergraduate biology students labeled students who scored high on both deep and surface survey items as *dissonant*, and students who scored low on both as *disintegrated* or *incoherent* (e.g., Quinn, 2011, Quinn & Stein, 2013; Quinnell et al., 2012, 2018; Tomanek & Montplaisir, 2004).

The argument to view approaches to learning as a continuum is not new. Kember (2016) proposed this theoretical perspective after an in-depth comparison of Chinese student approaches to learning to the approaches of students from Western countries (i.e., United States). Kember identified that Chinese learners primarily used intermediate approaches to learning, where they would first employ a deep approach to understand concepts and then committed the content to memory to satisfy assessment requirements. Since Kember, the student approaches to learning has continued to be conceptualized and operationalized as a dichotomy, potentially limiting a deeper understanding to the nuances associated with student learning. In addition, examining approaches to learning from a cultural and discipline-specific perspective adds to the complexities of student learning that must be carefully disentangled to first properly described how students approach learning in a discipline-specific context and second illuminate social and cultural factors that contribute to academic behaviors. Future research would benefit from the development of a more comprehensive framework for examining how students approach learning in discipline-specific contexts.

Conclusion

This study captured the lived experiences of WOC studying biology at the introductory level, to provide a broader perspective of socio-cultural factors that impact their approaches to learning biology. Understanding the role science identity and other multiple identities play in WOC's academic behaviors is critical in efforts to increase persistence and retention of WOC in science-related fields. This study positions the identities and experiences of WOC as critical factors in their academic success and ultimately their persistence as science majors. Examining academic behaviors through the lens of identity, illuminates how prior learning experiences have shaped the identities of students, and how future learning experiences may be shaped by student identities. From a disciplinary perspective, how students go about learning biology within a specific academic setting is an amalgamation of past science-related and culture-related experiences. It is then imperative that future research seek to capture the complexities of student learning experiences through the lens of who they are as individuals.

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CHAPTER V: DISCUSSION

Viewing learning through both a social and cultural lens broadens the perspective in which the complexities of the student learning process can be examined and understood. Social learning captures both psychological (the person) and sociological (the society) aspects of learning and emphasizes ways in which social interactions and experience affect individuals' sense of identity and self-esteem (Jordan et al., 2008). Cultural learning, learning both within and about culture, exposes the values, beliefs, and norms of a specific group and examines how these ways of thinking and acting cultivate human behaviors, such as learning (Jordan et al., 2008). Combining these two learning perspectives provides a more comprehensive understanding of how both social and cultural factors play a role in human academic behaviors. Examining the influences of social and cultural factors on academic behaviors served as a backdrop to this work. Each chapter added to the narrative of considering how factors within and external to the educational system shaped how students approach learning within a disciplinary context. The following sections highlight how findings from each chapter (Chapter II, III, & IV) embodied the combined frameworks of social and cultural learning to illuminate future implications for enhancing student learning.

Chapter II: Systematic Review of Literature

Literature examining students' approaches to learning (SAL) undergraduate biology posits a broader consideration for the methodological and theoretical approaches used to examine SAL that embrace the profound influence of student-specific characteristics. The acknowledgment that the educational system traditionally studied in

SAL literature interacts with a broader social system generated several studies suggesting that future research should consider the influence of student factors such as age, their life experiences, and cultural values on SAL (e.g., Balasooriya et al., 2009; Geller et al., 2018; Hazel et al., 2002; Lin et al., 2012; Quinn, 2011; Quinn & Stein, 2013; Quinnell et al., 2018).

According to Jordan et al. (2008), "learning occurs within social spheres and contexts, which inform, develop, deepen and influence individual identity, thinking, learning and meaning-making processes" (p. 69). To more effectively capture the influence that social systems have on SAL, studies recommend leveraging the affordances of both quantitative and qualitative data sources (e.g., Lee et al., 2016; Postareff et al., 2015; Quinn & Stein, 2013; Walker et al., 2010). Mixed methodologies provide multiple ways of making sense of the social and academic worlds students perform within (Warfa, 2016). With the specific focus on factors that influence SAL, methodological considerations should also align with the context-dependent nature of the construct to capture how students approach learning within a specific discipline (Biggs, 1987; Lee et al., 2016; Ramsden, 1988).

Chapter III: Discipline-Specific Methodology

A discipline usually reflects the values and cultural norms held by its constituent individuals or dominant groups (Laird et al., 2008). Culture can be defined as "a fuzzy set of attitudes, beliefs, behavioral norms, and basic assumptions and values that are shared by a group of people, and that influence each member's behavior and his/her interpretations of the 'meaning' of other people's behavior" (Spencer-Oatey, 2000, p. 4).

In this light, the science discipline holds certain cultural norms, experiences, valued products, and ways of thinking and acting. For this reason, it is imperative to examine student learning from a discipline-specific perspective to account for the disciplinary culture. Regarding the construct of SAL, both student learning strategies and motives are contextually bound. This perspective assumes that students may utilize different approaches to learning within different learning contexts, which supports the need for discipline-specific methodological considerations for examining SAL.

Chapter III utilized a discipline-specific inventory to examine demographic and course context patterns in how students approached learning introductory biology. In alignment with SAL's context-dependent nature, this study focused on how biology students approached learning to prepare for a midterm exam. Findings from this study first confirmed that demographic variables, such as gender and ethnicity, do not significantly predict how students approach learning. However, related literature informs us that such student factors do indeed influence students' academic behaviors (Quinn, 2011; Quinn & Stein, 2013). How students approach learning is shaped by their individual cultural and academic experiences, which are often revealed in the narratives of the individuals. This notion further supports the benefits of using broader, more comprehensive methods for understanding student learning experiences.

Chapter IV: Influence of Multiple Identities on SAL Biology

Methodologies that align with disciplinary cultural norms are only one facet of understanding the complex interplay between educational and social systems. Disciplinary culture is established by its dominant members and is often conceptualized as a community of practice (Lave & Wenger, 1991; Wenger, 1998). If science is viewed as a community of practice, it positions the process of learning science as a socialization of students into the norms and discourse practices of science (Brown, 2004; Kelly, 2007; Varelas et al., 2005; Warren, Roseberry, & Conant, 1994). Through socialization into the field, students learn what is appropriate, expected, and accepted behavior in the field, including how to learn (Becher & Trowler, 2001). In this light, how students recognize their competence and performance compared to the community of practice impacts how they learn and participate within the field (Carlone & Johnson, 2007). In other words, students' social interactions and experiences within the science community influence their science identity. Thinking broadly about the influence of social and cultural factors on students' approaches to learning biology, investigating student identities (disciplinary and cultural) provides a unique perspective into understanding the complexities associated with student learning.

Scholarly contributions of identity-based research have grown in significance in science education because they offer an ontological approach to learning (Avraamidou, 2020; Wenger, 1998). Learning is thought to transform who we are as individuals and what we can do (Wenger, 1998). Reciprocally, who we are as individuals transforms how we learn. From this perspective, examining SAL through a socio-cultural lens is critical to understanding how students' science and cultural identities shape how they approach learning.

Chapter IV examined the cultural and science identities of women of color (WOC) studying introductory biology. This study revealed how critical moments of recognition by those within and outside the science community shaped how these WOC approached learning biology. Such moments also shaped their perceptions of their science identity and, more specifically, their perceived competence in science. These findings hold practical implications for how instructors can enhance the student learning experience and aid in the science identity development for women of color. Practical implications include increased authentic science experiences and representation of women of color in science at the introductory level.

Conclusion

This dissertation contributes to a wider body of research that seeks to understand how the social and cultural aspects of student learning impact overall student success. Factors that contribute to student success are multifaceted in the sense that no one social or personal factor is solely responsible for any given student outcome. There is a complex interaction between academic and personal factors that must be carefully disentangled to reveal sometimes hidden influencers of academic success. Through broader methodological and theoretical considerations, future research can play an important role in the disentanglement of the complexities that relate to who students are and how they approach learning.

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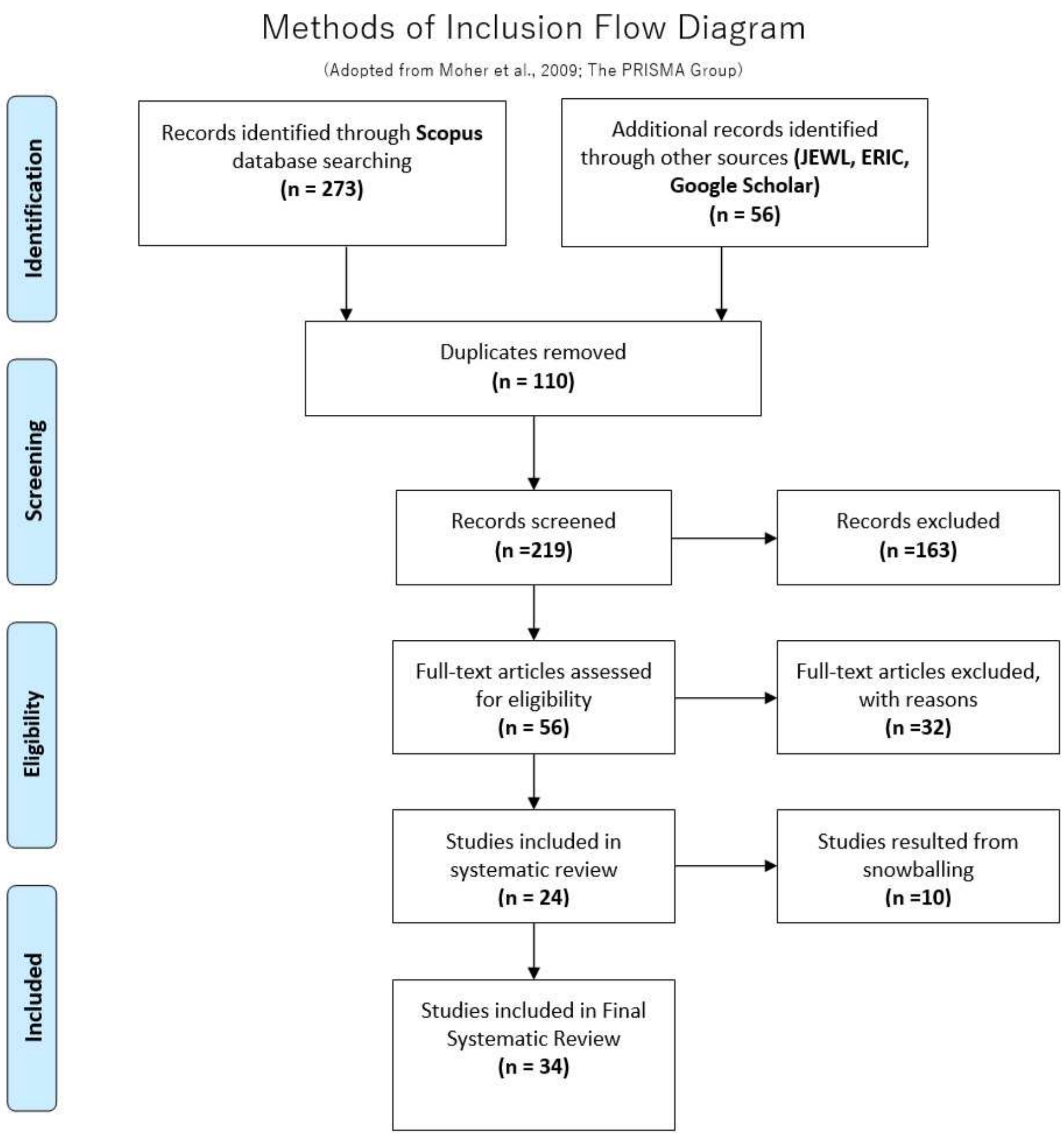
APPENDIX A: Methods for Article Inclusion Flow Diagram



APPENDIX B: Summary of Studies Reviewed: Location of study, methods, data sources, level of analysis, and purpose.

	Author(s)	**Location of Study**	**Methods**	**Data Source**		**Level of Analysis**	**Rationale of Study**
				SAL Instrument	**Other**		
1	Balasooriya et al. (2009)	Australia	Mixed methods	SPQ	Interviews	Course: Medical	**I**
2	Belzer et al. (2003)	United States	QUAN	MSLQ		Course: Concepts in Biology-Zoology	**C, I**
3	Buchwitz et al. (2012)	United States	Mixed methods		Test Scores & Focus Groups	Program/ Institutional	**I, D**
4	Chiou et al. (2012)	Taiwan	QUAN	ALB		Student Majors	**V, C**
5	Davidson et al. (2019)	Malaysia	QUAN	ALSI + ASSIST	The Big Five inventory, LSQ, ETLQ	Course- Pre-Biology	**C**
6	Dye et al. (2017)	United States	QUAL			Course: Cell Biology	**D**
7	Geller et al. (2018)	United States	QUAN	Hartwig & Dunlosky (2012)	Achievement Goals Questionnaire GPA	Course: Introductory Biology	**C**
8	Gouvea et al. (2019)	United States	Mixed methods		Interviews	Course: 3 Adv. Bio	**I**
9	Hazel et al. (2002)	Australia	Mixed methods	SPQ	OE questionnaire s, Concept Maps, Interviews	Task: Concept Maps & OE questionnaire	**D, C**
10	Holschuh (2000)	United States	Mixed methods	Strategies Checklist	Open-ended Questionnaire	Course: Intro Biology	**D**
11	Hora & Oleson (2017)	United States & Canada	QUAL		Focus Groups	Course: Biology + STEM	**D**
12	Hoskins et al. (2017)	United States	QUAN		Concept maps, Exams, outlines	Institutional Initiative: Supplemental Instruction	**C, I**
13	Kieser et al. (2006)	New Zealand	QUAN	SPQ		Course: Dentistry, Oral biology	**I**
14	Knight & Smith (2010)	United States	Mixed methods		BioClass, Observations, online survey, OE questionnaire.	Course: Genetics	**D ,C**

15	Kritizinger et al. (2018)	South Africa	QUAN	MSLQ		Course: Molecular & Cell Biology	**D**
16	Lee et al. (2016)	Taiwan	QUAN	ALB-Strategies		Student Majors	**V, C**
17	Lin et al. (2012)	Taiwan	QUAN	ALB		Student Majors	**I**
18	Metzger et al. (2018)	United States	Mixed methods	SMASH	Exam Wrappers	Unit	**V**
19	Micari & Light (2009)	United States	QUAL		Interviews	Program	**D**
20	Milner (2013)	Canada	Mixed methods	ASSIST	Open-ended questions, Visual Learning & cognitive skills	Course: Biochemistry	**V, C**
21	Minasian-Batmanian et al. (2005)	Australia	QUAL			Course: Biochemistry	**C**
22	Minasian-Batmanian et al. (2006)	Australia	QUAL			Course: Biochemistry	**C, I**
23	Quinn (2011)	Australia	Mixed methods	SPQ	Interviews	Topic: Cellular & Organismal Reproduction	**D**
24	Quinn & Stein (2013)	Australia	Mixed methods	SPQ	Interviews	Topic: Meiosis	**C**
25	Quinnell et al. (2012)	Australia	QUAN	SPQ		Course: Concepts in Biology	**D**
26	Quinnell et al. (2018)	Australia	QUAN	SPQ		Course: Introductory Biology	**C, I**
27	Rhodes & Rozell (2017)	United States	QUAN	SAL	Prior knowledge assessment, Unit Exams	Course: Intermediate Physiology	**C**
28	Rytkonen et al. (2012)	Finland	QUAN	ETLQ		Program/Department	**C**
29	Sebesta & Speth (2017)	United States	QUAN		Questionnaire	Course: Introductory Biology	**C, D**
30	Smith et al. (2019)	United States	Mixed methods	SMASH	Exam Wrappers	Unit	**D, C**
31	Stanton et al. (2015)	United States	QUAL			Course: Intro Biology	**D**

32	Tomanek & Montplaisir (2004)	United States	Mixed methods		Observations, pre/posttest, interviews	Topic: Cell Division	**D, I**
33	Watters & Watters (2007)	Australia	Mixed methods	SPQ	Interviews	Course: Biological Chemistry	**C**
34	Walker et al. (2010)	New Zealand	QUAN	ASSIST		Course Curriculum: Human Body Systems	**C, I**

NOTE: Rationale of Study: **(V)** Validation of new instrument (1-time), **(C)** Establish correlation (e.g., Student outcomes/ performance or student characteristics: gender, major, EBB, COLB, perceptions), **(I)** Determine Impact of curriculum change (Pre/post survey), **(D)** Descriptive (e.g., Learner profiles, frequency of strategies, categorization of strategies

APPENDIX C: Semi-Structured Faculty Interview Protocol

1. Please describe the general structure of your BIOL 1110 lecture.
    a. How many units, assignments, and exams are required?
2. How do you recommend students to study for your class?
    a. How much time do you recommend students study?
    b. What type of strategies do you feel will best prepare students for your course exams?
    c. What course materials do you provide to aid students in their study process?
3. Do you address study expectations with your students? If so, how?
    a. How often do you address study expectations with your students?
4. Do you believe students should study biology/ science differently than other subjects to maximize student outcomes?
5. What factors do you believe most influence how students' study for your class?
6. What can you students do to be most successful in your course?
7. How did you develop assessments to support student academic success?
8. Are you satisfied overall with the exam scores of this semester?
9. What changes would you make about the structure of your course if you could?
10. How would you define studying?
11. How would you define learning?
12. How would you define knowledge?
13. How would you define understanding?