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Transformative Pedagogy and Science Identity in Undergraduate Anatomy and Physiology

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TRANSFORMATIVE PEDAGOGY AND SCIENCE IDENTITY IN UNDERGRADUATE ANATOMY AND PHYSIOLOGY

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has been approved as meeting the requirement for the Degree of Doctor of Philosophy in the College of Natural and Health Sciences in the School of Biological Sciences, Program of Biological Education.

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ABSTRACT

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Anatomy and Physiology (A&P) courses are undergraduate biology prerequisite courses that cover many topics about human biology, including anatomy, histology, organ systems, and homeostasis. The purpose of the course is to equip students aiming to enter nursing and allied health education programs with an understanding of basic biological principles relevant to human biology and pharmacology. However, these courses have a high incidence of failure, and many students need to retake the course to progress in their competitive academic programs. Students tend to rely on memorization techniques to learn the course content, and given the nature of A&P as a discipline, this can be insufficient to achieve desired learning (i.e., mastery over the course content) and academic (i.e., course grades) outcomes in these courses. Thus, it is vital to identify evidence-based teaching practices and student factors that contribute to academic outcomes in this course. The three projects that compose the scholastic contribution of this dissertation collectively synthesize evidence-based teaching practices in A&P contexts, test how student affect factors (e.g., self-efficacy, science identity, and situational interest) impact student outcomes, and explore the experiences of students taking the class. The first project (Chapter II) is a systematic review that summarizes pedagogical interventions from 111 research articles about how A&P instruction impacts students' learning outcomes and satisfaction. The second project (Chapter III) uses mixed methods and found that in a sample of 83 introductory A&P

students, scores on a science identity metric predicted final grade in the course. The qualitative component of Chapter III also identifies emerging allied health identities alongside science identity as driving motivators for students repeating the course. The third project (Chapter IV) examines student experiences with A&P through the lens of transformative experience theory. This exploratory project examines student writing for evidence of students making connections between course content and their everyday lives using a mixed methods approach. Qualitative content analysis and epistemic network analysis reveal that students make salient connections between their interest in the course content, expansion of perception of the course content as relevant to their everyday lives, learning about A&P, and viewing the course content as relevant to their personal lives. In sum, these projects benefit A&P instructors and biology education researchers working to support student outcomes in A&P.

ACKNOWLEDGEMENTS

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There is a lot of invisible labor that goes into making a scientist, and I am incredibly grateful to my dissertation committee for investing guidance, collaboration, feedback, and mentorship as a part of my professional development. I am especially grateful to my research

advisor, Emily Holt, for her tireless advocacy and for bringing me into the biology education research fold. She has been pivotal in my journey from science person to scientist, has challenged me to grow beyond what I thought I could accomplish, and has been a constant source of support for both my teaching and research efforts. I am so grateful.

Finally, I would like to thank my husband, John, who committed to this adventure with me and has provided effusive support, made me coffee, and ensured there were French fries on bad days.

DEDICATION

I come from a family of talented teachers who masterfully model the art of the profession. The motivation behind my research sprouted from the compassion and authenticity that permeates their roles in their classrooms, offices, churches, homes, and anywhere where there is opportunity to kindly empower others to learn and grow. This dissertation is my investment in that legacy, which I dedicate to my Grandad, who (like me) always had too many projects but was particularly proud of this one.

TABLE OF CONTENTS

CHAPTER

APPENDIX

LIST OF TABLES

LIST OF TABLES, CONTINUED

LIST OF FIGURES

Figure

CHAPTER I

TEACHING AND LEARNING UNDERGRADUATE ANATOMY AND PHYSIOLOGY

Introduction

Undergraduate Anatomy and Physiology (A&P) courses are gateway prerequisite biology courses for students wishing to enter nursing and allied health fields (Brashinger, 2017). Like other introductory biology courses, A&P courses historically have high failure rates (Gultice et al., 2015). The topics within the course are challenging for students because of the high volume of specialized terminology that students rely on memorization to learn (Sturges & Maurer, 2013). Students and faculty agree that the nature of A&P as a discipline is challenging, especially in regards to causal reasoning, mathematical reasoning, and thinking about integrative systems (Michael, 2007; Slominski et al., 2019). These challenges face many instructors and students at universities and community colleges at a national scale, as numerous institutions offer A&P courses. Indeed, a sample of 20% of US higher education institutions (*n* = 1,600 course catalogs) revealed that 66% offered A&P courses (Royse & Tsosie, 2021). Understanding this student population is the underlying purpose of this dissertation, which includes investigations of pedagogy in A&P classrooms and students’ experiences in them.

Anatomy and Physiology Course Scope

Pedagogical innovations to teaching biology at the higher education level have been largely influenced by the Vision and Change Report (American Association for the

Advancement of Science [AAAS], 2011, 2018). The Vision and Change Report summarizes core concepts of biological disciplines broadly and student-centered pedagogical approaches suitable for teaching both science majors and non-majors (AAAS, 2011). The core concepts of biological literacy presented in Vision and Change have served as a starting point for identifying core concepts of physiology for use in undergraduate physiology classes (Michael & McFarland, 2011). While there are currently no published standards for core competencies in A&P, proposed themes (Hull et al., 2017) overlap with the Vision and Change and updated Core Concepts (Table 1.1).

Table 1.1

Comparing Core Concepts of Biology, Physiology, and A&P

Core Concepts for Biological Literacy (AAAS, 2011)	Core Concepts of Physiology (Michael & McFarland, 2020)	Key Ideas of A&P (Hull et al., 2017)
Evolution	Cell-Cell Communication	Adaptation
Information Flow, Exchange, and Storage	Cell Membrane	Barriers
Pathways and Transformations of Energy and Matter	Cell Theory	Causation and Correlation
Structure and Function	Energy	Communication
Systems	Evolution	Energy
	Flow Down Gradients	Enzymes and Chemical Reactions
	Genes to Proteins	Genes Code for Proteins
	Homeostasis	Gradients and Flow
	Levels of Organization	Homeostasis and Negative Feedback
	Mass Balance	Levels of Organization
	Physical Properties of Matter	Mass Balance
	Scientific Reasoning	Structure-Function
	Structure-Function	Water
	Systems Integration	

The key ideas outlined by Hull et al. (2017) illustrate how introductory A&P can differ from a physiology course for biology majors. As introductory courses, A&P courses may not have prerequisite course requirements, meaning that basic interdisciplinary science principles (i.e., the chemistry of water) may not be part of a students' understanding when entering an A&P course. Even in the scope of an introductory course, the nature of A&P as a discipline is challenging for students (Michael, 2007; Slominski et al., 2019), creating questions of how to support students in learning this content.

The Vision and Change Report outlines student-centered learning principles in addition to the core competencies described in Table 1.1 that apply to teaching both biology majors and non-majors. The pedagogical alternatives proposed by Vision and Change challenge the way biology has been traditionally taught in higher education. Instead of teaching biology primarily as a lecture, using cook-book style laboratory exercises that are divorced from real-world examples, Vision and Change proposes that designing courses with collaborative, inquiry-based activities and assessments offer an efficacious, student-centered approach to teaching biology (AAAS, 2011, p. 29-30). Indeed, Freeman et al. (2014) found that implementing student-centered learning practices improved course outcomes (i.e., exam scores) in multiple STEM courses. While aggregate syntheses of the efficaciousness of student-centered learning approaches are valuable, there is presently no synthesis of how A&P is taught. To improve student outcomes at scale, A&P learning environments must be researched to identify current pedagogical approaches and identify lines of inquiry to further refine these courses.

Student Population and Affect in Anatomy and Physiology

The population of students in A&P courses is largely nursing and allied health students, and the course does not typically serve biology majors (Griff, 2016; Royse et al., 2022). Previous research has demonstrated that A&P students have high extrinsic motivation for career goals and grade achievement (Finn et al., 2019; Sturges et al., 2016). Indeed, course grades in A&P can serve as a significant determinant of future educational opportunities, as programs often use science GPA in determining entry because it is a demonstrated predictor of performance in such programs (Al-Alawi et al., 2020). However, A&P grade distribution may not be equitable across demographic factors such as race and ethnic identity (Lindsay, 2020).

Students attribute their outcomes in A&P to a number of positive and negative affective factors (Johnson & Gallagher, 2021). Understanding the affect of A&P students has merit for addressing the challenges of A&P instruction and learning. One such student affective factor is science identity, which is predictive of persistence in STEM courses and careers (Cass et al., 2011; Estrada et al., 2011; Hazari et al., 2010). Indeed, calls for research investigating student affect note that such lines of inquiry are vital to improve student experiences and learning (Trujillo & Tanner, 2014) and thus warrant examination in A&P classrooms.

Project Descriptions

Institutional Context

The research included in this dissertation was conducted at the University of Northern Colorado. The University of Northern Colorado is an emerging Hispanic-Serving Institution, with 41% of the student population reporting they are first-generation students and 29% are eligible for Pell Grants (University of Northern Colorado, 2022). At the University of Northern Colorado, the two semester A&P course sequence has no prerequisite, though both courses are required prior to admission to the BSN Nursing Program (University of Northern Colorado, 2021). These courses follow national trends of having high drop-fail-withdraw rates (29% and 24% for BIO 245 and BIO 246, respectively; University of Northern Colorado, 2019).

Purpose of Projects

This dissertation outlines the findings of three projects, which identify instructor-oriented and student-oriented factors that influence student learning in A&P courses.

Chapter II: Evidence-Based Teaching Practices in Anatomy and Physiology

The aim of Chapter II is to systematically identify and summarize characteristics of peer-reviewed education research about A&P teaching practices and curriculum. In education research, conducting systematic reviews has the potential to form collaborations, define disciplines, and allow researchers to build off of one another (Bearman et al., 2012). Systematic review methodology was adopted early by medical and healthcare education communities (Bearman et al., 2012), but findings from medical and nursing education reviews (e.g., Daley & Torre, 2010; Hung et al., 2019; McVicar et al., 2014) may not be applicable to introductory A&P courses. Thus, Chapter II addresses the need for a synthesis of A&P teaching and curricular practices. Additionally, Chapter II evaluates the generalizability of findings from those studies that measured the efficacy of pedagogical intervention with learning outcomes. Health sciences education research broadly has been critiqued for historically focusing on student attitudes, and not learning outcomes (McVicar et al., 2014). Indeed, Jensen et al. (2018) noted student satisfaction with biology courses tends to be high in nursing education, even though grades and scores on standardized examinations are poorer than the high satisfaction would indicate. With this critique of trends in healthcare education literature in mind, Chapter II emphasizes how learning outcomes are presented in A&P education literature. The systematic presented in Chapter II addressing the research questions:

Q2.1 What are the characteristics of A&P education research investigating pedagogy?

Q2.1a. What are the institutional settings of and participant attributes in research studying A&P education?

Q2.1b. What types of pedagogy are evaluated in A&P education studies?

Q2.1c. What student outcomes are used to evaluate the success of A&P interventions?

Q2.2 How generalizable are A&P education research studies investigating quantitative learning outcomes?

Chapter III: Examining Student Affect and Experiences

Chapter III examines student performance and persistence in an introductory A&P course. This project used a mixed-methods approach to (1) predict academic outcomes (i.e., final grades) using various student factors and (2) examine the experiences of students retaking A&P courses. This project uses a social cognitive theory framework because biology education researchers have identified student affect as potential predictors of academic outcomes (Trujillo & Tanner, 2014). However, modeling the relationship between science identity and academic outcomes had not previously been explored in A&P. Additionally, little research has been conducted to explore the experiences of students retaking the course, despite the high drop-fail-withdraw rate (Gultice et al., 2015) and the proportion of retakers in the classroom (Schutte, 2016). Understanding why students retake the course and could offer insight into how students can be supported to meet their goals in the course. Thus, the aim of Chapter III is to examine student factors and experiences that may influence their academic outcomes (i.e., final grade) and persistence in A&P. The research questions addressed in this chapter are:

Q3.1 How do science identity, self-efficacy, and college course preparation predict academic outcomes for students enrolled in A&P courses?

Q3.2 What differences in student affect exist between re-takers (i.e., students retaking the course) and first-timers (i.e., students taking the course for the first time)?

Q3.3 Among re-takers, what experiences inform a student's decision to retake A&P, illustrate how they define science identity, and contextualize their academic and professional goals?

Chapter IV: Exploring Students' Transformative Experiences with Anatomy and Physiology

The project presented in Chapter IV is an exploratory study examining the transformative experiences of undergraduate A&P students. The theoretical framework of this study draws from transformative experience theory (Pugh, 2002, 2011), which posits that education should transform the way students view their everyday lives. For this project, "everyday lives" is interpreted through the lens of social ecologies theory (Bronfenbrenner, 1979), which proposes that people develop within multiple microsystems (i.e., communities like school, peer groups, and families) that interact with each other. In this study, A&P students' written reflections in response to the prompt, "How does what you learned in this unit relate to your life?" are analyzed first using qualitative content analysis. Then, epistemic network analysis (D. W. Shaffer & Ruis, 2017) is used to model the connections students make between A&P course content and their lived experiences. The questions addressed in this chapter are:

Q4.1 Which transformative experience elements and microsystems do students identify in written reflections about A&P topics?

Q4.2 What consistent connections do students make between transformative experience elements, microsystems, and A&P topics?

CHAPTER II

A SYSTEMATIC REVIEW OF UNDERGRADUATE ANATOMY AND PHYSIOLOGY EDUCATION: APPROACHES TO SUPPORTING AND EVALUATING STUDENT OUTCOMES

Contributions of Authors and Co-Authors

Manuscript in Chapter II

Author: Emily A. Royse

Contributions: Conceived study design, collected data, conducted all phases of the review (literature search, abstract screening, full-text screening, data extraction, and quality analysis), and wrote the initial draft of the manuscript.

Co-Author: Nicholas A. Pullen

Contributions: Contributed to study design, provided feedback on inclusion and exclusion criteria, contributed to full-text screening, and provided feedback on the manuscript.

Co-Author: Andi Cogswell

Contributions: Assisted in data collection, organization, and full-text screening phases.

Co-Author: Emily A. Holt

Contributions: Conceived study design, contributed to full-text screening, data extraction, and quality analysis phases, and provided feedback on the manuscript.

Abstract

Human Anatomy and Physiology (A&P) courses are essential prerequisites for upper-level coursework in nursing and allied health degree programs. However, studies in the UK, Australia, and US document difficulties nursing and allied health students face when learning A&P course content. Thus, a comprehensive analysis of pedagogical approaches to meet the needs of students in A&P courses is warranted. In this systematic literature review, we identified 111 journal articles published between 1969 and 2018 that describe A&P pedagogy and student outcomes in those courses. We extracted data about the research methods, institutional contexts, and student outcomes, and then described pedagogies and assessed the generalizability of findings about student learning outcomes. The results of our content analysis highlight the importance of alignment, formative assessment, modeling practices, and inquiry in A&P courses. The results of our generalizability assessment revealed that most studies in A&P were longitudinal, included comparison groups, and used simple inferential statistics. Grounded in the findings of our content and generalizability analysis, we propose future lines of inquiry to enrich existing evidence about pedagogical interventions in A&P courses.

Introduction

Human Anatomy and Physiology (A&P) courses lay the foundational framework for health sciences education. Students aspiring for careers in health sciences fields, including medicine, pharmacy, dentistry, nursing, and allied health (e.g., dietetics, dental hygiene, radiologic technology, and physical therapy; Committee to Study the Role of Allied Health Personnel, 1989) take coursework discussing A&P topics at many points during their formal and continuing education. The context we refer to as *A&P courses* refers specifically to undergraduate introductory biology courses for non-STEM, nursing, and allied health majors that are prerequisites for entering undergraduate educational programs or beginning clinical studies. They traditionally have high drop-fail-withdraw rates (Gultice et al., 2015) leading to a high proportion of repeat enrollments (Schutte, 2016). The preponderance of scientific terminology in A&P course content promotes memorization-focused study practices, which undermine mastery of complex systems in the human body (Johnson & Gallagher, 2021; Michael & McFarland, 2011; Slominski et al., 2019; Sturges & Maurer, 2013). However, study behaviors are not isolated determinants of learning in A&P courses. Evaluating the pedagogical and curricular practices in A&P courses is vital to supporting students. A compilation and synthesis of evidence-based practices, specific to these courses, can inform their design.

Evidence-based teaching practices are defined as pedagogical strategies investigated using scientific methods (Handelsman et al., 2004). In undergraduate biology education broadly, these practices include integrating frequent assessment and active learning to promote more equitable and stable learning outcomes (AAAS, 2011; Freeman et al., 2014). Research investigating evidence-based teaching practices in A&P courses appears limited when compared to other health sciences education contexts (Griff, 2016). For example, medical and nursing schools have journals dedicated to publishing work about education research in those fields (e.g., *Academic Medicine*, *Nurse Education Today*). Medical schools in particular have a robust history of educational innovation supported by research, including the development of problem-based learning curricula (PBL; Hung et al., 2019) and computer-assisted instruction (McGowan & Berner, 2002). Nursing is also renowned for educational innovations, such as teaching evidence-based practice, which links nursing theory and practice (Mackey & Bassendowski, 2017). However, innovations developed for and research investigating specific training in physician or advanced nursing practice may not translate to undergraduate A&P settings. Indeed, testing such innovations in A&P courses would be necessary to evaluate their efficacy for undergraduate students in introductory courses.

While individual research studies exist that investigate efficacy of teaching practices in A&P courses (e.g., P. J. P. Brown, 2010; DeHoff et al., 2011; O’Byrne et al., 2008), a synthesis of education research in these courses is needed to summarize teaching innovations in these courses. Education research is critical in generating evidence for efficacy and generalizability of teaching practices (National Research Council, 2012), especially teaching practices for diverse student populations. A&P courses reach a large number of students, as they are offered at both community colleges and four-year institutions. However, community colleges are historically under-represented in biology education research (Lo et al., 2019; Schinske et al., 2017) and enroll more students from minoritized groups than four-year institutions (American Association of Community Colleges, 2021), thus indicating the need to include these institution types in a review of A&P pedagogy. Analytic and systematic reviews are well suited for summarizing research in health sciences education contexts such as A&P courses (Bearman et al., 2012), as evidenced by existing reviews about concept mapping in medical school (Daley & Torre, 2010), PBL in medical curricula (Hung et al., 2019), and nursing school curricula (McVicar et al., 2014). Additionally, evaluating the methodological rigor of existing studies is important for assessing the generalizability for these studies, and thus inferring whether teaching innovations would be applicable to a larger sample of A&P students, a population we know is diverse.

Study Purpose and Research Questions

We chose to perform a systematic literature review of education research conducted in A&P courses to summarize existing research and identify gaps in the research (Tight, 2018). We defined A&P courses as any undergraduate introductory biology courses for non-STEM, nursing, and allied health majors. The goals of this systematic literature review were to identify peer-reviewed A&P education research, summarize the pedagogies and student outcomes described in those studies, and evaluate the generalizability of existing research. Our research questions were:

Q2.1 What are the characteristics of A&P education research investigating pedagogy?

  Q2.1a. What are the institutional settings of and participant attributes in research studying A&P education?

  Q2.1b. What types of pedagogy are evaluated in A&P education studies?

  Q2.1c. What student outcomes are used to evaluate the success of A&P interventions?

Q2.2 How generalizable are A&P education research studies investigating quantitative learning outcomes?

Methods

Systematic Review Methodology

To answer our research questions, we used a systematic literature review methodology, which synthesizes findings from research that meet detailed inclusion criteria, using rigorous methods to search and vet the resulting compilation of literature (Gough et al., 2012). The protocol for this review was in the style of Cochrane systematic reviews (Higgins, 2019), which included the development of inclusion and exclusion criteria, search process, data collection and synthesis, and quality appraisal. We aimed to synthesize findings from peer-reviewed research that analyzed quantitative or qualitative student data to evaluate pedagogical or curricular components of A&P courses. As a part of the search process, we systematically searched six databases (PsycInfo, ProQuest, PubMed, Medline, Cumulative Index of Nursing and Allied Health Literature [CINAHL], and Web of Science) to find peer-reviewed education research conducted in undergraduate A&P courses published through December 31, 2018. We used the same Boolean search terms in each database to find sources that potentially met our inclusion criteria (see Table 2.1). Additionally, we included all research articles published in the *HAPS Educator* journal volumes from 2016 through 2018. While the scope of this journal includes research conducted in undergraduate A&P courses, it was not indexed at the time of this review and its articles would not otherwise have been included as part of our standard database search process. The date bounds of articles within *HAPS Educator* differ from other articles in our query because peer-review was an inclusion criterion and *HAPS Educator* articles did not undergo peer-review until 2016.

Table 2.1

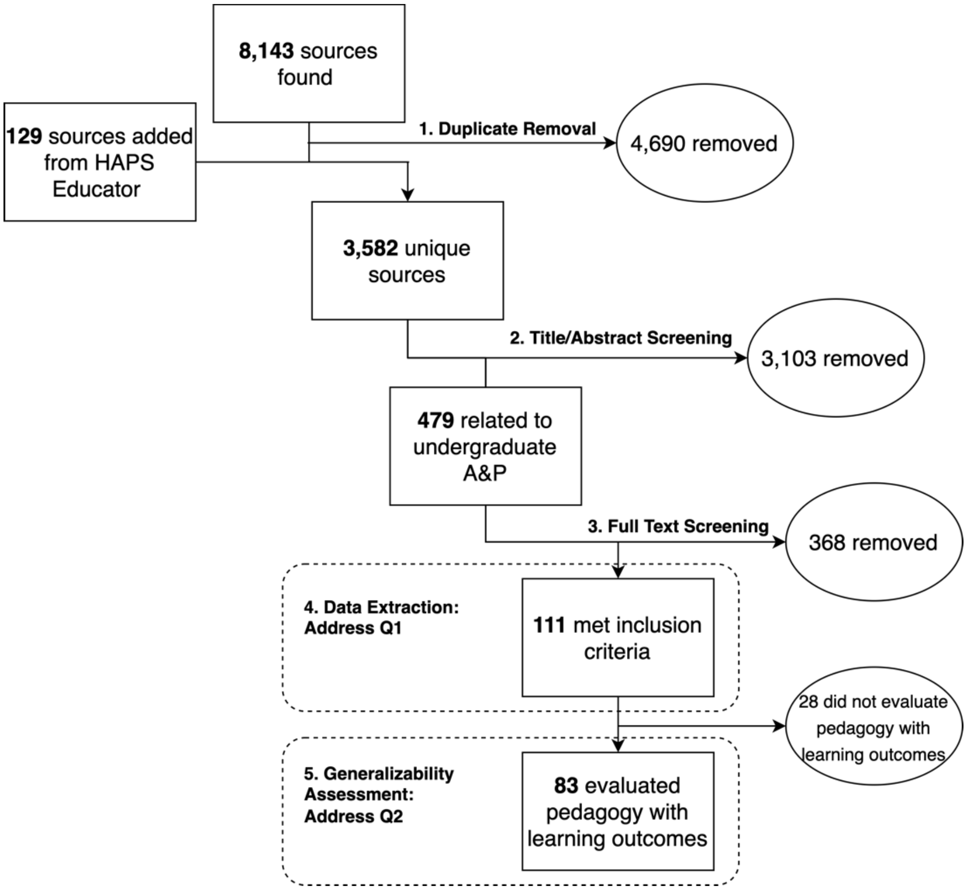
A Priori Criteria and Search Terms for the Systematic Search and Screening of Articles

Search and Screening Criteria	**Description**
Search Terms	[("anatomy and physiology" OR "human anatomy") AND (educat* OR "education research" OR curricul* OR pedagog* OR "allied health" OR instruct* OR activit* OR teach* OR "teaching methods")] OR [("homeostasis") AND (educat* OR "education research" OR curricul* OR pedagog* OR "allied health" OR instruct* OR teach* OR "teaching methods")]
Inclusion Criteria	Research included must meet all of the following: • Conducted in undergraduate A&P courses or course sequences at four-year or two-year institutions • Students identified as allied health, nursing, or non-biology majors • Published in academic journals • Peer-reviewed • Empirical (including quasi-experimental, qualitative, quantitative, and mixed methods research) or descriptive methodologies utilized
Exclusion Criteria	Research meeting any one of the following criteria was excluded: • Student data not systematically collected and reported • Does not describe a pedagogical or curricular component of the course context

The tiered approach of the search and screening processes, and the number of articles that passed each benchmark, is illustrated in Figure 2.1. After compiling the search results from all databases and all peer-reviewed *HAPS* articles, we manually removed duplicate citations and retracted citations. The number of duplicates we removed was in line with overlap commonly reported in systematic reviews (Rathbone et al., 2015). The remaining articles were uploaded into Covidence, an online software tool to facilitate the systematic review process (Covidence systematic review software, n.d.), where additional duplicates were removed and the next phases were conducted. One researcher screened titles and abstracts, removing articles unrelated to undergraduate A&P courses (including high school and medical school populations). Two members of the research team independently conducted the full-text screening of all articles that passed the previous phase to remove articles that did not meet all inclusion criteria (e.g., the population was not undergraduate allied health, nursing, or non-biology majors) or met one of the exclusion criteria (Table 2.1). To meet the pedagogical or curricular component description criterion, we required that the article describe or evaluate of one of the following: assessment, activities completed during the class time, learning objectives, or assignments completed by students. Descriptions of curricular approaches (e.g., PBL or process oriented guided inquiry learning), specific practices (e.g., test-retest interventions), and student activities (e.g., dissection exercises) all broadly met this criterion. In contrast, articles solely describing the credit hours, course topics, and division of time spent in lab/lecture were excluded for meeting the exclusion criteria. In cases of disagreement during the full-text screening phase, a third member of the research team acted as a tiebreaker.

Figure 2.1

Tiered Screening Process Flowchart



Data Extraction

The data extraction step of our analysis aimed to address Q2.1. First, we extracted information from the finalized set of studies to describe the study context, including institution type, country in which the research was conducted, and demographic data of student participants (Q2.1a). Second, we extracted data from our finalized set of studies to summarize the types of pedagogies assessed in A&P education research (Q2.1b). We used content analysis to organize articles into type of pedagogy (Gough, 2007). We began the pedagogical analysis using categories from the Vision and Change Report, including learning objectives, assessments, and instruction (AAAS, 2011). We defined learning objectives as measurable goals for student learning of A&P content knowledge. Assessments could include formative or summative measures to qualify student learning, using a variety of modalities. Instruction could include multiple elements of the course delivery, course design, or student activities. Given our experience with pedagogical interventions in biology education research, we parsed instruction into several finer categories. We created an out-of-class activity category (Assignment) and a category describing activities completed during scheduled class meetings (In-class Activity) to differentiate learning exercises completed with different levels of instructor supervision. Alternately, studies that evaluated course delivery, organization, or assessment involving multiple changes or changes that occurred multiple times during the course were coded as Curriculum. During the full-text screening phase and coding for this research question, we noted several articles describing optional resources (e.g., computer-based anatomy atlases) as part of pedagogical intervention, and studies investigating instruction given outside of class meeting times that were not independent assignments. Therefore, Resource and Supplemental Instruction categories, respectively, were added into our data extraction codebook to better describe these studies. The final codebook for Q2.1b included seven elements (Learning Objectives, Assessment, Assignment, In-class Activity, Curriculum, Resource, Supplemental Instruction; see Table 2.2).

Table 2.2

Definitions of Each Pedagogy Type Code

Pedagogy Type	Definition
Learning Objectives	Describes development or evaluation of learning objectives (i.e., student content knowledge).
Assessment	Implementation of formative or summative assessments, both inside and outside of class meeting times.
Assignment	Learning activities assigned for students to complete outside of class meeting times, either individually or in groups.
In-class Activity	Learning activities completed during class meeting times, either individually or in groups.
Curriculum	Pedagogical innovations impacting multiple instances of course delivery, organization, or assessment.
Resource	Intervention based on non-compulsory tools to aid in student learning.
Supplemental Instruction	Interventions taking place as instruction given outside of class meeting times.

To address Q2.1c, we conducted an additional content analysis of our dataset to summarize the types of student outcomes measured in A&P education research. We deductively coded articles into whether the researchers systematically collected and reported student data that were learning outcomes, satisfaction outcomes, outcomes that did not fall into either category, or a combination of different outcomes. We defined a learning outcome as an outcome relating to A&P content skills or knowledge. Meanwhile, satisfaction outcomes are related to students' enjoyment, interest, or perceived utility of the course. Examples of outcomes that fit neither of these categories were perceived learning, student engagement (e.g., study behaviors or attendance), and other cognitive constructs (e.g., empathy or test anxiety). Because so few studies in our sample measured these other outcomes, we did not differentiate this category further. We also noted the research instruments used to measure those outcomes (e.g., exam grades, final grades, validated psychometrics).

Generalizability Assessment

While the purpose of the data extraction phase was to address Q2.1 and describe pedagogical interventions and study contexts used in published A&P education research, the generalizability assessment addressed Q2.2. We aimed to summarize how generalizable the findings from our final set of studies are to broader applications. Traditionally in Cochrane-style systematic reviews, this analysis is referred to as quality assessment, though we use *generalizability assessment* to describe the purpose of this phase in our study. We adapted assessment criteria from Martin et al. (2019) outlining markers of methodological rigor in quantitative research (Table 2.3). The criteria include markers of generalizability such as sampling robustness, statistical modeling techniques used to relate independent and dependent variables, and statement of limitations. Most criteria were scored as meeting (+1) or not meeting (+0), with the exception of statistical modeling techniques. For this criterion, regression was weighted more heavily (+3) than other inferential statistics, such as correlation (+2) and t-tests (+1). Regression is scored highest because it accommodates both continuous and categorical data and estimates the effect of independent variables on the dependent variable using predictive modelling.

We only evaluated studies that we coded as using learning outcomes from the data extraction phase in the generalizability assessment. Our decision to use only this subset of studies (86 of the final 111 studies) was because these studies reflect student learning as the generalizable goal behind education as a whole and therefore were most relevant to Q2.2. We then assessed the research methods (qualitative, quantitative, or mixed methods) for each article in this phase. Due to low number of qualitative (n = 1) and mixed methods studies that addressed student learning outcomes (n = 1), coupled with the fact that most qualitative approaches do not aim to be generalizable (Carminati, 2018), we only analyzed articles with quantitative analyses (i.e., full quantitative designs and the quantitative portion of mixed methods designs; *n* = 83).

One member of the research team completed the Data Extraction and Generalizability Assessment for all included articles, and 20% of the scores were checked for agreement of consistency with the rubric by another member of the research team. Final point values for each level of the generalizability criteria were summed into a final generalizability score for each article. A higher score indicated an article used multiple methodological elements which make it more generalizable to a larger sample. However, we do not interpret higher-scoring articles as “better” in this review; instead we argue rather they used methodology to promote generalizability beyond the sampled population, which can be critical in interpreting trends across many articles.

Table 2.3

Generalizability Assessment Rubric (Adapted From Martin et al., 2019)

Generalizability Marker	Criteria	Response	Points
Sampling Robustness	What was the institutional setting?	Statewide or multiple institutions	+1
		One institution	+0
	What was the sample size?	Sample size equal or above 300 participants	+1
		Sample size below 300 participants	+0
	Was there a comparison group?	Comparison group	+1
		No comparison group	+0
	Was the study a longitudinal design (i.e., data at multiple times for at least one cohort of students)?	Yes, it was a longitudinal study.	+1
		No, it was not a longitudinal study.	+0
	Did the study examine multiple cohorts?	Yes, it was multiple cohorts.	+1
		No, it was not multiple cohorts.	+0
Modeling Technique	What method(s) were used to test relationship(s) between learning outcomes and independent variables?	Regression	+3
		Correlation	+2
		T-test, ANOVA, or chi-square analysis	+1
		Descriptive analysis	+0
Limitations Stated	Did author describe the limitations of the study’s findings or methods?	Yes	+1
		No	+0

Results

Sample Settings and Participants

As illustrated in Figure 2.1, 111 articles met our inclusion criteria and were considered for data extraction. While the research presented was primarily conducted in the United States (*n* = 78), Australia (*n* = 12) and Canada (*n* = 9) were represented along with the UK, New Zealand, Brazil, Italy, and Malaysia. The greatest proportion of journal articles were found in *HAPS Educator* (*n* = 26), *Advances in Physiology Education* (*n* = 22), and *Anatomical Sciences Education* (*n* = 17). A few studies were conducted in multiple institutional contexts, though the most common institutional setting was public four-year institutions (*n* = 58, either exclusively or as one of the contexts), followed by community colleges (*n* = 18), unspecified four-year institutions (*n* = 18), and private four-year institutions (*n* = 13).

All papers reported the majors or career objectives of the students of their population of interest, but we found most did not quantify the distribution of students per major in their sample (*n* = 76). Additionally, few articles reported race and/or ethnic identity data from their sample (*n* = 5) and only two articles reported first-generation student status. Of the five articles reporting race and/or ethnic identity data, the sample of three of the studies was primarily white. The samples of both studies reporting first-generation student status were primarily continuing generation students. However, 27 of the research articles in our sample reported gender distribution of their participants. In every instance where gender was reported, the majority of students in the sample were identified as female or women, with the proportion reported ranging from 53.7% to 91.7% women, and only three studies reporting a proportion of women under 60%.

Pedagogy Types

No articles in our sample investigated A&P learning objectives (*n* = 0), thus this category of pedagogical innovation was not analyzed further. The most common pedagogy types in our sample were Curriculum (*n* = 34), In-class Activity (*n* = 23), Assessment (*n* = 17), and Resource (*n* = 17), with Assignment (*n* = 11), and Supplemental Instruction (*n* = 9) found less often.

The Curriculum category was likely enlarged by the number of laboratory activities assessed, which was not surprising given the ubiquity of laboratory course components in A&P curricula. Anatomy-focused lab activities included cadaveric prosection demonstrations (Barton et al., 2018; Dunbar & Nichols, 2012; Saltarelli et al., 2014), clay modeling and animal dissections (Anderton, Chiu, & Aulfrey, 2016; DeHoff et al., 2011; Haspel et al., 2014; Motoike et al., 2009; Vitali et al., 2020; Waters et al., 2005, 2011), or use of plastic models (Johnston & McAllister, 2008; McDaniel & Daday, 2017). Inquiry-focused lab curricula were also described in our sample, especially as approaches for teaching physiological concepts (Casotti et al., 2008; Harrison et al., 2001). Case studies were sometimes integrated within collaborative inquiry activities, such as process-oriented guided-inquiry learning (POGIL; P. J. P. Brown, 2010; Rathner et al., 2013) and PBL (Bevan et al., 2015; Mayner et al., 2013). A&P lecture formats, such as flipped classroom interventions and hybrid instruction, were also coded to the Curriculum category (Eleazer & Scopa Kelso, 2018; Entezari & Javdan, 2016; Hopper, 2016; Kuyatt & Baker, 2014; Rosli et al., 2017). While studies coded as Curriculum described many types of interventions, every study coded in this category described approaches to instruction impacting multiple facets of course delivery and activities.

The second most common pedagogy type in our sample was In-Class Activity. The studies coded to this category assessed a variety of different activities that occurred during class meetings. In-class Activities in our sample included writing exercises (Carnegie, 2012; Crowther et al., 2017; Petzold et al., 2016), discussion exercises (Dearden & Anderson, 1969; Geuna & Giacobini-Robecchi, 2002; Sturges et al., 2009; Yucha, 1995), diagraming and modeling activities (Guy et al., 2017; Petto et al., 2017; Salvage-Jones et al., 2016; Slominski et al., 2017), and specific lab activities (e.g., spirometry; Wolf et al., 2015). Lab activities were coded as In-Class Activities if they were used to teach specific topics over a short period of time (i.e., a few class sessions). In contrast, lab activities were coded as Curriculum if they impacted full units of instruction impacting other course activities (i.e., assessment or out-of-class assignments).

The third most common pedagogy types were Assessment and Resources. An important trend included incorporating formative assessments in the course. The Assessment code captured examples of non-compulsory online quizzes (Utz & Bernacki, 2018; Van Nuland et al., 2015) and required quizzes (G. A. Brown et al., 2015; Dobson, 2013; Gannon & Abdullahi, 2013). The use of "clicker questions" in our sample (i.e., polling questions delivered in-class through the use of Audience Response Systems), were also a frequently coded form of Assessment (FitzPatrick et al., 2011; Stein et al., 2006; Termos, 2013). Studies coded to Resources described several digital and analog tools made available to students. Digital resources included the use of digital anatomy atlases (Chakraborty & Cooperstein, 2018; Guy et al., 2015, 2018; O'Byrne et al., 2008; Yeom et al., 2017) and class websites (Gopal et al., 2010; S. M. Green et al., 2006; Johnston et al., 2013). Studies investigating textbooks and supplements to textbooks were also coded as resources, and included commercially available (Dunn-Lewis et al., 2016; Raynor & Iggulden, 2008) and instructor-authored texts (Hutchinson et al., 2017; Hutchinson & Elbatarny, 2016; Rae, McGoey, et al., 2017; Rae, Newman, et al., 2017; Reuter & Weiss, 2017).

Assignment and Supplemental Instruction were less frequent pedagogy types found in our sample of articles. Assignments reflected types of activities students completed outside of class, either individually or in groups. The two most common types of assignments were centered around either case studies or evaluating scientific research. Case studies of clinical scenarios were often implemented to activate student interest through realistic health applications (Cliff & Wright, 1996; Ediger, 2017; Hilvano et al., 2015), and research-oriented projects were designed to increase familiarity and confidence in scientific literature (Bentley et al., 2015; Crisp et al., 2007; Hurtt & Bryant, 2016). The Supplemental Instruction code in our sample referred to structured peer-learning and tutoring sessions (de Oliveira et al., 2015; Hughes, 2011, 2018), instructor-led non-compulsory instruction conducted outside of class (Rompolski et al., 2018). The Supplemental Instruction code was also used for studies describing concurrent courses and pre-semester workshops, which were designed for remediating students or students identified as benefitting from additional supports (Abdullahi & Gannon, 2012; Hopper, 2011; Owens & Moroney, 2017).

Student Outcomes

In our sample, 29 studies reported student data in the form of learning outcomes only, 16 reported satisfaction outcomes only, five reported outcomes other than learning and satisfaction exclusively, one reported a mix of satisfaction and other non-learning outcomes, and 60 reported a mix of both learning and other outcomes. The majority of studies included at least one learning outcome in their analysis (*n* = 89), most commonly in the form of exam, quiz, or assignment scores (*n* = 55) or final grades (*n* = 26). Satisfaction outcomes included multiple attitudes about the course that were not necessarily defined in the articles as a specific construct, including enjoyment, interest, perceived helpfulness, perceived relevance, or usability (see Table 2.4 for example questionnaire items for each attitude). Of the 68 studies reporting satisfaction outcomes, 65 measured the outcomes using non-validated questionnaires. Other outcomes represented in our sample included perceived learning (*n* = 3), test anxiety (*n* = 1), confidence (*n* = 1), and study behaviors (*n* = 4).

Table 2.4

Sample Items Measuring Facets of Satisfaction

Satisfaction Attitude	**Sample Questionnaire Item**
Enjoyment	"Did you enjoy the clay modeling?" (Haspel et al., 2014)
Interest	"I was able to find a topic that was interesting to me personally." (Ediger, 2017)
Perceptions of helpfulness	"The interactive nature of the activity facilitated my learning of the content area." (Sturges et al., 2009)
Perceptions of relevance	"How relevant was the experience to your study of anatomy and physiology?" (Johnston, 2010)
Usability	"Was it easy to use the system to explore the anatomical region?" (Yeom et al., 2017)

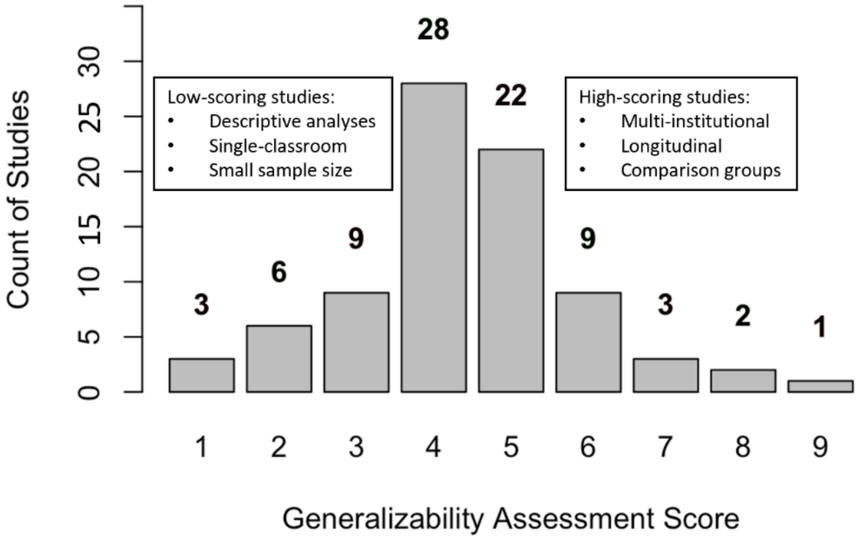
Generalizability Analysis

The majority of the studies in our sample were quantitative (*n* = 92), followed by studies that utilized mixed methods (*n* = 15), and studies that were strictly qualitative (*n* = 4). Of these studies, 89 reported a learning outcome (quantitative = 76, qualitative = 1, and mixed methods = 12). The qualitative portion of most mixed methods studies (*n* = 10) focused on student perceptions and not student learning outcomes. Of the two remaining mixed methods studies, one transformed the qualitative data into a quantitative score, and the other blended the results of the quantitative and qualitative data. This second study and the qualitative study did not progress to the generalizability analysis stage.

Of the subset of studies that quantitatively measured a learning outcome, 83 studies used the learning outcome to evaluate a pedagogical or curricular component of the course. These 83 studies were our sample for the generalizability analysis phase of the systematic review. As described in Table 2.3, the generalizability assessment score reflected weights based on the number of discrete campuses from which data were collected, the number of participants, the presence of a comparison group, the collection of longitudinal data, the collection of data from multiple cohorts, the complexity of analysis, and the discussion of limitations. The potential score range was 0 to 9, with the majority of studies scoring 4 or 5 (Figure 2.2).

Figure 2.2

Generalizability Assessment Score Distribution



The generalizability assessment criterion adding the greatest number points to the generalizability assessment score was the use of statistical analysis tools (see Table 2.3). The statistical analyses used by researchers in our sample were most often comparisons of means or frequencies (e.g., t-test, ANOVA, or chi-square test; *n* = 62), followed by descriptive comparisons (*n* = 10), correlation (*n* = 6), or regression (*n* = 5). Lower scoring studies tended to be single-classroom interventions with small sample sizes, which are less generalizable to the larger A&P student population. In our sample, all studies scoring three points or fewer were from single institutions, half used descriptive analyses only, and only three discussed limitations. Higher scoring studies often included multiple cohorts and institutions, and subsequently had larger sample sizes. Studies scoring six or higher in our sample all stated limitations, were longitudinal studies, and had comparison groups. Of the five studies sampling from multiple institutions in our entire dataset, four were in this group. Additionally, all four instances of regression analyses were in this group.

Discussion

The aims of this systematic review were to summarize existing peer-reviewed research about A&P education and to identify potential needs warranting future investigation. The articles included in our sample described diverse teaching practices and used a range of methods to evaluate the efficacy of those practices in undergraduate A&P courses.

Teaching Practices in Anatomy and Physiology

The largest category of pedagogical interventions in our sample was Curriculum, which encompassed multiple changes to course activities, assessment, and delivery. While a breadth of teaching practices was represented in our sample, the common approaches included inquiry practices, clinical case studies, and modeling exercises. Modeling exercises were also prevalent outside the Curriculum code. We identified examples of modeling activities in In-class Activity and Resource codes as well, indicating their importance in A&P teaching. In addition to the articles included in our sample, we noted several papers during our initial search phase that described the development of digital models, atlases, and simulations. These were removed during screening because student data were not reported or were only reported for non-A&P students. Future work is warranted to determine the efficacy of such tools for undergraduate A&P students.

Compared to the spectrum of curricular interventions, we found relatively few studies exploring out-of-class assignments, resources, and supplemental instruction in A&P contexts. From an education research standpoint, this could be because it is difficult to evaluate the effect of non-compulsory activities or activities that take place outside the bounds of a classroom, as the researcher is unable to observe the activity. However, we posit that the efficacy of supplemental instruction warrants further investigation. Corequisite supplemental instruction is an effective approach in higher education math contexts for providing remedial support to students (Boatman, 2021; Logue et al., 2019). As high DFW and high remediation rates are endemic in A&P contexts (Gultice et al., 2015; Royse et al., 2020; Schutte, 2016), more pedagogical investment and research evaluation is warranted to determine the efficacy of supplemental instructions for students in these course.

While this systematic review identified multiple types of pedagogical innovation in A&P, we caution that future work is required to determine the strength of effect of beneficial teaching practices. Our purpose in compiling these numerous studies was to synthesize the approaches that have been tested in the A&P classroom and measures to evaluate their efficacy. It is out of the scope of this review to assess the strength of effects of A&P interventions. However, meta-analyses of specific practices in A&P are needed in the future to better inform innovation in A&P education. Meta-analyses about specific practices (e.g., modeling exercises in A&P laboratories) would be especially useful for addressing questions about how to allocate resources in these classes to best support students' learning outcomes. Such analyses could also move beyond asking whether interventions work to investigating the mechanisms behind learning A&P. We note that these future directions will need to account for the multiple measures of student outcomes, as they were not equivalent in our sample and learning objectives were not commonly described as the basis of assessment.

Assess Student Learning with Learning Outcomes

At the onset of this review, we wondered how the outcomes measured in A&P education research would align with other health sciences contexts. Reviews of education research in both medical and nursing contexts suggest this research tends to be limited by the lack of learning outcomes reported (Jensen et al., 2018; Vorstenbosch et al., 2011). In contrast, we found the majority of studies about A&P courses did report student learning outcomes (*n* = 89), most often as exam grades or final grades. Unfortunately, exam and final grades can be unreliable data about student learning, due to documented equity issues with multiple choice exams (C. D. Wright et al., 2016) and the subjective nature of what contributes to a final grade based on instructor preference or curving practices (Bygren, 2020; Schinske & Tanner, 2014). Alternatively, concept inventories may provide a robust route to assess student conceptions about A&P content, rather than exams and final grades that pool knowledge with measures of effort. Further, concept inventories undergo more extensive validity and reliability testing than a standard exam (e.g., the Homeostasis Concept Inventory; McFarland et al., 2017).

Over half of the works (*n* = 68) in this investigation included satisfaction metrics to evaluate A&P instruction. Asking students to rate satisfaction across a single scale may not capture satisfaction accurately (Elliott & Shin, 2002), but the majority of studies in our sample used non-validated measures styled in this way. Additionally, satisfaction in an educational experience is rooted in student expectations and preferences, and is impacted by multiple institutional and student characteristics (H. J. Green et al., 2015). Student satisfaction thus reflects the alignment of students' expectations with their assessment of teaching, not necessarily their learning (Wiers-Jenssen et al., 2002). Indeed, the multiple articles in our sample that reported both learning and satisfaction outcomes did not consistently report that satisfaction was related to higher learning outcomes (Anderton, Chiu, & Aulfrey, 2016; O'Byrne et al., 2008; Rudolph et al., 2018; Salvage-Jones et al., 2016; Stein et al., 2006; Sturges et al., 2009, 2017; Sugrue et al., 2017; Zitzner, 2017). Given these discrepancies between learning and satisfaction, we posit that future investigations may contribute most by prioritizing assessment of learning-focused outcomes instead of satisfaction.

Aim for Greater Generalizability in Future Anatomy and Physiology Education Research

Our generalizability assessment identified room for growth in future A&P education research. We recommend that future work aim to replicate and pedagogical innovations in multiple contexts. While the articles gathered in our search included international and multi-institutional projects, community college contexts and multi-institutional studies were underrepresented in our sample. Studies conducted at community colleges were less common than four-year institutions (*n* = 18 and 87, respectively), mirroring the trend that these contexts are underrepresented in biology education research as a whole (Lo et al., 2019; Schinske et al., 2017). The only article in our sample using multiple institution types identified differences in intervention efficacy between institutional settings (Griff & Matter, 2013). Thus, testing interventions in multiple contexts with multiple cohorts will help inform the generalizability and feasibility of implementing pedagogical interventions.

Additionally, while not formally part of our generalizability assessment rubric, the dearth of reported demographic data we discovered during data extraction is problematic for describing representation in A&P courses. Less than one-third of our sample of articles reported the demographics of the participants. Further lack of disaggregation by demographics perpetuates a dominant identity experience as the “universal” experience (Hammer, 2011). Reporting and disaggregating findings by demographics can help untangle how interventions may be differentially aiding some students and not others (Connelly, 2013) and enrich demographic analysis beyond simplified, often inaccurate, panethnic groupings (Bhatti, 2021). This consideration is especially important when examining pedagogical intervention, as curricular structures affect student groups differently (Bailey et al., 2020) and there is evidence of inequity in A&P grades across demographics (Lindsay, 2020). Future work investigating learning outcomes of disaggregated student groups can illuminate the reliability of research findings and promote equity and inclusion in A&P classrooms.

Limitations and Conclusions

The synthesis presented in this systematic review relies on the pedagogy type coding. The pedagogy described in the studies was not always clearly aligned with our categories, and so we needed to make coding decisions when categorization was ambiguous. The risks of bias in systematic reviews can arise from accountability to the search protocol and bias in the primary sources (Drucker et al., 2016). While it was not published, we composed a protocol prior to beginning the review to mitigate this bias. However, only 42 of the 83 studies in our generalizability assessment set reported any limitations in the manuscript, and so our mitigation of bias from primary sources is limited. Our final dataset, like all systematic reviews, is limited by the scope of our search and our search terms. Unindexed, non-digital resources, and gray papers relevant to A&P education were not included in our scope, and so some descriptions of innovative A&P pedagogy are not represented in our sample. Additionally, other evidence relevant to our research questions may have been missed due to semantic differences, such as A&P courses with different course titles, or types of pedagogy and curricula that were not described with the search terms we used. International approaches to teaching anatomy and physiology may be underrepresented in our sample due to differences in terminology or differences in course objectives. However, regardless of these differences, prior evidence suggests that the importance and difficulties of A&P prerequisites are globally relevant (McVicar et al., 2015). The foundational concepts in these courses are conceptually difficult for students to learn (Michael & McFarland, 2011). To further develop the base of evidence-based teaching of A&P to nursing and allied health students, further empirical investigations using student learning outcomes to test A&P course innovations are needed to identify points of intervention at scale.

CHAPTER III

THE ANATOMY OF PERSISTENCE: REMEDIATION AND SCIENCE IDENTITY PERCEPTIONS IN UNDERGRADUATE ANATOMY AND PHYSIOLOGY

A previous version of this chapter has been published in *International Journal of Higher Education*.

Contributions of Authors and Co-Authors

Manuscript in Chapter III

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Contributions: Conceived study topic and design, collected and analyzed quantitative data, conducted interviews and analyzed qualitative data analysis, and wrote the first draft of the manuscript.

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Contributions: Conducted interviews, contributed to qualitative data analysis, and provided feedback on earlier versions of the manuscript.

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Contributions: Provided feedback on earlier versions of the manuscript.

Co-Author: Emily A. Holt

Contributions: Contributed to the study design, provided feedback on quantitative and qualitative analyses, and provided feedback on the manuscript.

Abstract

Undergraduate Anatomy and Physiology (A&P) courses are gateway courses nursing and allied health students must pass before progressing through their academic programs. Many students need to retake the course to receive grades acceptable to progress in their programs, but identifying students at risk of failure may help instructors extend support. In this study, we examined self-efficacy and science identity as potential predictors of student success in these courses, and, by extension, a potential way to identify students at risk of failing. We found that science identity, and not self-efficacy nor completion of science prerequisite courses, explained the most variance when predicting A&P final grade in hierarchical regression. Additionally, we interviewed a purposive sample of students retaking the course to explore their experiences and perceptions of these constructs in A&P over multiple enrollments. Students retaking the course described their experiences of being “biology people” in their interviews, further suggesting that having a science identity is relevant to A&P students and may be leveraged to support students in A&P contexts.

Introduction

Undergraduate Anatomy and Physiology (A&P) courses are biology service courses that cover introductory biological topics related to human anatomy and homeostasis for students studying to enter nursing and allied health fields. Anecdotally, these courses are rife with student retention problems (Griff, 2016; Vitali et al., 2020). While high school under-preparation contributes to poor performance in these introductory classes (Anderton, Evans, & Chivers, 2016), it does not account for much of the variance that explains the traditionally high Drop-Fail-Withdraw (DFW) rate in A&P courses (Gultice et al., 2015). While nursing and allied health fields have a growing need for professionals to be trained and enter the workforce (Liu et al., 2017), A&P courses can become gateways that many students do not pass through. Some students may opt to attempt the course again, or remediate, after failing or receiving a passing grade that is unsatisfactory to make progress in their programs (Entezari & Javdan, 2016; Wehrman et al., 2020). While instructors may anecdotally postulate why their students retake their courses, scant research literature explains which students retake courses and why. Existing research in A&P contexts suggests that gender, ethnicity, major of study, and SAT scores may predict student remediation, yet these factors do not account for all the variance (Schutte, 2016). A&P courses cover disciplinary topics known to be academically challenging for undergraduate students (Slominski et al., 2019; Sturges & Maurer, 2013), but examining factors that contribute to student success in these courses, such as student affect and college course preparation (Harris et al., 2004), is one step in exploring how to tangibly support students so they can make progress toward their personal ambitions. Additionally, early identification of students who may be at risk for needing remediation (Vitali et al., 2020) and exploring both affective and academic at-risk factors may better support students' progress in their allied health programs (Goradia &

Bugarcic, 2019). Indeed, calls to investigate affect in biology education contexts suggest that affect could help inform or possibly predict how students succeed in biology courses like A&P (Flowers & Banda, 2016; Trujillo & Tanner, 2014).

Social Cognitive Theory is a historically fruitful lens through which to view student affect, and may be particularly relevant when examining affect relating to remediation, as persisting despite academic failure can be emotionally burdensome (Ajjawi et al., 2020). Bandura (1986) described how behavior, personal factors (i.e., affect or sense of self), and the environmental systems in which people are situated are all influencing factors to how people learn and achieve goals. Self-efficacy, defined as a person's self-assessment of their ability to complete a given task, is one such affective factor shown to be predictive of student academic achievement and persistence (Bandura, 1997; Zimmerman, 2000). For students entering nursing programs, low self-efficacy in science contexts is common (Caon & Treagust, 1993), and in one study, low self-efficacy for science tasks predicted lower academic performance in nursing school courses (Andrew, 1998). The challenges of learning science that nursing students experience have been documented globally, but McVicar et al. (2015) suggest that this "bioscience problem" may be best remediated by both better prerequisite preparation and by supporting student self-efficacy.

While examining student self-efficacy provides insight into how confident students are in their ability to complete situated tasks, investigating students' sense of self is another perspective that could explain student outcomes in A&P courses. Science identity, or how one feels that they relate to a science domain, is composed of self-assessment of competence, performance, interest, and recognition, and has been shown to be an important predictor of persistence in STEM fields, especially for minoritized groups (Carlone & Johnson, 2007; Hazari et al., 2010). Science identity is increasingly a construct of interest in research literature, as it has been implicated in persistence in physics (Hazari et al., 2010), engineering (Godwin et al., 2016), math (Cribbs et al., 2015), and graduate-level biology (Carlone & Johnson, 2007). However, the persistence described in these studies is tied to long-term career pursuit and academic program completion, while student persistence through smaller goals, such as completing or remediating a single course, has not been examined through this lens. Additionally, nursing and allied health are not considered basic sciences or STEM fields, and so it is unknown whether students in A&P courses relate to having a science identity and if that science identity relates to short-term or long-term persistence in this context.

Study Purpose and Research Questions

Our study investigated self-efficacy and science identity as it relates to course outcomes and remediation in A&P contexts. Considering that the competence and performance subconstructs within science identity align closely with the definition of self-efficacy, examining both constructs in tandem explores self-assessment of both academic and long-term goals (Flowers & Banda, 2016). We utilized a mixed methods approach to address the research questions:

Q3.1 How do science identity, self-efficacy, and college course preparation predict academic outcomes for students enrolled in A&P courses;

Q3.2 What differences in student affect exist between re-takers (i.e., students retaking the course) and first-timers (i.e., students taking the course for the first time); and

Q3.3 Among re-takers, what experiences inform a student’s decision to retake A&P, illustrate how they define science identity, and contextualize their academic and professional goals?

Methods

Participants

Data collection for this study was conducted in accordance with the permission of the Institutional Review Board of the university where the study took place (Project #1312887-3; Appendix A). The context for this study was a public, regional university in the western United States, which serves approximately 9,400 undergraduate students per year. Participants were recruited during the Fall 2018 semester from one section of an Introductory Anatomy and Physiology (A&P) course and were compensated with a small amount of extra credit. This course is taught in the school's biology department by biology faculty and has no required prerequisite courses, though many students take introductory chemistry or biology classes before A&P to fulfill other requirements for their majors. It is the first of a two-course sequence required before students may apply for the school's competitive nursing program. At this institution, A&P also serves as a prerequisite for majors that feed into allied health careers, including nutrition, sports and exercise science, and audiology.

In the Fall 2018 semester cohort, 84 students consented to participate in this research and completed the first of two surveys. Of these students who participated in this first survey, 83 completed the course and were included in our pretest dataset. We had a low response rate (*n* = 44) for the second survey, which included demographic information questions. Those who did respond identified primarily as female (*n* = 36; male = 5; nonbinary = 1; declined to report = 2), and the majority were non-Hispanic white (*n* = 33), followed by Latino/Hispanic American (*n* = 3) or other racial/ethnic origins (*n* = 3). The participants represented many of the allied health majors for which A&P is a prerequisite biology course, with the majority of students coming from nursing (*n* = 11), sports and exercise science (*n* = 11), audiology (*n* = 11), and nutrition programs (*n* = 7), though some students reported their major as psychology (*n* = 2), anthropology (*n* = 1), or biology (*n* = 1). As a 200-level course, the majority of students enrolled were underclassmen (freshman = 3, sophomore = 21, junior = 12, senior = 8).

Potential interview participants for the qualitative portion of our study were identified as students who reported they had previously taken an undergraduate A&P course before enrolling in this course. For our research, A&P courses taken at community colleges qualified as a previous attempt, but concurrent enrollment and high school A&P courses were not considered a previous attempt (though nine students did report having taken an A&P course in high school). Of the 83 participants in the pretest dataset, 28 reported that they were retaking the course after a previous attempt at the current institution or an analogous A&P course at another institution. We decided in our analysis that students who withdrew from the previous course would not be considered re-takers, as they would not have been exposed to the entire curriculum, leaving a final pool of 27 re-takers. Chi-square analysis demonstrated no difference between the first-timers and re-takers by gender (= 1.07, *df* = 3, *p* = .785) or major (= 9.09, *df* = 6, *p* = .169). There was not a sufficient response rate to conduct a Chi-square analysis for re-taker status across ethnicities.

From this pool of re-takers, participants were randomly selected and invited to complete an interview with one of the members of the research team. Of the 27 students who reported they were retaking the course, 25 were invited to complete an interview, and seven participants responded to the interview invitation. Of those respondents, five completed an interview. Interviewees were compensated with a $10 gift certificate. While a sample size of five participants is relatively small, it is acceptable for phenomenology, given that thematic saturation is reached (Creswell, 2013). After we had completed the five interviews, we noticed that interviewee responses were consistent with one another and no new ideas were emerging, and so we stopped recruiting interview participants at that time.

Research Design

We chose a sequential explanatory mixed methods approach, as our research questions necessitated primarily quantitative analyses, but these analyses were followed and enriched by qualitative interview interpretations (Creswell, 2014). We utilized a phenomenological approach to qualitative data collection and analysis to examine and richly describe the shared experiences of students retaking A&P (Moustakas, 1994). Quantitative methods consisted of distributing pretest and posttest surveys to all participants with metrics to assess self-efficacy and science identity to address our first two research questions. The pretest was distributed via Qualtrics during the fifth week of a 16-week semester, qualitative interviews took place between weeks 8-14, and the posttest was distributed during weeks 13-15 of the semester to students who had completed the pretest. The interviews allowed us to address our third research question, as we probed their experiences of and perspectives on science identity and self-efficacy in the context of taking the course more than once. After the conclusion of the semester, the instructor for the course provided the researchers with the final course grades of all participants.

Quantitative Data Collection and Analysis

The pretest and posttest consisted of three previously published metrics to capture students' self-efficacy and science identity. One self-efficacy measure came from the Motivated Strategies for Learning Questionnaire (MSLQ; (Pintrich et al., 1993), which has several independent subscales meant to capture different components of students' motivations in academic settings and learning behaviors. We used only the self-efficacy subscale of the MSLQ, consisting of eight Likert-style items anchored on seven points (i.e., one = not at all true, seven =

very true); student responses to the items are averaged to give a single numeric score for self-efficacy. Subscales of the MSLQ have been used independently of the entire metric elsewhere, and the self-efficacy subscale (abbreviated as the SE subscale for the remainder of the paper) has been used reliably in higher education science contexts (Hilpert et al., 2013; Partin & Haney, 2012).

In addition to the SE subscale, we chose to modify the Sources of Self-efficacy in Science Classrooms – Physics (SOSESC-P) instrument, an instrument with 33 Likert-style items anchored on five points (i.e., one = strongly disagree, five = strongly agree) originally designed to assess changes in self-efficacy in undergraduate physics classrooms (Fencl & Scheel, 2005). These items are analyzed as four subscales (i.e., vicarious learning, emotional arousal, social persuasion, performance accomplishment), capturing the facets of self-efficacy originally described by Bandura (1977). The instrument is scored by averaging student responses for all items and by calculating the average for student responses within each subscale (Fencl & Scheel, 2005). We intended to use the overall score in our analysis but also examined the scores on each of the subscales to assess the validity of the metric. While the original metric specified that students respond to each item in the context of physics classes, we modified the metric wording to specify Anatomy and Physiology class as the context. We refer to this instrument as the SOSESC for the remainder of this paper.

To assess science identity, we used a selection of 12 Likert-style items, anchored on five points (i.e., zero = not at all, four = very much so), to assess students' personal identification as a science person (one item), recognition of science identity by their communities (three-item subscale), sense of competence when performing science tasks (five-item subscale), and their interest in science (three-item subscale) (Hazari et al., 2010). This instrument is scored by calculating the average of the items within each subscale, and then the subscale scores are averaged to create a science identity proxy variable (Wang & Hazari, 2018). We refer to this assessment as the ID metric and describe the proxy variable as the ID score for the remainder of the paper.

Iterations of the ID metric have been used in studies examining persistence in undergraduate physics and engineering education and careers, and the construct validity of the subscales for assessing being a “physics person” or a “math person” has been confirmed using factor analyses (Cribbs et al., 2015; Godwin et al., 2016). For this study, we modified the item wording to ask students about being a “biology person,” because anatomy and physiology topics fall within the domain of biology and require competency in using biological terminology. A&P is an introductory biology course that contains advanced scientific language taught by biologists in our context, but it is designed for students who are not biology majors. Thus, the outcome of completing A&P is not to be a biologist, but to apply biology knowledge in health contexts. We argue that the shared language and skills of these basic and applied sciences are rooted in biology, and so being a “biology person” may be an important negotiation for students to make to successfully develop the skills and knowledge they are expected to as part of successfully completing an A&P course.

While the metrics in the pretest and posttest were identical (i.e., the SE subscale, SOSESC, and ID metric), the pretest also contained questions asking students to select undergraduate chemistry and biology courses they had already completed, as well as a question asking if they had taken a college-level introductory A&P course previously. We consolidated student responses of taking either science majors or non-majors introductory chemistry or biology courses into two binary variables describing having taken chemistry or biology classes previously. Reporting that they were retaking A&P was also a binary variable, regardless of if that attempt was at the present or a previous institution. At the end of the posttest, students were asked to report demographic information (i.e., gender, racial or ethnic heritage, major, and class).

All quantitative analyses were conducted using R (R Core Team, 2019, version 3.6.0). We utilized the lavaan (Rosseel, 2012) and sem (Fox et al., 2017) packages for factor and path analyses, the lm.beta package (Behrendt, 2014) for regression analysis, the ggplot2 (Wickham, 2016), GGally (Schloerke et al., 2016), and reshape2 (Wickham, 2007) packages to construct correlation matrices, and the psych package (Revelle, 2018) to conduct reliability analysis. We opted to use the larger pretest dataset (*n* = 83) for all analyses as opposed to the paired dataset because the low response rate on demographic questions precluded statistically powerful comparisons across demographic factors in our pilot models, and because paired pretest and posttest survey comparisons of all metrics were not statistically different. Further, our research questions did not seek to measure change over time, and so quantifying the relationship among factors measured at one time point was sufficient.

Qualitative Data Collection and Analysis

Semi-structured interviews were conducted by a member of the research team, who asked about each participant's decision to retake A&P, their experiences of self-efficacy when completing challenging A&P tasks, and their definitions and experiences of being a biology person. While we also asked about test-taking strategies as a potential angle to view self-efficacy, the responses from that question were linear and did not describe either science identity or self-efficacy, and so no major themes emerged from responses to those questions. The interviews were professionally transcribed prior to analysis. Pseudonyms were assigned to each interviewee. Two members of the research team iteratively read and coded the transcripts separately before coming together to discuss their codes, after which codes were consolidated and definitions were clarified. In phenomenology, themes emerge from the participants' narrative of their experiences and related emotions (Creswell, 2013), which are coded and described by the researchers. The transcripts were re-coded using this agreed-upon coding scheme, and this code/re-code strategy completed by at least two researchers bolsters the trustworthiness of our study by increasing the dependability of our methods. A third member of the research team acted as a peer debriefer to further refine the coding scheme until consensus was reached. Through the consensus of multiple researchers and a peer debriefer, we increased the credibility of our qualitative analysis, and as a mixed methods study, the quantitative data we collected are a source of triangulation, further bolstering the credibility and trustworthiness. By using purposive sampling, we addressed the transferability dimension of trustworthiness (Anney, 2015). Codes representing major themes were included in our final codebook, while concepts described less frequently by few participants were determined to be not characteristic of the phenomenon of retaking A&P, and so they were removed from further analysis.

Results

Validity and Reliability of Self-Efficacy Metrics

The prerequisite step to answering our quantitative research questions was to establish the validity and reliability of the instruments we used in our situated context (Dolan, 2015; Knekta et al., 2019). Because the SOSESC and ID metric had not been used in biology classrooms previously, we were especially interested in determining their validity in this context. Using Cronbach's alpha, we determined that both the SE subscale and the SOSESC measure were reliable in our context ($\alpha = 0.96$ and $\alpha = 0.93$, respectively); however, the individual subscales of the SOSESC did not all demonstrate reliability. The Performance Accomplishment ($\alpha = 0.84$)

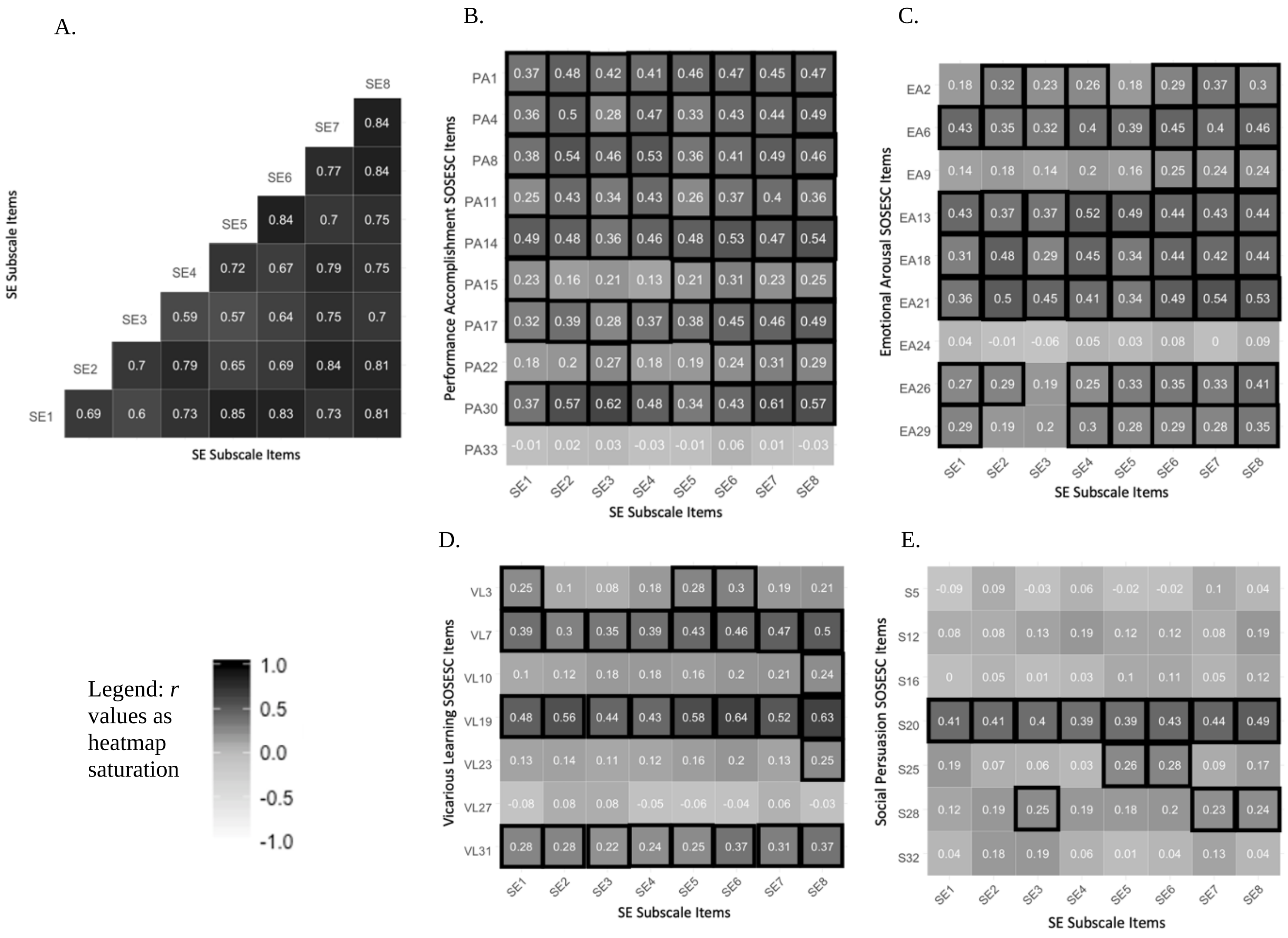
and Emotional Arousal ($\alpha = 0.85$) subscales demonstrated good reliability, though the Vicarious Learning ($\alpha = 0.69$) and Social Persuasion ($\alpha = 0.64$) subscales narrowly failed to meet the acceptable 0.70 threshold (P. Kline, 2000).

The SE subscale of the MSLQ has been used reliably in many settings, and other studies have demonstrated convergent and divergent validity comparing the SE subscale to other subscales within the MSLQ (Hilpert et al., 2013), indicating that it does not capture elements of the other learning strategies and student affect measured by other subscales of the MSLQ. As the SOSESC is a newer, less established metric, we investigated whether it demonstrated concurrent validity with the more-established SE subscale.

Correlations of SOSESC items with SE subscale items were weakly to moderately correlated ($r \leq 0.64$) compared to correlations within the SE subscale alone, which were more highly correlated to each other ($0.57 \leq r \leq 0.85$). While all items within the SE subscale were correlated with one another, fewer items were significantly correlated between the SOSESC and the SE subscale (60.6% of pairwise correlations; Figure 3.1). The Emotional Arousal and Performance Accomplishment subscales overall had more items that were significantly correlated with items on the SE subscale (75.0% and 80.0%, respectively) than did the Social Persuasion and Vicarious Learning subscales (23.2% and 51.8%, respectively). Because the items on the SOSESC did not demonstrate concurrent validity with items on the SE subscale, and because the SOSESC subscales had low reliability, we decided not to use participant responses on this metric in further analyses.

Figure 3.1

Pearson's Correlation Matrix Between Eight Items on the SE Subscale (Columns) and SOSESC Subscale Items (Rows)



Note. The SOSESC item rows are labeled by subscale abbreviation and item number in the 33-item metric. Shading represents the value of the correlation coefficient between 1.0 (black) and -1.0 (white). Pearson's correlation coefficient are within the boxes in white text; for ***B-E***, significance at the $p < .05$ level is indicated by a black outline around the correlation coefficient. ***A.*** SE subscale items were all correlated with each other at the $p < .0001$ level. ***B.*** The ten items of the Performance Accomplishment (PA) subscale had the highest number of correlations with the SE subscale; 80.0% of the pairwise comparisons correlated significantly with SE subscale items. ***C.*** The nine Emotional Arousal (EA) items had 75.0% pairwise correlations with SE subscale items. ***D.*** The seven items of the Vicarious Learning (VL) subscale correlated moderately with the SE subscale (51.8% of pairwise correlations). ***E.*** The Social Persuasion (SP) subscale had the fewest significant correlations with the SE subscale (23.2%).

Validity and Reliability of Science Identity Metric

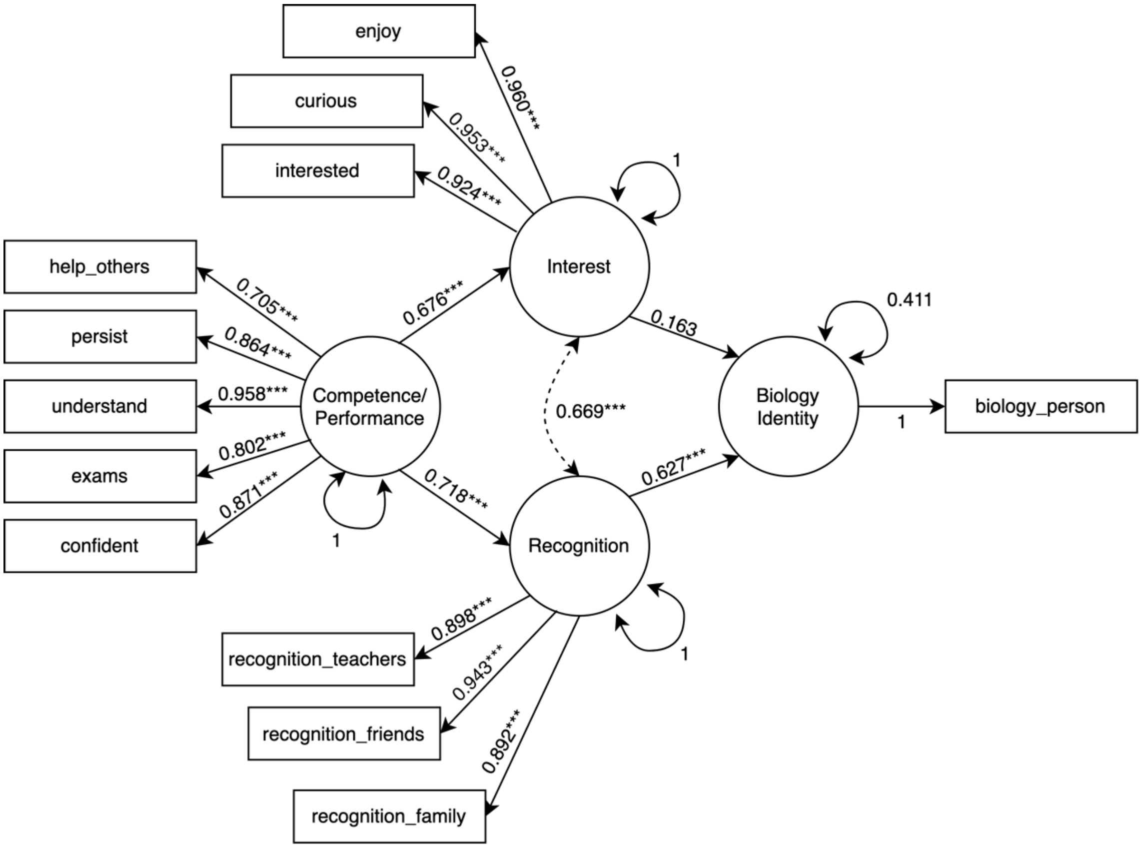
The ID metric had not been previously used in a biology context, but we found it to be reliable using Cronbach's alpha ($\alpha = 0.96$). Previous research and factor analyses in physics and mathematics contexts using this metric has resulted in a proposed four-factor model for science identity, with "Interest" and "Recognition" constructs regressing directly to "Science Identity" and serving as mediators between "Performance/Competence" and "Science Identity" (Cribbs et al., 2015; Godwin et al., 2013).

Though our sample size is smaller than the 200 recommended for factor analysis (R. Kline, 2005), the ID metric scored "marvelously" on a Kaiser-Meyer-Olkin test for sampling adequacy (KMO = 0.92), indicating that the dataset was well-suited for factor analysis (Kaiser, 1974). Therefore, to evaluate the structural validity of the subscales within the metric, we conducted a confirmatory factor analysis (CFA) on the model, accounting for multivariate non-normality using the robust "MLM" estimator (Rosseel, 2012). To test the efficacy of this model in our context, we chose to include the four fit indices recommended by Kline (2005): χ^2, root mean square error of approximation (RMSEA), comparative fit index (CFI), and the standardized root mean square residual (SRMR).

Most of the paths identified in the original model were found to be significant in our analysis at the $p < .0001$ level, except for the regression of “Interest” to “Science Identity,” which was not significant (Figure 3.2). While the individual items fell satisfactorily within their constructs (Tabachnick & Fidell, 2000; Table 3.1), the model fit overall was poor. The SRMR approached an acceptable value to indicate a good fit, but none of the other fit indices fell into acceptable ranges (Hu & Bentler, 1999, Table 3.2). While we cannot make sweeping conclusions about the structural validity of this metric due to our sample size, these results offer a first step to explore how this metric is defined and used to describe science identity in biology contexts. The lack of a significant path between the constructs of “Interest” and “Science Identity” suggests that an alternative factor arrangement may be useful. While the structural validity of this metric in terms of the relationships between subscales was not aligned with previously published work in other contexts, each subscale loaded independently and contributed to overall science identity.

Figure 3.2

Confirmatory Factor Analysis Model for Science Identity, Proposed by Cribbs et al. (2015)



Note. All paths in the model between latent variables in this model were significant except for the regression between Interest to Biology Identity.

Table 3.1

Confirmatory Factor Analysis Factor Loadings for ID Metric Items

Latent Variable	Label	Item	Standardized Factor Loading
Biology Identity Recognition	biology_person	I see myself as a biology person	1.000
	recognition_family	My family sees me as a biology person	0.892
	recognition_friends	My friends/classmates see me as a biology person	0.943
	recognition_teachers	My science instructors/teachers see me as a biology person	0.898
Competence			
	understand	I am confident that I can understand biology	0.871
	exams	I can do well on exams in biology	0.802
	concepts	I understand concepts I have studied in biology	0.958
	persist	I can overcome setbacks in biology	0.864
	help_others	Others ask me for help in biology	0.705
Interest			
	interest	I am interested in learning more about biology	0.924
	curiosity	Topics in biology excite my curiosity	0.953
	enjoy	I enjoy learning about biology	0.960

Table 3.2

Confirmatory Factor Analysis Model Fit Indices for Science Identity

Fit Index	Acceptable Value	Model Value
Model	$p > .05$	$= 39.76$, $df = 51$, $p < .001$
RMSEA	< 0.06	0.145, CI 0.118, 0.172
SRMR	< 0.08	0.085
CFI	> 0.95	0.923

Note. None of the fit indices fell within acceptable ranges (Hu & Bentler, 1999).

To determine whether the composite score would be an appropriate science identity score for our analyses, we correlated the composite ID score with participant’s response to the single science identity item ("I see myself as a biology person") to test the validity of the ID score (Hazari et al., 2015). The single item and the ID score were highly correlated in a Pearson's correlation test ($r = 0.92$, $p < .0001$), suggesting that participant responses to the subscale items closely mirror their self-identification of being a biology person. We used the ID score in further analyses, as it still captured the overall construct of identity despite the unclear relationships between subscales within the metric.

Relating Self-Efficacy, Identity, and Course Outcomes

After testing the reliability and validity of our data using these three instruments, we sought to clarify if science identity, self-efficacy, or college course preparation factors predict course outcomes (i.e., final course grade) for students enrolled in A&P courses with hierarchical regression models. We also sought to explore differences in student self-efficacy and science identity between re-takers and first-timers.

We tested for normality using the Shapiro-Wilk test, which revealed that the SE score was normally distributed ($p = .095$), but the ID score and final grade were not ($p < .0001$ and $p = .002$, respectively). Using a two-sample t-test, we determined that there were no differences between re-takers and first-timers on the SE subscale ($t = -0.49$, $p = .630$). A Wilcoxon Rank Sum Test revealed that students' ID scores did not differ based on their re-taker status ($W = 797.5$, $p = .690$). Interestingly, when comparing final grade as a course outcome, re-takers ($M = 82.09\%$) on average scored no differently than first-timers ($M = 83.29\%$; $W = 748$, $p = .942$), despite having taken the course previously.

We created hierarchical regression models using prior college science coursework as potential predictor variables before adding SE and ID scores to the subsequent models. Prior coursework did not predict final grade in the first regression model (Model 1: $F = 0.97$, $df = 79$, *p* = .410; Table 3.3). Next, we added SE score and ID score individually into two versions of a second model. Model 2-SE, including SE score, was significant (*F* = 3.06, *df* = 78, *p* = .022), with SE score being a significant predictor (*p* = .003; Table 1). The other variation of the second model, Model 2-ID, including ID score had greater explanatory power (*F* = 3.66, *df* = 78, *p* = .009), with ID score being the significant predictor in the model (*p* = .001; Table 3.3). The third iteration of the model which added both SE and ID scores explained the most variance (*F* = 3.39, *df* = 77, *p* = .008), but the significance of SE score as a predictor was lost, and ID score was the only significant predictor (*p* = .043; Table 3.3).

Table 3.3

Results of Hierarchical Regression Analysis of College Science Prerequisites and Affect Scores Predicting Final Course Grade

	Model 1		**Model 2-SE**		**Model 2-ID**		**Model 3**	
Predictor Variables	**β**	**t**	**β**	**t**	**β**	**t**	**β**	**t**
Biology Prerequisite	-0.158	-1.409	-0.126	-1.172	-0.185	-1.745	-0.159	-1.493
Chemistry Prerequisite	0.098	0.877	0.039	0.365	-0.013	-0.123	-0.016	-0.143
Previous A&P Course	0.081	0.719	0.037	0.343	0.081	0.759	0.056	0.524
SE score			0.324	3.001*			0.184	1.457
ID score					0.368	3.365**	0.266	2.057*
R^2	-0.001		0.091*		0.114**		0.127**	

**p* < .05; ***p* < .01; ****p* < .001

Qualitative Findings

Our five interviewees had reported on the pretest survey that they were retaking A&P after a previous enrollment at either their present or a previous institution. The interview topics probed the experiences of students retaking the class from a social cognitive theory lens, asking them to describe environmental and personal factors that they experienced in both enrollments, and to expand on their definition of a “biology person.” In the analysis of interviewee responses, five major themes emerged, falling under identity (Table 3.4) or social cognitive (Table 3.5) factors. Our initial hypothesis was that students retaking A&P may feel disconnected from science or have low academic self-efficacy, as prior academic failure can dampen students’ self-efficacy (Ajjawi et al., 2020) and self-efficacy historically has been a positive predictor of course performance (Richardson et al., 2012), but instead, our interviewees shared that they felt that they were biology people and their course performance did not reflect that truth about themselves.

Table 3.4

Emergent Identity Themes, Definitions, and Example Quotes from Interviewees, Labeled by Participant Pseudonyms

Theme	Subtheme		Definition	Example Quotes	
Who is a biology person?	Traits they have	Ability traits	Participants detail the abilities or characteristics of abilities that "biology people" have.	Gaia: [A biology person is] Definitely a more logical person...a science person would definitely be somebody who, you know, looks at the base level of things before looking out at the entire picture.	Kaylee: [A biology person is] someone more like scientifically-inclined, enjoys it...it clicks for them.
		Affective traits	Participants detail the personal qualities that biology people have or ways they feel about biology.	Amy: I feel like a biology person is someone who wants to know more about the world and about themselves. They usually carry themselves in a great way.	Meredith: I usually do think that [biology people] are passionate about it, usually. And I feel like there's always a level of "I want to tell other people" to a lot of biology people – like they wanna share what they've learned.
	Who	Other people	Participants describe the ways that other people (i.e., not themselves) fit the category of "biology person" due to having ability or affective traits that they attribute to "biology people" as defined in the "Traits" subthemes.	Gaia: My brother went to school for, I want to say like biochem or something like that. With him, I honestly relate everything to his personality...He is very scientific about things...whether it's how he ties his shoes in the morning, or his morning routine and things like that.	Amy: A lot of people in the biology courses that I'm with also have the same mentality. They want to get up and move around and learn new things and experience things.
		Me	Participants describe the ways and reasons they fit the category of "biology people," including personal qualities, abilities, and affect that they attribute to "biology people" as defined in the "Traits" subthemes.	Lennon: I would probably describe [a biology person as]...somebody who's very scientific based...'Cause I describe myself like that. It's like wanting to know how things work at, you know, like, a structural or functional level which I think is kind of based on, like, how our world is right now.	Amy: I love biology...It's very interesting. Even [in] anatomy, just some of the things that go on within yourself that you wouldn't even expect go on like moving your muscles, it's crazy all the things that have to happen.

Table 3.4, continued

Emergent Identity Themes, Definitions, and Example Quotes from Interviewees, Labeled by Participant Pseudonyms

Theme	Subtheme	Definition	Example Quotes	
Allied health identity	Perceptions of allied health identities	Participants describe their perceptions of allied health people and qualities of those with allied health identities.	Meredith: Just like, [nursing] is exciting, because every day will be different, and then it’s just like you’re actually doing something good? And I just feel like there’s nothing bad about it, except for like, the stress on your own self...it’s just exciting. You’re part of this inner community too, of people who are fine with gross things and they’re fine with helping people.	Lennon: I had a surgery that, like, impacted my life. And the nurses that were surrounding me, they were very compassionate and they had a really good bedside manner and so that was important to me. I feel like it's a very rewarding career.
	Practicing allied health identities	Currently working within the allied health community is an important key for participants to prepare for and be with people in their desired careers.	Amy: I'm very excited to begin the nursing program. I always see nursing students in their scrubs walking in the [nursing school building] and I'm just so envious. I'm like, "I wanna be them."	Meredith: Um, and then I started, I like, worked as like, or I still do, as a care manager. And then I was like, “Oh my gosh, yes!” And then it’s like, wow, I wish I could do more.
	Vision for career	Participants describe vivid, compelling career goals and the reasons they chose to pursue them	Kaylee: My career goal is to be, eventually, a NICU nurse. It's appealing 'cause, well, I love science and I love kids so I kind of just want something that's not the same all the time or it's just also is like rewarding.	Meredith: I’ve noticed like, a lot of nurses, it’s just like, “I wanna help people.” And it’s like, “yeah, that’s good, but can you do this?” And, so, I think it’s gonna be really cool to take what I’ve learned and actually use it, and be able to see it in a lab chart, or be able to explain in my head like why this may be happening in a person.
Identity is practiced in community	Academic community	Students work together to achieve their goals as biology people and discuss seeking out and interacting with their academic community. While the community is supportive, students describe the competition within it to secure spots in the nursing program.	Amy: Some of us are SES majors, which is Sports and Exercise Science, and some of us are nursing majors. We both have different goals at the end, but currently we're working towards the same thing, and it's nice to feel like we're all focused towards one goal.	Meredith: I think with my friends, I definitely identify as someone who’s a biology person. But with some of my other peers, I feel, just from, like, competition, sometimes I do not feel equal...[the competition] makes people feel bad about their knowledge and what they don’t know, or what they haven’t done.

Table 3.5

Emergent Social Cognitive Themes, Definitions, and Quotes from Interviewees, Labeled by Participant Pseudonyms

Theme	Subtheme	Definition	Example Quotes	
The role of the academic environment	Mismatch of their expectations and what they perceive to be expected of them	Participants describe frustration when they are not appropriately recognized for what they know on exams or by instructors. The mismatch between what students feel are fair expectations and what is assessed threatens their legitimacy of being a biology person.	Gaia: I think it's just with A&P in particular, I'm very interested, but sometimes that just doesn't show necessarily in my grades...[I am] definitely more of a big picture science person, so the entire body rather than just the small details of it.	Lennon: As the course of the semester went on, I honestly feel like it's [become] a little bit resentful, 'cause a lot of the people who I have studied with, and I've even gone to tutoring, will spend like two and a- half, three weeks studying for this [exam], trying to power through it and then... the test scores aren't what we hoped it would be.
	Relevance of content	Participants relate how A&P course content has varying degrees of relevance to their career and academic goals, which influences both their motivations and abilities to learn it.	Meredith: I think when you look at [it from] afar, you're like, "This is too stupid"...But then when you actually think about it, the questions you're gonna have [to] ask yourself, as a nurse, you realize, oh, it's [the] little things...So you realize it's important but while you're taking the class it just seems…really overwhelming. It's like you're never gonna need to use this information.	Amy: I was a CNA for a year and I currently work as a med tech. And to learn about these things that go on within your body and to actually experience it in like a clinical setting. It's easier to relate back to course work.
The role of people in their success	Attribution Theory	Participants comment on areas within their own locus of control and external to their locus of control that influence their performance and success in the class.	Gaia: I definitely really value, um, having just, you know, a lot of open communication with my professors just so I know, "Hey, you're concerned with my success and so am I."	Lennon: When there's an engaging environment, I feel [more] obligated to engage…outside of class than when it's a non-engaging environment...[my] want to participate is declining, I guess, due to the environment.
	Mindset	Participants speak from a place of growth mindset (they can achieve difficult things even after failure) or fixed mindset (they are helpless to change their circumstances after failure) (Dweck, 2000).	Gaia: I just need this confidence...if I get a bad grade I'll [sometimes tell myself], "Oh, you're not good at this. You know, like come on..." [I'm] doubting [myself] and [my] self-efficacy and things like that. So, [instead I] definitely talk myself through it and say, "Hey, okay, this is why you missed it. Here's what we could do next time. Just learn from your mistakes and then continue on to the next test."	Lennon: I feel great going into [the test]. And then if I don't know, like the first question, I'm like dead inside. Like it kinda like crushes me a little bit... I'm like "Oh, I'm gonna fail again because I've- I flopped...no matter how hard I try, this is gonna happen."

Identity Themes

When asked to describe who a “biology person” is, interviewees described biology people as having certain affect (e.g., confidence or enthusiasm) and abilities (e.g., critical thinking or logic; Table 3.4). Each participant reported being a biology person themselves, and they described being a biology person in both their lives and in other people’s lives. The other people they described as being biology people were often friends or family members, but interestingly, participants did not mention teachers or authority figures as examples of biology people. While one participant, Amy, only described biology people as having affective traits, all other participants described both affective and ability traits relatively equally. Additionally, the total number of mentions that interviewees gave about each combination of “who” and “traits” of biology people was roughly equal (Table 3.6).

Table 3.6

Number of Times an Interviewee Response Was Coded as a Pair of Subthemes Under the “Who is a Biology Person?” Theme

Subtheme	Amy	Gaia	Kaylee	Lennon	Meredith
Me/Affect	3	3	2	1	2
Me/Ability	0	3	3	2	4
Others/Affect	2	1	1	2	4
Others/Ability	0	5	1	1	4

Interviewees often described allied health identities when asked to describe their goals in taking and retaking A&P, including their perceptions of being in those careers, their participation in health care systems, and their career visions (Table 3.4). Within these descriptions, it is evident that these careers are desirable – desirable enough for students to endure a second or third time to retake a course for another chance to enter that career. Additionally, our interviewees recognized that they were not alone in their aims; other members of their academic community, while not always wishing to enter the same profession as them, were both supporters and competitors. While they banded together to learn the material, the competition to secure a place in the nursing program left some interviewees feeling insecure about their chances of achieving their goals, even though they so strongly identified with those goals (Table 3.4).

Social Cognitive Themes

While one of our initial aims was to explore students' self-efficacy, the experiences interviewees described reflected other constructs within social cognitive theory, notably causal attributions and self-regulation (Eccles & Wigfield, 2002). First, our participants described the role of their academic environment presented to them that they, as self-identified biology people, needed to navigate through (Table 3.5). Each student needed to retake the course to move forward in their programs, but when asked about their prior experiences with A&P and their current enrollment, interviewees described a mismatch of expectations in assessment and course content. While some parts of what students were learning seemed immediately relevant to their current or future jobs, other topics, especially the finer details, seemed like an overwhelming amount of information to digest for the little value they perceived that it may have in their future.

Our second social cognitive theme describes the role of people in their success. While each interviewee reported similar experiences of being a biology person, they diverged in their descriptions of the power others had in their academic success. Subthemes under the role of people in their success describe the attributions and mindsets rather than their own self-efficacy, but interviewees diverged on how they attributed their performance in both enrollments and what types of mindset (i.e., fixed or growth) they maintained during their current enrollment. Gaia and Lennon epitomized this dichotomy; while Gaia reported collaboration between herself and the instructor, Lennon attributed performance primarily on the type of environment her instructors created. Both Gaia and Lennon described having test anxiety, but while Gaia demonstrated growth mindset in her approach to exams, Lennon described feelings of defeat after encountering questions to which she did not know the answer (Table 3.5).

Discussion

Affect Predicts Course Outcomes

In our sample, having taken an undergraduate chemistry or biology course previously did not predict course grade in this A&P context; however, previous work suggests that the quantity of prior experience in undergraduate science courses (Harris et al., 2004) and high school science experiences (Gultice et al., 2015) do improve final grade in A&P classes. Our findings regarding the predictive value of taking prerequisite courses bolster the argument that prerequisite courses in higher education science settings may not predict outcomes in future science classes (R. Wright et al., 2009) and may not support students without proper curricular alignment along their educational pathways (J. F. Shaffer et al., 2016).

Our findings from the hierarchical regression models indicate that, in our best model, Model 3, ID score is the only significant predictor, but this model offers only negligible improvement on the predictive power of course grade when compared to the two versions of Model 2, with ID score and SE score added independently (<5% improvement in variance explained; Table 3.3). The single-affect models performed similarly well, yet the Model 2-ID minimally explained more variance of the two; this indicates that while self-efficacy and science identity are important predictors of A&P performance, science identity may be slightly better. As examining science identity in A&P contexts is a novel contribution, our results suggest that investigations of this construct are appropriate to inform future research and pedagogy.

The loss of significance of self-efficacy as a predictor to course outcomes when in a combined model with science identity is notable. A host of research described in a systematic literature review supports the use of self-efficacy – as measured by the same self-efficacy metric we used in our analyses (i.e., the self-efficacy subscale from the MSLQ; Pintrich et al., 1993) – above other self-regulated learning constructs as a predictor of tertiary Grade Point Average (GPA; Richardson et al., 2012); though, these studies did not include any disciplinary identities as potential predictors. Additionally, our study examined academic performance in only one undergraduate class instead of cumulative GPA of students. Further, as self-efficacy is a construct situated within domains and tasks (Bandura, 1986), academic self-efficacy may not be the only type of self-efficacy students have when engaging with A&P. Other work that has observed that self-efficacy is not always the best predictor of narrower academic outcomes, such as exam grade, where previous academic performance is a better predictor (Ainscough et al., 2016).

Science identity as a predictor of a short-term academic outcome, such as final grade, is a novel finding in this study. Previous research has demonstrated that adolescent student participation in formal and informal science activities can be predicted by science identity (Vincent-Ruz & Schunn, 2018). Indeed, the long-term summation of these choices is associated with graduate study and career choice, which undergraduate students' sense of science identity predicts (Estrada et al., 2011; Hazari et al., 2013). While studies investigating science identity have shown intricate trajectories of science identity in relation to persistence and career pursuit throughout students' undergraduate careers (Jackson & Seiler, 2013; Robinson et al., 2018), our findings suggest assessing students' science identity also has utility for predicting short-term academic goal achievement.

Re-Takers and First-Timers Do Not Perform Differently

Our findings indicate that while affect can predict academic outcomes in A&P, re-takers and first-timers do not differ in affect nor academic course outcomes. In our study, re-takers did not differ from first-timers in final grade, which is inconsistent with prior findings comparing first-timers and re-takers in A&P contexts that suggest that first-timers tend to perform better than re-takers (Schutte, 2016), though our sample had a higher ratio of re-takers to first-timers than previous work, perhaps mathematically diluting the differences between the two groups. Additionally, out of all re-takers in our sample, 41% received the same or lower letter grade than the letter grade they reported from their previous attempt, in line with some work that suggests that prior anatomy coursework does not significantly benefit undergraduate students (Wehrman et al., 2020), but in contrast with other research which suggests that prior exposure to A&P or retaking the course has a positive impact on student assessment grades (Schutte, 2016). Variance in re-taker success could be due to engagement in formative assessments, as prior research suggests that re-takers who complete formative assessments fare better than those who do not (Dibbs, 2019; Holland et al., 2016). Though we did not examine types of engagement quantitatively, one participant, Lennon, reported her difficulty staying engaged in the course during her second enrollment (Table 3.5). Interventions encouraging the completion of formative assessments may be an additional support re-takers would benefit from in A&P contexts.

Potentially poor-achieving students who opt not to retake the class may have lower self-efficacy or science identity than those who return and try again, and thus those students would not appear in our sample. We were initially surprised that our interviewees, all taking the class for a second or third time, reported that they were biology people, despite needing remediation. The disaffect they felt was not in their own performance, as Ajjawi et al. (2020) reports, but rather in the course itself. It could be that re-takers have negative perceptions of the course but not low general self-efficacy, similarly to results of a study in chemistry education (Reardon et al., 2010). Indeed, this type of frustration with instruction or perceived relevance of content may predict academic outcomes (Wilde, 2012), and in undergraduate anatomy contexts, student expectations of the course may aid their development of favorable perceptions of learning in the course (Anderton, Chiu, & Aulfrey, 2016; Entezari & Javdan, 2016).

Re-Takers Describe Themselves as Biology People

Though we coded the interviews using an emergent coding scheme, interest in biology as an affective trait of biology people thematically overlapped with the theoretical model behind the ID metric. The “Recognition” subconstruct within science identity also overlapped with the theoretical model and interviewees’ experiences, as the mismatch of our interviewees’ expectations and the grades they received in their previous and current enrollment speaks to their sense of a lack of recognition. When participating in science activities, recognition from faculty (Thompson & Jensen-Ryan, 2018) and peers (Le et al., 2019) supports students’ science identity development in undergraduate biology contexts, but perhaps the importance of recognition extends beyond the affirmation of science practices to the affirmation of academic practices. Participants reported practicing allied health careers through their jobs as certified nursing assistants, which illuminates a way they may perform their science identities in a competent way. While performance and competence beliefs cannot predict science identities apart from interest and recognition (Godwin et al., 2016), this finding suggests that active participation as health care professionals-in-training may be an expression of being a biology person. Previously, Carlone and Johnson (2007) described science identities of biology graduate students pursuing health care careers as being altruistic science identities as opposed to research science identities, and our findings suggest that undergraduate non-biology majors may similarly embody altruistic science identities. Future work is needed to parse out the convergence and divergence of biology and allied health identities.

We were initially perplexed about the lack of interviewee discussion of self-efficacy as part of their experience retaking the course. Though no question in our protocol explicitly asked interviewees to reflect on their confidence, when asked about their performance in A&P, they described attributions and mindset, which both fall within social cognitive theory. Indeed, considering that self-efficacy is overshadowed by science identity in our regression models, we posit that science identity is a greater contributor to persistence for all students in A&P courses. This aligns with findings from Estrada et al. (2011) that suggest that persistence is not weighted in some students' confidence of their ability, but rather rooted in their sense of belonging and identity within science communities.

Limitations and Conclusions

While previous work highlights problems with retention and remediation within A&P courses (Gultice et al., 2015), much evidence that exists about A&P attrition and retention is anecdotal or highly contextual, and further investigation is warranted to define the scope of this issue. Our study is similarly contextual and limited in that it occurred over one semester with a homogeneous population of students; thus, we were unable to look at potential demographic effects reported elsewhere, such as gender (Schutte, 2016; Vitali et al., 2020). Our use of final course grade as a proxy for academic success in our regression models is another limitation, as course grade does not necessarily capture student learning, but instead is only one facet of academic success (Schinske & Tanner, 2014). Additionally, while the fact that our interviewees strongly identified as biology people initially surprised us, this could be partially explained by self-selection bias. Not all students who remediate may feel like biology people, and not all students who become part of the DFW statistic come back to take the course again. Furthermore, as we did not interview first-timers, we cannot describe the science identity experiences and expressions of those enrolled in A&P for the first time.

Structurally, it would benefit both students and institutions to define what is important for nursing and allied health students to know so curricula could be framed as relevant to students' flourishing allied health identities. Given our findings about the perceived mismatch of what students expected to learn and what was relevant to their professional development, it would be beneficial to systematically investigate which topics students see as unimportant and develop pedagogical methods to frame those topics in a more explicitly relevant way. Additionally, soliciting student feedback about the relevance and familiarity of content both within A&P and in introductory science courses may better prepare students and improve attitudes about these courses (Sato et al., 2017).

Future work in A&P contexts is needed to identify additional factors relating to student success in these courses and how to support students in these contexts. From the lens of social cognitive theory and other expectancy/value theories, it would be beneficial to examine these intersections and self-regulated learning in A&P. These investigations could help design interventions meant to support learning outcomes in A&P; intervening during this biology prerequisite courses could benefit students' learning of their current coursework and further along in their programs as well (S. J. Brown et al., 2017; McVicar et al., 2015).

The role of science identity warrants further study, especially investigating the structural validity of existing science identity metrics in biology contexts. Additionally, it would also be beneficial to explore further what a biology person is in relation to allied health identities. Our findings suggest that science identity is relevant to A&P students, and so capturing who students believe themselves to be and to which communities they feel that they belong may be an efficacious avenue for motivating and retaining students. In this way, science identity may be leveraged in the future to better build learning communities to support academic and learning outcomes for A&P students.

CHAPTER IV

ANATOMY AND PHYSIOLOGY BEYOND "THIS IS INTERESTING:" ASSESSING TRANSFORMATIVE EXPERIENCES THROUGH EPISTEMIC NETWORK ANALYSIS

Contributions of Authors and Co-Authors

Manuscript in Chapter IV

Author: Emily A. Royse

Contributions: Conceived study topic and design, collected, organized, and analyzed data, and wrote initial manuscript.

Co-Author: Kevin J. Pugh

Contributions: Contributed to study design and theoretical framework, and provided feedback on the presentation of findings.

Co-Author: Dylan Kriescher

Contributions: Contributed to design of qualitative codebook and contributed as a second coder for the qualitative data.

Co-Author: Emily A. Holt

Contributions: Conceived study topic and design, provided feedback on analyses approaches, advised on presentation of findings, and provided feedback on the manuscript.

Abstract

Transformative experiences mark learning that impacts students' everyday lives and are desired outcomes of education. In our study, we explored the transformative experiences of undergraduate anatomy and physiology (A&P) students through their written reflections about the course topics. Using a mixed methods approach, we qualitatively coded 151 reflections from 31 A&P students for markers of transformative experiences, learning motivation constructs, and their everyday lives. We utilized epistemic network analysis (ENA) to examine the frequency of connections that students made between these codes. The generated network revealed that students tend to make connections in their writing between their personal experiences, triggered interest in the course content, expansion of perception of seeing and applying the topics, and stating that they had learned something in the course. These codes were present in most students' reflections and also had the greatest number connections between them across the entire sample. However, not all students had transformative experiences and there was variance between the number of connections and the strength of connections in students' individual networks. This variance may be partially explained by the amount of participation a student contributed in the course. We conclude that students do have transformative experiences in A&P, and instructors wishing to support these experiences as an outcome should structure participation activities to leverage students' communities and personal experiences.

Introduction

Transformative Experiences and Everyday Life

Transformative learning, by definition, refers to learning that empowers the student to experience both conceptual change and transfer to real-world applications (Mezirow, 1978, 1997). While Mezirow’s perspective on transformative learning focuses on these cognitive markers of learning (Mezirow, 1978, 1997), transformative learning also promotes meaningful, flow-like engagement with the world (Dewey, 1980). More modern applications describe markers of transformative learning as transformative experiences (TE) in which students’ perspectives develop in a way that they notice how they encounter course content in their daily lives (Pugh, 2002, 2011). Transformative experience theory states that learning is transferable when students are motivated to use class content outside of academic settings (motivated use; MU), have an expanded perception of the relevance of course content (expansion of perception; EP), and value the experiences they have as a result of their learning (experiential value; EV; Pugh, 2002, 2011).

Transformative education must be experiential for students to engage inside the classroom, so meaningful transfer can occur outside the classroom (Pugh, Bergstrom, Heddy, & Krob, 2017). Student engagement with education can be initially driven by their interest and valuation of educational tasks (Eccles & Wigfield, 2002). For example, elements of the instruction may promote short-term interest (i.e., situational interest), which can motivate student engagement in education with learning activities (i.e., triggered interest; Hidi & Renninger, 2006; Linnenbrink-Garcia et al., 2010). Over time, that interest may be maintained as students have positive feelings about the topics, leading to greater engagement (Harackiewicz et al., 2008; Hidi & Renninger, 2006). Individual interest describes more consistent interest regardless of educational setting over time (Eccles & Wigfield, 2002; Hidi & Renninger, 2006). While interest and valuation of course topics may predict TE (Heddy et al., 2021; Pugh et al., 2019), TE markers go beyond these typical learning motivation constructs (Heddy et al., 2021). Finding utility in understanding course content is different than finding personal value in it. Without connection to personal everyday life experiences, traditional learning motivation constructs such as perceived career utility fall short of TE. Everyday life in transformative experience theory broadly refers to lived experiences outside of the classroom (Heddy & Pugh, 2015; Pugh, 2002; Pugh & Bergin, 2005), though students are involved in multiple communities in their everyday lives.

One way to differentiate facets of everyday life is through Bronfenbrenner's ecological systems theory, which posits that multiple communities impact individual development, including family, peer group, religious, and educational contexts (Bronfenbrenner, 1979). These immediate communities are microsystems, which interact with each other and affect personal development. While there are broader societal forces described in ecological systems theory, we propose that the everyday life experiences that TE describes are the interactions between the microsystem of an educational context and other microsystems in one's personal life. Historically, ecological systems theory describes child and adolescent development, especially from the lens of social communities and influences (Neal & Neal, 2013). In higher education research literature, researchers have used microsystems (e.g., peer groups and classes) as a lens to contextualize students' experiences within academia (Ertem, 2020; Wayne, 2018). Other researchers have used Bronfenbrenner's ecological systems theory to explore professional development of expertise in chemistry education (Lewthwaite & Wiebe, 2012) and exercise science (Uehara et al., 2016). Utilizing the complementary elements of transformative experience and ecological systems theories, we propose that if outside microsystems impact educational development, the education microsystem also impacts other microsystems, potentially in the form of TE.

Transformative Potential of Anatomy and Physiology

Transformative learning theory is gaining traction as a research and pedagogical lens in nursing and medical education, as expansion of perception is valuable in training health care professionals (Greenhill et al., 2017; Pepin et al., 2017; Vipler et al., 2021). In one qualitative study, nursing educators reported that incorporating transformative learning ideas into their pedagogy helped them take a learner-centered approach that better supported their students (Bernard, 2019). Students also report that they experience many characteristics of transformative learning in their nursing education, including experiential learning which incorporates their personal experiences into their developing nursing identity (Hunter Revell et al., 2021; Kear, 2013). However, research about transformative learning prior to the clinical studies in nursing education has not been conducted.

Undergraduate Anatomy and Physiology (A&P) courses are prerequisite biology courses taken by nursing and allied health students prior to completing clinical coursework. As A&P is a prerequisite for nursing programs, these students may be similarly motivated to those described in nursing education literature. However, the human interaction (namely, clinician-to-patient) element in nursing education, which is crucial in supporting transformative learning (Kear, 2013), is outside the scope of most A&P classes. Instead, undergraduate A&P classes focus on the biological concepts rather than clinical practice (Griff, 2016; Royse et al., 2022). However, other elements of the course have potential to foster transformative learning. Because A&P is intimately relevant to every student (i.e., course topics are exclusively about the human body), the course is well suited to trigger interest and prompt students to encounter course topics in their everyday lives.

Identifying how students connect course content with their everyday lives provides insight into their experiences learning the prerequisite biology content that will be the foundation for their future coursework. Taken together, research is needed to explore whether students in an A&P class have transformative experiences, as is noted in similar fields. Student writing in these classes seems like an appropriate window from which to view their experiences and attitudes. Therefore, we chose to use ENA to model the TE theoretical framework constructs in an analysis of A&P student writing.

Assessing Transformative Experiences with Student Writing

Assessing TE is often accomplished through qualitative interviews (e.g., Pugh, Bergstrom, & Spencer, 2017) or psychometrics (e.g., Transformative Experience Questionnaire, Koskey et al., 2018; Pugh, Bergstrom, Heddy, & Krob, 2017). However, using students' written reflections to assess TE can be beneficial because it adds rich details about TE experiences over time (Heddy & Sinatra, 2017). Indeed, student writing can be a rich source of data about students' engagement with science knowledge (Hole et al., 2018; Natale et al., 2021). The act of reflection itself can support student interest in course content (Curry et al., 2019; Erickson et al., 2021).

While traditional qualitative analyses can provide thick description from qualitative data, complex pattern detection is limited to what is observable by human researchers. A new approach, Epistemic Network Analysis (ENA), marries qualitative data with the automation power of network analysis. Network analyses develop and test models representing the linkages among actors (Wasserman & Faust, 1994). Broadly, these types of analyses have utility for evaluating the cognitive processes and connections evident in participant writing (Siew, 2020). In ENA specifically, the actors modeled can be practices and constructs evident in qualitative data (D. W. Shaffer & Ruis, 2017). Further, ENA can model the strength of connections made in a participant's writing that would not otherwise be captured in closed-response surveys (Mulvey et al., 2021; Peters-Burton et al., 2019). In education research, ENA has been used to analyze how students perceive different course elements (Lim et al., 2020), as evidence of metacognitive patterns in student writing (Wu et al., 2020), and for predicting performance on assessments (Fougt et al., 2018).

Study Purpose and Research Questions

The purpose of this study was to examine A&P students' written reflections for evidence of transformative experiences. We aimed to describe how transformative experience elements related to students' microsystems (i.e., interactions with peers, family, careers, or education). Using a mixed methods approach incorporating qualitative thematic analysis and quantitative ethnography we addressed the following research questions:

Q4.1 Which transformative experience elements and microsystems do students identify in written reflections about A&P topics?

Q4.2 What consistent connections do students make between transformative experience elements, microsystems, and A&P topics?

Methods

Participants

This research was conducted during the Fall 2020 semester at a mid-size public university in the western United States and was approved by the institution's review board (Project #2006004531; Appendix A). Participants were recruited from a high enrollment introductory Anatomy and Physiology (A&P) course via a verbal announcement during an online synchronous class meeting during the first week of the semester and via an announcement on the course's Learning Management System (LMS) webpage. This 200-level course has no prerequisites and typically serves pre-nursing and allied health majors (i.e., nutrition, audiology, exercise science, etc.). No compensation was offered for participation in this research, and students were assured that their participation in the research would not affect their grade in the course.

While the A&P course used in this study is typically offered exclusively in an in-person format, in light of the COVID-19 pandemic, the Fall 2020 course was designed and implemented in a semi-flex format with some online, synchronous components and some in-person components (Li & Wong, 2018). The final grade for this course reflected formative quizzes (15% of final grade), five unit exams (30%), one comprehensive final exam (15%), laboratory course grade (25%), written reflection assignments (5%), and participation (10%). Students earned participation points through multiple forms of synchronous and asynchronous online engagement of their choice. The written reflection assignments (5 total corresponding to the five course units) were required metacognitive exercises completed outside of the synchronous meetings. These written reflections were graded for completion and served as the qualitative data basis for our analyses, and are described further under *Data Collection* below.

Data Collection

During the first weeks of the semester, 25 students consented for their classwork to be used for research purposes. To encourage more students to participate, this consent form was distributed again the last week of the semester and was completed by an additional 10 students (n = 35 out of a total of 96 students enrolled). Of these 35 consenting students, 31 students completed at least 4 written reflections and were included in this study. The data collected from these students included their responses to written reflection assignments, the number of participation points they earned, and their unit exam scores. Participation points and unit exam scores were used to explore trends in connections discovered in student writing. There were multiple opportunities through attendance, discussion board participation, and supplemental writing assignments to earn up to 240 participation points. Students could mix-and-match which opportunities to engage in and needed to earn 180 to receive a 100% in the Participation category of the gradebook (worth 10% of their final course grade). For all of our post hoc analyses, we binned students as earning the highest number of participation points (greater than 191 points; *n* = 9), meeting the 180 point criteria (170-190 points; *n* = 8), or earning fewer than 170 points (*n* = 14). There were five unit exams over the course of the semester containing multiple choice and short answer questions, scored out of 50 points. The total number of points students earned on all exams they took was averaged into a single score for research purposes.

Over the course of the semester, all students were required to write five written reflections in response to the prompt: “Choose a topic (or topics) that we have learned about in the past two weeks to reflect on the following prompt...How does what you learned in Unit [1, 2, 3, 4, or 5] relate to your life?” In our sample of students, four students completed four reflections and the remaining 27 students completed all five reflections. This total of 151 reflections was included in our analysis.

Data Analysis

To answer our research questions, we first qualitatively coded student writing and then used quantitative ethnographic methods to model those codes to visualize the connections students made between codes in their writing.

Qualitative Coding of Written Reflections

We created an *a priori* codebook defining themes of transformative experiences (TE) and microsystems (Table 4.1). After an initial read of the reflections, additional themes were added to capture learning motivation constructs that did not meet criteria of transformative experiences yet seemed critical for inclusion as they may predict such experiences (Heddy et al., 2021; Pugh et al., 2019). These additional codes noted student statements about the utility of the content, that they were learning something from the class or content, and that they had triggered interest, maintained interest, and personal interest in the class or content (Eccles & Wigfield, 2002; Linnenbrink-Garcia et al., 2010). The codes corresponding to these constructs (referred to as “LM” codes in our analyses) differ from TE codes in that students describe seeing course content in a new way, without meeting the TE criteria of students deriving personal meaning to their lived experiences. For example, an Expansion of Perception (EP) code would be used for a statement that specifies how a student views their own health in a new way, while a Learned Something code (Learn) would be used for a statement that just states that a student broadly views health in a new way. Interest codes were included under the LM parent code, as a student could express interest in a topic without that interest having personal relevance.

Table 4.1

Codebook Used to Code Written Reflections, With Example Quotes Illustrating Each Theme

Theme	Definition	Example
Microsystems		
Career	Student describes their future or current career experiences, ambitions, or goals.	“Currently, I am a nurse’s assistant and I work with a lot of patients who are experiencing kidney problems.”
Course	Student describes experiences completing course objectives, engaging with course activities, or participating with classmates.	“Doing the Dig Deeper Study Report was fun for me because I got the opportunity to learn a bit more about kidney function and dialysis.”
Family	Student describes experiences/relationships with close or extended family members.	“Whenever I was sick my mom would always check my lymph nodes to see if they were swollen.”
OtherEd	Student describes experiences in prior formal classrooms.	“I remember when I was in 7th grade during science class, we were learning about the heart and at the end of the unit my teacher told us that she had a surprise for us.”
Peers	Student identifies, mentions, or describes experiences/relationships with friends or peers in their writing.	“I actually have a friend whose parents refused to vaccinate him so he had to catch up and get them as soon as he went to [college].”
Self	Student describes their identity or health.	“I would say a couple of the topics relate to my life as an athlete but also as someone who is very conscious about their skin.”
Transformative Experiences		
Expansion of Perception (EP)	Student describes seeing examples of the course topics and related topics in examples relevant to their everyday lives, or in viewing the course content through a new lens that is relevant and meaningful to them personally.	“Dance pushes the boundaries of what your body can do and after learning about the skeletal and muscular system I understand how my body was able to do what it did.”
Experiential Value (EV)	Student describes enjoying/appreciating the content, or finding a deeper meaning to knowing the content.	“Overall this unit was really rewarding to learn about, and I feel it could relate to my experiences and future career well.”
Motivated Use (MU)	Student indicates they have used or are using or learning about course topics outside of the bounds of course assignments or scope.	“After the nervous system chapter, I spoke to my physiologist about supplementing GABA.”
Research (RE)	Student specifically conducted or referenced outside research or reading of the course text.	“I did what every millennial does, and googled it.”
Learning Motivation		
Learned Something (Learn)	Student describes they learned something, without describing how that knowledge affects them, their goals, or their lived experiences.	“This lesson taught me a lot just because I knew that diabetes existed, but I never knew much about it.”
Utility (Util)	Perceived utility of knowing concepts.	“The study of anatomical terminology such as planes, body regions, and directional terms will be useful in my professional career in the medical field.“
Triggered Interest (Triggered)	Student describes finding a topic introduced in class interesting (not “I am interested” but “this was interesting”).	“It was really interesting to me to learn about the types of immune responses and how each part of the system works together.”

Table 4.1, continued

Codebook Used to Code Written Reflections, With Example Quotes Illustrating Each Theme

Theme	Definition	Example
Learning Motivation		
Maintained Interest (Maintained)	Student describes positive affect toward a topic ("it's cool") beyond a single instance engaging in coursework, or asks a question that indicates they are interested in learning more about a topic.	"I was curious how I could have nearly perfect hearing, but still have tinnitus?"
Personal Interest (PersonalInt)	Student describes being personally interested in science topics in general and/or course topics; student describes being historically interested or curious in such topics.	"I'm always curious about things so to me that was kind of cool to find out."

Note. Parent themes are listed in bold text with child themes nested beneath them. Abbreviations of child themes referred to in latter analyses are noted in parentheses, and Transformative Experience (TE) themes are all signified with two letters. Participant quotes are lighted edited for clarity.

All written reflections were coded by a member of the research team (E. A. R.) and 10% of the participant reflections were independently coded by another member of the research team (D. K.). Coding was first completed in NVivo 12 (QSR International, 2020), and then exported into a table to capture the binary presence of a code ("0" for absent and "1" for present) for each phrase (i.e., sentence) within each written reflection. Phrases were coded for all themes present in the sentence. The percent agreement between the two coders was between 84.1-99.4% for each code in that sample, which exceeds the acceptable minimum of 80.0% (Hartmann, 1977). We summarized the binary presence of a code ("0" for absent and "1" for present) across all reflections each student completed in our qualitative analysis, and summarize those data as number of students who included that code in their writing.

Epistemic Network Analysis Model Construction

While the qualitative coding summarizes the incidence and number of students reporting certain transformative experience elements, microsystems, and learning motivation constructs in their writing, we used a quantitative ethnographic approach to investigate the connections students made between these codes. The product of the qualitative coding step was a data matrix outlining the binary presence or absence of all codes for each sentence in students' reflections. We used epistemic network analysis (ENA) to build a model using the qualitative matrix to identify which themes occurred in the writing, which codes occurred in close proximity to other codes (i.e., co-occurrences between codes), and the relative frequency of co-occurrences that students made across all of their writing.

ENA models co-occurrences by summing and mapping the presence of thematic codes for individual units of analyses and creating a network modeling each unit's connections. The unit of analysis in our ENA model was each participant (n = 31). Each individual written reflection was considered a *conversation* of each participant, or a related series of *phrases* (i.e., sentences, ranging from 4-82 within a single reflection) that are temporally linked and modeled together (D. W. Shaffer et al., 2016). Conversations may contain multiple *stanzas,* or combinations of phrases that are topically related, which determine the weight of connections between codes based on temporal proximity of the phrases. We built the ENA model using a moving stanza window, which grouped four phrases together and summed the co-occurrence of codes within those phrases. ENA creates adjacency matrices that accumulate the incidence of codes that co-occur in the same stanza, and assigns a weight of zero to codes that do not occur in a stanza (D. W. Shaffer et al., 2016). Adjacency matrices are summed for each unit of analysis, and these matrices are converted into an adjacency vector which is normalized by its length (D. W. Shaffer et al., 2016).

ENA translates the high-dimensional structure of connections between codes, rendered into the adjacency vectors, into a fewer number of dimensions using singular value decomposition (SVD; D. W. Schaffer et al., 2016). While ENA produces many SVD dimensions to explain the variance within the data, the dimensions that explain the most variance in the dataset are traditionally used to interpret mean network structures (Ferreira Mello & Gašević, 2019). Within the ENA model, the network of each unit of analysis (i.e., participant) was plotted in a projection space along two SVD dimensions to view the structure of connections between codes. These structures are weighted by the co-occurrences between codes and can be summarized by a centroid that represents the network for the unit of analysis (D. W. Shaffer et al., 2016). The centroid is a single point in the projection space that represents the participant's entire network, given the frequency of co-occurrences in their writing, which informs the weights of the edges in their network. Thus, determining the coordinate of the centroid along an SVD dimension illustrates both relative code frequency and co-occurrence frequency. Comparing coordinates between participants offers the means of grouping students based on similar underlying network connections. In our analyses, we used the centroid coordinates along the two SVD dimensions that explained the most variance in the model: SVD1 (used as the horizontal dimension when plotting the networks) and SVD2 (used as the vertical dimension in those plots).

We used the ENA webtool (version 1.7.0; Marquart et al., 2018) to create the model and corresponding network plots. As a part of Research Question 2, we used these plots to describe the average co-occurrences of codes across all participants. We also examined the variance in these connections or co-occurrences among students by viewing each participants' individual plot.

Results

Descriptive Overview

Our sample of A&P students earned between 99 and 245 participation points (*M* = 173.25, *SD* = 31.40 points), with 14 of the 31 students meeting or exceeding the 180 point criteria for receiving a 100% in the gradebook for the Participation category. Students in our sample had an average unit exam grade between 56.12%-92.28% (*M* = 80.13%, *SD* = 9.42). The ENA modeled codes from 1,847 phrases divided into 151 conversations (i.e., full reflections). The number of phrases per participant ranged from 20-290 phrases across all reflections (*M* = 59.58, *SD* = 52.06).

Common Codes in Student Writing

Each students' writing received between 3-15 codes across all their reflections. No single code appeared in all 151 reflections nor was used by all 31 participants. However, the codes that most students used were Self, Learned Something, Expansion of Perception, and Triggered Interest (Table 4.2).

Table 4.2

Number of Students (n = 31) Whose Writing Received Each Code

Parent Code	Code	Number of Participants
TE	EP	26
	EV	15
	RE	10
	MU	7
LM	Learn	28
	Triggered	26
	Maintained	21
	Util	18
	PersonalInt	7
Microsystems	Self	29
	Course	23
	Career	20
	Family	18
	Peers	13
	OtherEd	7

Note. Codes arranged by parent code, and then from most to least frequent. Full code titles are available in Table 4.1.

The TE code, all noted with a two-letter abbreviation (see Table 4.1), that appeared most frequently in the dataset was EP followed by EV (Table 4.2). The RE code represented a more specific type of action than MU broadly, and so these instances were not double-coded. The LM codes were present in more students writing, with Learned Something being the most common LM code, followed by Triggered Interest and Maintained Interest. For the Microsystem codes, the Self code was most abundant and was mentioned by nearly every student in our sample, followed by the Course and Career codes. Of the three types of parent nodes, the TE codes generally occurred less frequently in students' writing.

Describing the Epistemic Network Analysis Projection Space

The model generated by the ENA summarizes connections between codes across a dataset. ENA plots each code as a fixed node inside a projection space that accounts for the most variance in the dataset (D. W. Shaffer & Ruis, 2017). Of the multiple SVDs calculated by the ENA, two dimensions explained the most variance in our dataset; 15.4% variance was explained by the first dimension (SVD1) and 11.4% variance was explained on the second dimension (SVD2, Figure 4.2A). We use these two dimensions to partition the projection space into four distinct quadrants.

The prominent codes (i.e., larger circles in Figure 4.1A and C) defining each quadrant is consistent with the most frequent themes during our initial qualitative analysis (see Research Question 1; Table 4.2), including Learn, EP, Self, and Triggered Interest. However, the ENA added depth to our qualitative analysis by highlighting connections students made between codes and the frequency of those connections. Not only were Learn, EP, Self, and Triggered Interest prominent codes, but they were also connected to each other frequently within the plot (i.e., thicker lines in Figure 4.1A and C), indicated by the edge weights of the lines connecting those codes. The arrangement and prominence of these four codes and their sizable edge weights, due to the high frequency of co-occurrences between these themes, created a “kite” shaped portion of the network plot. An example of a stanza that was coded with all four points of this kite was a story told by Participant 1785:

> When it comes to relating Unit 3 to my life the skeletal system comes to mind because I have 3 bulging disks in my vertebrae due to a fractured tailbone [Self]. I learned about how bone remodeling and repair works [Learn]. After I broke my tailbone the hematoma formed, then the external and internal calli formed, and then the cartilage of calli is

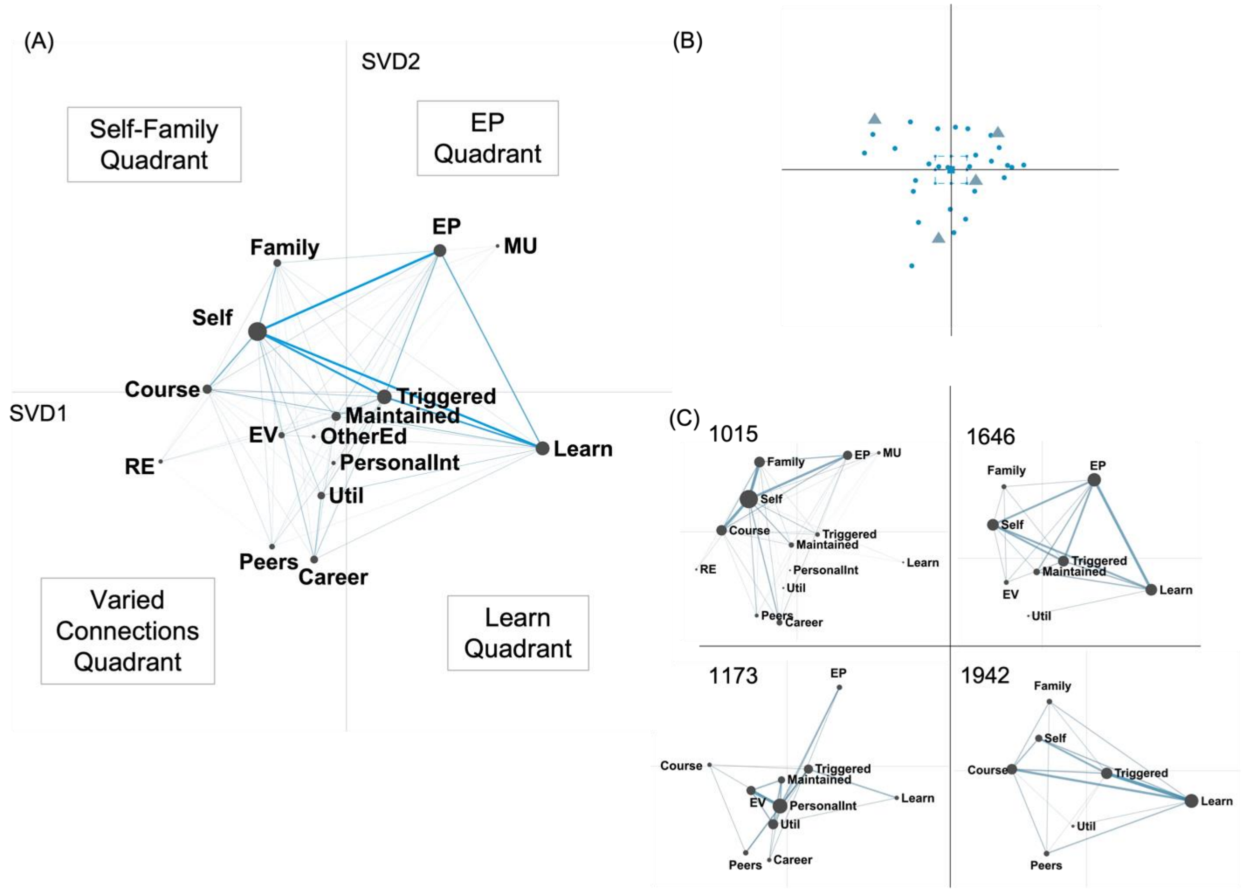
> replaced by trabecular bone where remodeling then occurs [EP]. This process is very interesting to me because when I received my MRI results they told me that the bulging discs were caused by improper bone repair [Self, Triggered]. (Participant 1785)

The arrangement of nodes within the network were displayed over four quadrants of the projection space, which we named according to the most prominent codes within those quadrants. First, the Self-Family quadrant (upper left space created by negative end of SVD1 and positive end of SVD2) was the portion of the project space occupied by three of the five microsystems, and most notably by the most commonly mentioned code, Self. Second, the EP quadrant (upper right space created by positive end of both SVD1 and SVD2) was occupied by solely by the most and least frequently mentioned TE codes (i.e., EP and MU). Third, the Learn quadrant (lower right space created by the positive end of SVD1 and negative end of SVD2) was occupied only by the two most frequent LM codes, Learn and Triggered. The connection between codes in the three above-described quadrants represent the “kite” of the most salient pattern, where students linked combinations of Triggered Interest, Expansion of Perception, and Learned Something about A&P, all connected strongly to the most frequent microsystem code: them-Self. Fourth, the Varied Connections quadrant (lower left space created by the negative ends of both SVD1 and SVD2) contained all the remaining nine codes representing a mix of TE, microsystems and LM codes. Notably, the most prominent nodes, strongest edge weights, and thus the “kite” are not included in this quadrant.

Each participant is plotted as a centroid in the ENA projection space, which represents the underlying network of that participant determined by the mean frequency of code co-occurrences in their reflections (Figure 4.1B). Centroids located within a quadrant reflects that those participants’ networks tended to be weighted more heavily toward connections to those codes. Nine of our participants' centroids plotted in the Self-Family quadrant, because they tended to have greater frequency of the Self and Family codes and heavier edge weights between them (Figure 4.1C). The centroids in this quadrant had the greatest spread along SVD1. We found the greatest number of participant centroids (*n* = 11) plotted in the EP quadrant. Underlying networks of these centroids had strong connections to EP, and those plotted closest to the SVD1 axis tend to also frequently connection with the Triggered Interest code. There were only five participant centroids plotted within the Learn quadrant and all underlying individual networks had frequent connections to the Learn code. Six centroids plotted in the Varied Connections quadrant and deviated most from the "kite" connections found in most students networks. These participants made connections with the Utility code, Maintained interest, or less frequent microsystems (e.g., Peers). The centroids in this quadrant had the greatest spread along SVD2.

Figure 4.1

ENA Projection Space



Note. The location of thematic codes in the projection space is determined by all participant data, thus are consistent across all participants and the average of all participants. The edge weights (i.e., thickness of the line connecting two codes) is determined by the mean co-occurrence of those codes across the full dataset. The presence and size of the node is proportional to the frequency of the code. (A) The mean network of all participants. (B) The 31 participant centroid coordinates, with confidence interval for the network indicated by the blue box. The triangles represent participants whose individual networks are shown in Figure 4.2.C. (C) Four example participant networks (four-digit numbers are randomly assigned participant identifiers) to help clarify the patterns in each quadrant of the projection space. Centroids falling in these quadrants tended to have more weighted connections toward the primary codes in each quadrant: Self-Family, EP, Learn, or atypical Varied Connections that differ most from the “kite” connections. In this representation, the networks are physically arranged as the quadrant in which the participant centroid is found, yet the actual projection space is visible as light grey lines behind each network.

Frequency of Co-Occurrences

In addition to denoting which co-occurring codes students had in their writing, ENA also characterizes the connections as the number of edges within a student's network. The frequency of connections between codes can be operationalized two different ways in ENA. First, the number of participants (lower corner of Table 4.3) summarizes how many students linked any given set of codes. Second, the edge weight (upper corner of Table 4.3) estimates the frequency of connections between any given set of codes across all conversations. While the frequency of students who had a certain edge in the network (e.g., the frequency for Family-EV and Course-EV edges are each 5; Table 4.3) is proportional to the edge weight in the mean network, the edge weight also takes the frequency of the co-occurrence within the writing into account. For example, the frequency for Family-EV and the Course-EV edges is equal ($n = 5$), but the Family-EV edge weight (0.016) is slightly greater than the Course-EV edge weight (0.013; Table 4.3) because the students who made the Family-EV connection made it more frequently within their writing than the students who made the Course-EV connection. Co-occurrence frequency within individual students could vary greatly; for example, while 10 students have the Family-EP edge in their networks (Table 4.3), the number of the Family-EP co-occurrences per student ranged from 1-21 instances. This variance is evident in the differences in edge weights between individual networks, available in Appendix E.

We predicted that TE themes (i.e., EP, EV, MU, and RE) would co-occur with Microsystem themes (e.g., Family), as transformative experience theory proposes that transformative learning impacts students' views of their everyday life outside the classrooms (Heddy & Pugh, 2015; Pugh, 2002; Pugh & Bergin, 2005). The strongest edge weight occurred between a TE theme (EP) and a microsystem (Self), but most other TE-Microsystem pairs were weakly connected (Table 4.3). The most frequent element of TE that microsystems were connected with was EP, and the most frequent microsystem that was connected to TE markers was Self (Table 4.3). LM codes (i.e., Utility, Learned Something, and Interest codes) emerged during our coding and we anticipated that they may have linkages to TE codes, and thus may also connect with Microsystem codes. However, LM codes were more frequent than TE codes in our sample; therefore, we found more connections and mostly stronger connections between LM and Microsystem codes than TE and Microsystem codes (Table 4.3). The LM codes also co-occurred frequently with the Self code, with the Triggered Interest and Learned Something codes being the most common connections made with all microsystem codes (Table 4.3).

Table 4.3

Co-Occurrence Matrix of Number of Participants With Co-Occurrence Between Codes (Lower Left) and Average Edge Weight of Connection Within ENA Plot (Upper Right)

	Microsystems						TE				LM				
	Career	Course	Family	Peers	OtherEd	Self	EP	EV	MU	RE	Learn	Util	Triggered	Maintained	PersonalInt
Career	-	0.024	0.022	0.002	0.005	0.070	0.017	0.012	0.001	NA	0.047	0.078	0.057	0.045	0.004
Course	8	-	0.034	0.038	0.004	0.124	0.047	0.013	0.009	0.011	0.080	0.021	0.061	0.026	0.007
Family	5	7	-	0.024	NA	0.109	0.047	0.016	0.004	0.008	0.028	0.008	0.032	0.035	0.013
Peers	2	7	7	-	NA	0.036	0.020	0.003	0.006	0.007	0.017	0.001	0.036	0.028	0.005
OtherEd	2	2	NA	NA	-	0.010	0.011	0.007	NA	NA	0.005	0.001	0.017	0.016	NA
Self	11	14	12	7	2	-	0.227	0.035	0.018	0.027	0.222	0.058	0.202	0.069	0.013
EP	7	10	10	8	2	23	-	0.031	0.013	0.007	0.136	0.031	0.106	0.054	0.012
EV	3	5	5	2	1	8	9	-	0.001	0.007	0.032	0.023	0.046	0.033	0.017
MU	1	6	3	2	NA	5	6	1	-	NA	0.001	NA	0.003	0.014	NA
RE	NA	5	4	3	NA	5	3	3	NA	-	0.002	NA	0.023	0.028	0.001
Learn	10	13	7	4	2	20	15	6	1	2	-	0.057	0.176	0.040	0.008
Util	9	8	3	1	1	11	8	4	1	NA	12	-	0.061	0.024	0.005
Triggered	11	13	10	8	4	20	17	7	2	7	20	12	-	0.068	0.014
Maintained	9	9	7	4	4	14	12	6	3	5	10	4	12	-	0.014
PersonalInt	1	3	2	2	NA	4	3	1	NA	1	3	2	5	4	-

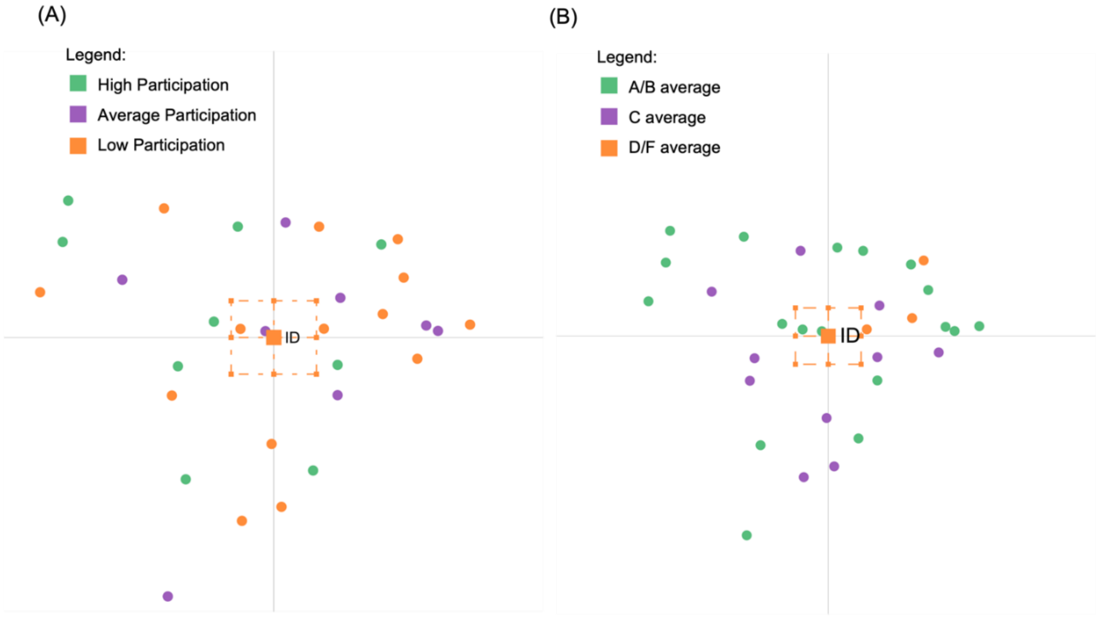
Note. Numbers in the lower left corner represent the number of participants making the connection between the codes. Co-occurrences occurring in more than 14 students are shaded in light grey. Numbers in upper right corner indicate the average edge weight between codes within the networks of participants making that connection. An average edge weight of 1.0 would indicate that all instances of the two codes were paired, while 0.0 would indicate that when the two codes appeared in the dataset that they were never paired. The highest lines weights (over 0.1) are shaded in dark grey.

Post Hoc Analysis: Course Outcomes and Network Complexity

Above we summarize the patterns in the mean network to identify consistent patterns of connections across all our participants. However, we also noted that individual participants represent a spectrum of connections between TE, LM, and Microsystems, and their centroids are distributed across the projection space (Figure 4.1B). To explore possible reasons for variability in individual networks, reflected in a broad distribution of centroids in the projection space, we examined whether student centroids clustered together on the ENA plot by course outcomes. We found no clear pattern in centroid location based on participation scores (Figure 4.2). While there was no pattern for the largest bins for average unit exam scores (A/B and C), all three participants in the D/F category fell within the EP quadrant (Figure 4.2).

Figure 4.2

Participant Centroids Color-Coded by Binned Participation Levels and Average Unit Exam Letter Grade

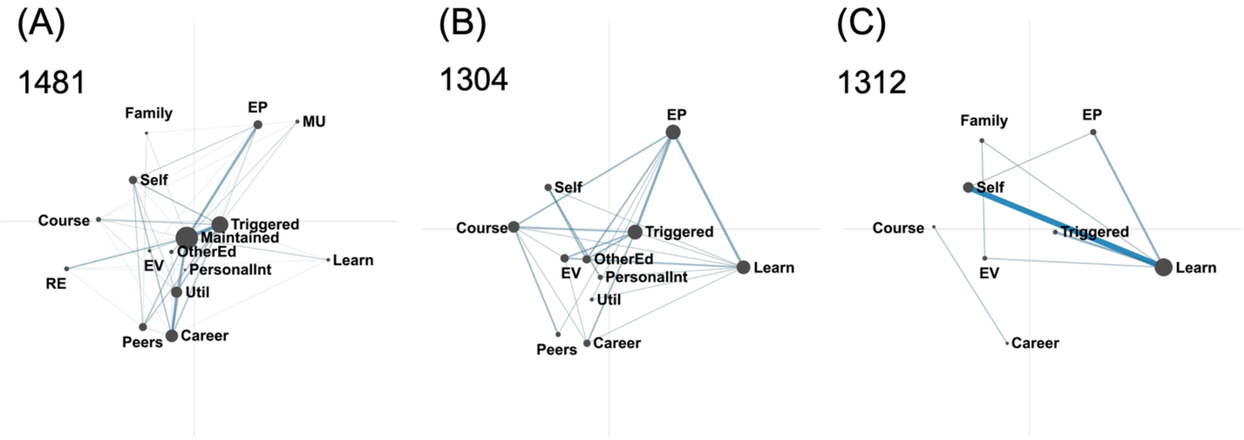


Note. (A) Participant centroids color-coded by level of participation points earned, as described in the Methods. (B) Participant centroids color-coded by the average letter grade across all unit exams.

In addition to the participant centroid coordinates plotted in the ENA model (Figure 4.1B), the network structures across individual participants varied significantly, illustrating that some students connected many themes in their reflections while others made only a few connections (Figure 4.3; all plots available in Appendix E). We found the number of code co-occurrences (i.e., edges) in students' writing ranged from 1 to 53 ($M = 20.16$, $SD = 14.18$), which largely contributed to this diversity in complexity. While the number of edges in participant networks were highly correlated to the number of phrases in their writing ($r = 0.56$, $p < .001$), network complexity was not necessarily indicative of whether a student made the overarching "kite" connection between TE (i.e., EP), microsystems (Self), and LM (Learned Something and Triggered Interest).

Figure 4.3

Three Participant Example Network Plots by Number of Edges Included



Note. All students shown in these plots earned a B on average on their unit exams but each varied in their participation scores. (A) Participant 1481 had a high participation score and their network has 53 edges, (B) Participant 1304 had an average participation score and their network has 23 edges, and (C) Participant 1312 earned fewer participation points and their network has 8 edges.

We investigated whether the complexity of individual participant networks, defined as the number of edges within the network, could be related to course outcomes (i.e., participation points or average unit exam grade). We noticed qualitatively that students in the highest participation bin tended to have more complex networks with more edges, compared to students in the lower participation bin (Appendix E, Figure E.2). Indeed, we determined using a Pearson's correlation test that the number of edges in a participant's network was significantly related to a student's participation points earned (*r* = 0.40, *p* = .03). However, we did not observe any trends relating unit exam grades to network complexity qualitatively or using a Pearson's correlation test (*r* = 0.29, *p* = .11).

Discussion

Connecting Transformative Experiences and Microsystems

The purpose of our study was to explore the presence and intersections of transformative experiences with A&P students' everyday lives outside the classroom. Prior studies measuring TE have noted that students report transformative experiences in facets of their everyday lives, such as seeing examples of the content in the media or in the experiences of family members (Pugh et al., 2010b, 2020). Our study adds to this framework by defining facets of students' everyday lives through the lens of Bronfenbrenner's social ecologies theory (Bronfenbrenner, 1979). Through our first research question, our qualitative coding indicated that the four most common codes (Self, Learned Something, EP, and Triggered Interest) were narrowly followed by the Career and Course codes (Table 4.2). Clearly our sample of A&P students experienced TE and were sharing course ideas as they related to several of their microsystems.

The ENA addressed our second research question to expand on our qualitative analysis of the simple frequency of occurrence of these codes and visualize connections among them. In our overall ENA model, we show A&P students made connections between TE, LM, and microsystem codes. However the edge weights and frequency of connections indicate that there were stronger connections to TE codes and the Self and Family codes than TE codes and the Career and Course codes. This nuance of external microsystem experiences, with family having more connections to TE than career aspirations, was only evident in the ENA and hidden in traditional qualitative analyses. While previous research has demonstrated that A&P students have high extrinsic motivation for career goals and grade achievement (Finn et al., 2019; Sturges et al., 2016), our findings suggest that students make impactful connections to family and personal experiences when learning A&P content. Future research with a larger dataset may also be able to parse out the connections students make with A&P content and their personal experiences. For example, the Self code was abundant in our dataset and could be further divided in a larger dataset into categories like health choices, study habits, or childhood experiences.

While connections between microsystems to the MU, RE, and EV markers of TE were less strong in our dataset than their connections to EP, prior research suggests that experiences with these markers are characteristics of profiles of TE and engagement (Pugh, Bergstrom, & Spencer, 2017). Instances of EV in our data capture the aesthetic ideals that transformative experience theory is based on (Pugh, 2002, 2011). As one participant wrote:

> I have begun to think about myself and my peers on a cellular level. I never have really thought particularly about how complex the human body is and learning about all of the layers of tissues and how they work together has increased my critical thinking. I have broadened my perspective and learned how to understand the complexity of life. It is truly fascinating and makes me realize that life is so beautiful. (Participant 1785)

Taken together, our results from mixing these qualitative expressions with the ENA indicate that A&P content is well-situated to be transformative, as students use the course content to make sense of their own lived experiences. However, future efforts to deepen TE in these courses could focus efforts on MU and EV elements.

Moving from Interest to Transformative Experiences

The LM codes were more abundant in our sample than TE codes overall, with two (Learned Something and Triggered Interest) being key points in the ENA "kite." The frequent connections with Triggered Interest underscore a strength of A&P courses as promoters of TE: A&P offers opportunities to view tangible biology content in compelling ways. However, while situational interest has been predictive of TE in other science education studies (Heddy et al., 2021; Pugh et al., 2010a), findings from other studies have noted that triggered interest alone does not predict TE (Pugh et al., 2019). The individual networks in our sample illustrate that triggered interest code was not as strongly connected to EP as it was to the Learn and Self codes (Table 4.3). While some students connected their interest to TE markers (most commonly, EP), others did not (Appendix E, Figure E.1 and Figure E.2). An underlying goal of biology education research is to investigate for whom pedagogical interventions work and why (Dolan, 2015), and so we recommend future research examine what factors explain the "tipping point" from interest to TE.

Conclusions

Our research questions explored the possible relationships between transformative experiences, learning motivation constructs, and microsystems in undergraduate A&P student writing. Our findings from qualitative analyses indicate how many students reported having different types of TE in their writing. Using ENA, we modeled the co-occurrence of thematic codes to demonstrate the intersections of students' TE, LM attitudes, and everyday lives. In sum, our conclusions are:

1. The most commonly reported marker of TE in student writing was EP. While evidence in students' writing suggests that they experience EP in A&P courses, A&P instructors may be able to do more to scaffold MU and EV to more holistically support TE in their courses.
2. Students made connections between TE codes (most commonly, EP) and Microsystem codes in their writing. However, more students made connections with LM codes and Microsystems. This trend may reflect findings from other researchers that in Likert-style surveys, statements about some elements of TE (e.g., motivated use of content outside of the classroom) are more difficult for students to agree with than statements of interest or utility value (Koskey et al., 2018).
3. When comparing the connections students made between TE and Microsystem codes versus LM and Microsystem codes, we noticed that some microsystems had stronger connections to TE. Students made the strongest connections between TE codes their own sense of Self and their experiences with Family. In contrast, the Career and Course codes had stronger connections to LM codes.

Instructors wanting to promote TE for their students may find design principles such as Teaching for Transformative Experiences in Science Framework (TTES; Pugh, Bergstrom Heddy, et al., 2017) useful in their instruction. The TTES design principles outline multiple practices instructors can use to promote EP, EV, and MU, including re-framing course content as "big ideas," and designing activities around real-world applications of the content (Garner et al., 2016; Pugh, Bergstrom, Heddy, & Krob, 2017). Previous research indicates that implementing

TTES principles in higher education can promote transformative experiences (Heddy et al., 2016; Pugh, Bergstrom, Heddy, & Krob, 2017). Indeed, the findings from our post hoc analyses suggest that student engagement with the course may be more indicative of TE than grades. Further, the findings from the ENA offer that TE in A&P may be linked more closely to experiences with some microsystems more than others. Thus, A&P instructors may have greater success promoting TE by offering activities that leverage students' experiences with friends and family over those that focus solely on connections with future careers.

Limitations

The limitations to the generalizability of our quantitative findings include the small sample from our population of interest and the lack of demographic data for our sample. In A&P courses, the distribution of demographics does not consistently reflect the demographics of institutions at large (Royse et al., 2022), and so we chose not to report demographic data from the institution as a proxy to the demographic make-up of our sample.

We acknowledge the risk of bias in the confirmability dimension of trustworthiness (Lincoln & Guba, 1985) resulting from the first author (E.A.R.) being the primary instructor for the course in which data were collected and responsible for the design and analysis of this research. We mitigated this risk to qualitative credibility by having a second coder for a portion of the dataset (D. K.). Another consideration to trustworthiness is the historical context, which can affect transferability of qualitative findings (Frechette et al., 2020). Our data were collected during the Fall 2020 semester, during the COVID-19 pandemic. Student affect suffered during the tumultuous shift toward online education, resulting in loss of self-efficacy and of sense of belonging (Camfield et al., 2021). In our sample, a few students noted in their reflections how their personal lives were impacted by the COVID-19 pandemic (e.g., increased caretaker roles with family members or management of workplace risks). These types of challenges exert a high amount of extraneous cognitive load on students, which could impact their learning experiences (Tzafilkou et al., 2021). Anxiety and negative affect are associated with lower levels of TE (Pugh et al., 2019), and so it could be that external factors to the course were not conducive for having transformative experiences.

Leveraging ENA in this context was an exploratory application of this quantitative ethnographic approach, and so replication in future studies is necessary to make inferential claims about where the variance in students' cognitive structures arises. An ancillary finding of this exploratory work was the considerable amount of variance observed between individual student networks in the ENA. Our qualitative observations indicate that student participation in course activities may explain individual variance, but future work is needed to establish a quantitative relationship between student engagement with the course and transformative experiences in A&P.

CHAPTER V

CONCLUSIONS: TRANSFORMING UNDERGRADUATE ANATOMY AND PHYSIOLOGY

Undergraduate Anatomy and Physiology is a compelling context in which students persist and remediate if needed as a part of their efforts to achieve their goals of entering nursing and allied health professions. The questions I asked as a part of my dissertation research probed what instructional practices have been researched in A&P courses, examined what student factors impact their academic outcomes, and asked how students integrate course content with their perceptions of their lives. While inferential statistics were used to draw conclusions about the utility of survey measures to predict outcomes, the mixed methods approaches used in Chapters 3 and 4 amplified the voices of students themselves in qualitative interview data and written data.

One gap this dissertation aimed to address was the identified lack of research about best practices in A&P courses (Griff, 2016). I anticipated that there would be a lack of A&P research outlining pedagogical practices that impact learning outcomes, as this limitation has been identified in allied health and medical education research (Jensen et al., 2018; Vorstenbosch et al., 2011). Over the course of the systematic review (Chapter II; Royse et al., 2022), we learned that A&P courses are not understudied, but rather a significant portion of research about them had not been indexed (e.g., published in *HAPS Educator*). However, while the majority of research meeting our inclusion criteria reported learning outcomes, the learning outcomes were primarily final grades and exam grades, which are not equitable or reliable measures of learning

(Bygren, 2020; Schinske & Tanner, 2014). The field of A&P education research would benefit from the use of valid and reliable learning assessments, as it would give greater evidence to the generalizability of findings of intervention studies.

Examining student affect and experiences in A&P was another key aim of the dissertation. The project reported in Chapter III examines science identity as a predictor of academic outcomes (Royse et al., 2020), and contributes to an emerging trend of research promoting science identity as a valuable construct to examine in A&P (e.g., Perkins et al., Under Review). I had initially hypothesized that students in A&P courses would not feel like science people, especially after failing to meet criteria to progress in their coursework as a result of performance on science tasks. However, I was surprised at how interviewees identified strongly as science people, even after needing to retake the course. Additionally, the expressions of emerging allied health identities warrants future investigation, as these beliefs appeared to be deeply motivating to students in our sample. Indeed, science identity beliefs appear qualitatively different between students in basic science versus health care fields (Carlone & Johnson, 2007; Dou et al., 2021), and examining the role of developing identities in tandem with science identity may help explain these differences.

One finding from the systematic review was that a common criteria in the assessment of intervention efficacy was student satisfaction. Satisfaction was a broadly defined outcome, including measures of interest, enjoyment, and perceived utility. These outcomes fall short of transformative experiences, which would mark deeper investment and engagement with the topic in areas of students' everyday lives (Pugh, 2002; Pugh, Bergstrom, Heddy, & Krob, 2017). Triggered interest emerged as a dominant code in the Chapter IV written reflections dataset, affirming how A&P is interesting to students. However, we observed that there is a distribution of “next steps” after a student expresses interest that was not captured in the systematic review dataset, and would otherwise have been missed in measures of interest. Some students made connections beyond interest in course topics to how they say those topics in their everyday lives, while others reflected on their learning and the utility of knowing the content. There is opportunity for instructors and A&P educators to pursue how to tip the scales toward more transformative experiences.

A&P is a gateway course in a traditional sense, meaning it can be a challenging barrier for students to pass through in pursuit of their goals. However, rooted in the findings across my dissertation projects, I propose that undergraduate A&P courses have the potential to engage students deeply, not only as future healthcare professionals, but as science people and people who need to know science to engage with their everyday lives. It is worth reimagining the gateway. Instead of a barrier, A&P can be a point-of-entry to greater, more transformative engagement with STEM.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL LETTERS AND CONSENT FORMS

Institutional Review Board Approval Letter for Chapter III

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

DATE:	September 6, 2018
TO:	Emily Royse
FROM:	University of Northern Colorado (UNCO) IRB
PROJECT TITLE:	[1312887-1] The Anatomy of Persistence: A Mixed Methods Investigation of Student Affect in Anatomy and Physiology Courses
SUBMISSION TYPE:	New Project
ACTION:	APPROVAL/VERIFICATION OF EXEMPT STATUS
DECISION DATE:	September 6, 2018
EXPIRATION DATE:	September 5, 2022

Thank you for your submission of New Project materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

Thanks for such a well-written study. Before you send the consent out please be sure to update the IRB Office contact information to the below.

If you have any concerns about your selection or treatment as a research participant, please contact Nicole Morse, Office of Research, Kepner Hall, University of Northern Colorado, Greeley, CO 80639; 970-351-1910.

Best,

Maria

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Nicole Morse at 970-351-1910 or nicole.morse@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.

Consent Form for Chapter III

UNIVERSITY OF
NORTHERN COLORADO

ELECTRONIC CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO

Before you begin, please read the following information about our study. If you have any questions you would like to have answered before you start the survey, please email Emmy Royse at emily.royse@unco.edu.

Project Title: The Anatomy of Persistence: A Mixed Methods Investigation of Student Affect in Anatomy and Physiology Courses

Student Researcher: Emmy Royse
Phone: (303) 304-0033 **E-mail:** emily.royse@unco.edu

Senior Personnel: Melanie Peffer, Ph.D., School of Biological Sciences
Phone: (970) 351-2923 **Email:** melanie.peffer@unco.edu

Purpose and description: The purpose of this study is to examine Anatomy and Physiology (A&P) students' attitudes and beliefs about learning science. We want to understand: How do students' perceived science identity and self-efficacy relate to course outcomes in Anatomy and Physiology?

What you will be asked to do in this study: Participants in this study will be asked to:

- Take two online surveys: one at the beginning of the semester, and one at the end.
- Allow the research team to view your final grade.
- You may be invited to participate in an optional interview with a member of the research team for additional compensation.

Eligibility: You must be over 18 years old and currently enrolled in BIO 245 at the University of Northern Colorado to participate.

Location: The surveys at the beginning and the end of the semester can be completed anywhere on a computer that can access Qualtrics. If invited to complete a follow-up interview, the interview will take place at a mutually agreed upon location on UNC campus.

Time Required: The surveys at the beginning and the end of the semester will take approximately 20-25 minutes to complete. If invited to complete a follow-up interview, the interview will last approximately 45 minutes.

Risks: The risks of participation in this study are no greater than everyday computer use. Completing a follow-up interview has risks no greater than personal reflection and conversation about academic goals, which may cause some stress or frustration. If you are uncomfortable sitting for an extended period of time, you are welcome to take a break at any time.

Compensation: You will be awarded extra credit points in an amount to be determined by your instructor toward your BIO 245 grade at the end of the semester for completing both the pre and post-tests. If you are invited to complete the follow-up interview and do so, you will also be awarded with 10 Bear Bucks.

Benefits: You may indirectly benefit from your participation by reflecting on your learning strategies, which is a known beneficial cognitive practice. The discipline of science education will benefit from your participation as we seek to understand factors that influence student success.

Confidentiality: We will take every precaution to protect your anonymity. Your name will not be submitted as a part of the surveys; you will be assigned a random identifier which will apply to all your data. All digital data will be stored on password-protected UNC computers which are only accessible by members of the research team and IT staff. Audio recordings from the interview, should you choose to participate, will be deleted after transcription.

Participation is voluntary. You may decide not to participate in this study, and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact Sherry May, IRB Administrator, Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1910.

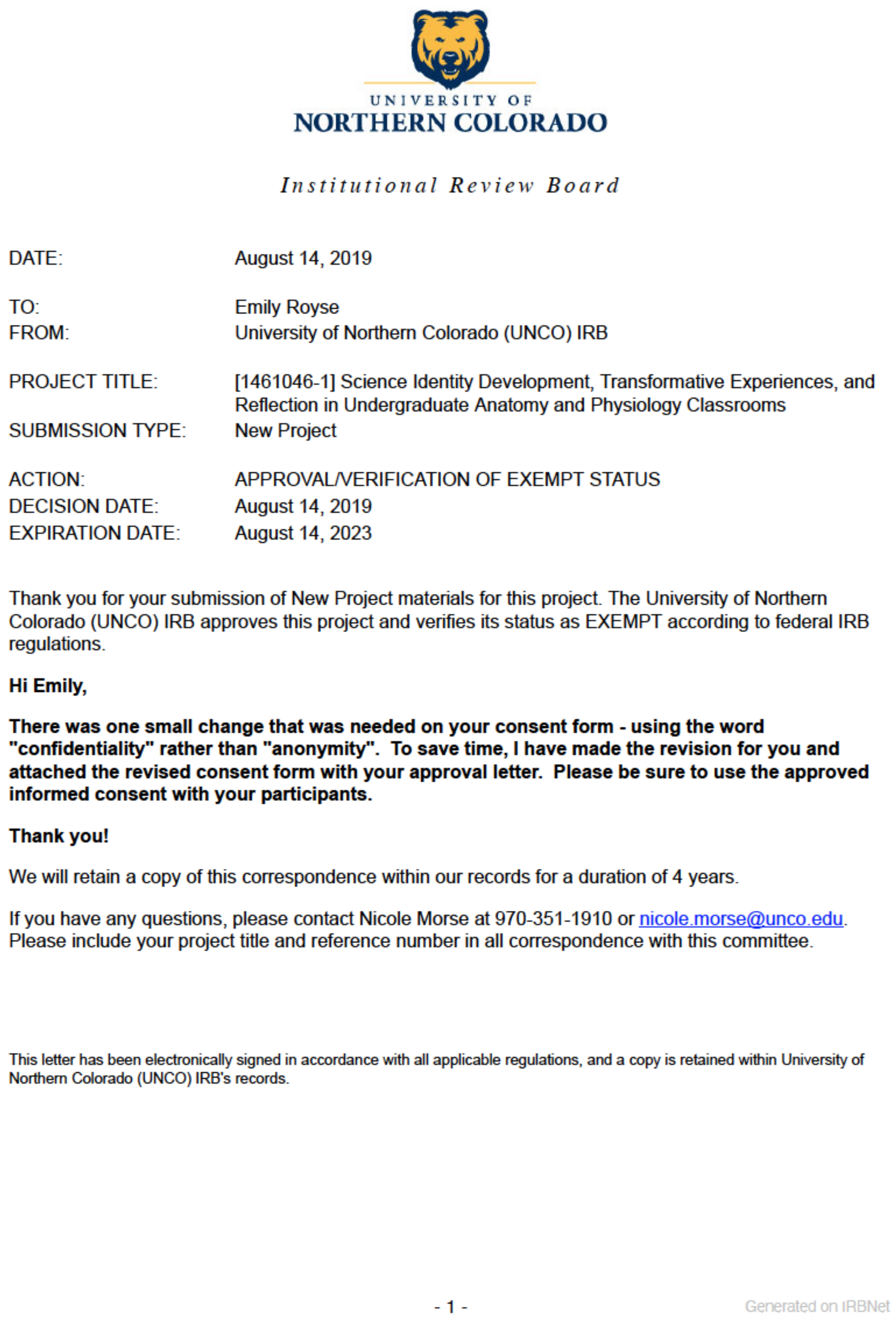
ELECTRONIC CONSENT: Please select your choice below. You may print a copy of this consent form for your records. Clicking on the “Agree” button indicates that

- You have read the above information
- You voluntarily agree to participate
- You are 18 years of age or older

☐ Agree

☐ Disagree

IRB Approval Letter for Chapter IV



UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

DATE: August 14, 2019

TO: Emily Royse
FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [1461046-1] Science Identity Development, Transformative Experiences, and Reflection in Undergraduate Anatomy and Physiology Classrooms
SUBMISSION TYPE: New Project

ACTION: APPROVAL/VERIFICATION OF EXEMPT STATUS
DECISION DATE: August 14, 2019
EXPIRATION DATE: August 14, 2023

Thank you for your submission of New Project materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

Hi Emily,

There was one small change that was needed on your consent form - using the word "confidentiality" rather than "anonymity". To save time, I have made the revision for you and attached the revised consent form with your approval letter. Please be sure to use the approved informed consent with your participants.

Thank you!

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Nicole Morse at 970-351-1910 or nicole.morse@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.

Consent Form for Chapter IV

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO

Before you begin, please read the following information about our study. If you have any questions, please email Dr. Emily Holt at emily.holt@unco.edu.

Project Title: Science Identity Development, Transformative Experiences, and Reflection in Undergraduate Anatomy and Physiology Classrooms

Student Researchers: Emily Royse, Dylan Kriescher
Phone: 303-304-0033, 307-314-2413 Email: emily.royse@unco.edu, dylan.kriescher@unco.edu

Faculty Advisors: Kevin Pugh, Ph.D., Emily Holt, Ph.D.
Phone: 970-351-2989, 970-351-4870 Email: kevin.pugh@unco.edu, emily.holt@unco.edu

Purpose and description: The purpose of this study is to investigate the science identity of Anatomy and Physiology (A&P) students and how A&P students encounter course content outside of the classroom.

What you will be asked to do in this study: Participants in this study will be asked to:

- Take three surveys during class, either on paper or digitally, at three points in the semester.

Eligibility: You must be 18 years of age or older and currently enrolled in BIO 245 at the University of Northern Colorado to participate.

Location: The first two surveys will be completed during class time, and the third survey can be completed anywhere on a computer that can access Qualtrics.

Time Required: Each survey will take approximately 15-20 minutes to complete.

Risks: The risks of participation in this study are no greater than everyday computer use and class participation.

Compensation: For each survey you complete, you will be entered into a random drawing to win one $25 Amazon gift card (for example, if you complete one survey, you will be entered once into the drawing, but if you complete all three surveys, you will be entered three times into the drawing).

Benefits: You may indirectly benefit from your participation by reflecting on your learning and attitudes about the course, which is a known beneficial cognitive practice. The discipline of science education will benefit from your participation as we seek to understand factors that influence student success.

Confidentiality: We will take every precaution to protect your anonymity. Your name and BearMail email address will be used to match your survey data to this consent form, after which you will be assigned a random identifier which will apply to all your data and your name and BearMail will be deleted from our files. All digital data will be stored on password-protected computers and will only be accessible by members of the research team. Your participation in this study will also be confidential to the instructor of BIO 245; this consent form will be sealed into the provided envelope and stored in a filing cabinet located in a locked office until after final grades are submitted.

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact Nicole Morse, Office of Research, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1910.

Please check one of the following boxes and sign and print your name below:

- ☐ I **do** give permission for my data to be used by the research team
- ☐ I **do not** give my permission for my data to be used by the research team

Participant's Printed Name Date

Participant's Signature Date

Researcher's Signature Date

APPENDIX B

SYSTEMATIC REVIEW INCLUDED STUDIES

Table B.1

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

Citation	GA Score	Sample Size	Demographic Data Reported			Institutional Setting	Learning Outcome	Pedagogy Category	Specific Pedagogy Described
			Majors	Gender	Racial/ Ethnic Identity				
Abdullahi & Gannon, 2012	6	1,525				Community college	Final grades, not validated questionnaire	Supplemental Instruction	Pre-semester workshop
Anderton, Chiu, & Aulfrey, 2016	2	138	X	X		Four-year institution	Final grades	Curriculum	Lab activities: modeling
Bradshaw & Bradshaw, 2016	5	353				Not specified	Exam, quiz, or assignment scores	Curriculum	Lab curriculum: systemic and regional organization
P. J. P. Brown, 2010	4	91				Four-year institution (private)	Exam scores, final grades	Curriculum	Process Oriented Guided Inquiry Learning
G. A. Brown et al., 2015	6	234	X			Not specified	Exam, quiz, or assignment scores	Assessment	Online quizzes
Bryans Bongey et al., 2005	5	646				Four-year institution (private)	Exam, quiz, or assignment scores	Assessment	Online quizzes
Burleson & Olimpo, 2016	2	36				Four-year institution	Exam scores, not validated questionnaire	In-class activity	Word game
Carnegie, 2012	4	566				Four-year institution (public)	Final grades	In-class activity	Writing activity

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

Citation	GA Score	Sample Size	Demographic Data Reported			Institutional Setting	Learning Outcome	Pedagogy Category	Specific Pedagogy Described
			Majors	Gender	Racial/ Ethnic Identity				
Carnegie, 2016	1	290				Four-year institution (public)	Exam, quiz, or assignment scores	Assignment	Individual presentation assignment
Carnegie & Leddy, 2017	2	569				Four-year institution (public)	Exam question	Assessment	Justify response multiple choice questions
Casotti et al., 2008	5	300				Four-year institution	Exam, quiz, or assignment scores	Curriculum	Lab activities: inquiry-based
Chakraborty & Cooperstein, 2018	4	324	X	X		Four-year institution	Final grades	Resource	iPad resource
Cliff & Wright, 1996	4	66				Four-year institution	Exam, quiz, or assignment scores	Assignment	Case studies
Cronmiller et al., 2017	3	225				Community college	Exam, quiz, or assignment scores	In-class activity	Exam wrappers
Csikar & Stefaniak, 2018	5	63	X	X		Community college	Exam, quiz, or assignment scores	Curriculum	Storytelling lectures
de Oliveira et al., 2015	4	226	X	X		Four-year institution (public)	Exam, quiz, or assignment scores	Supplemental Instruction	Peer-assisted learning sessions
Dearden & Anderson, 1969	5	241	X			Community college	Exam, quiz, or assignment scores	In-class activity	Discussion activity

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
DeHoff et al., 2011	4	110				Four-year institution (public)	Exam scores, Final grades	Curriculum	Lab activities: cat dissection versus clay sculpting
Dobson, 2013	5	234				Four-year institution (public)	Exam, quiz, or assignment scores	Assessment	Ongoing retrieval assessments
Dearden & Anderson, 1969	5	241	X			Community college	Exam, quiz, or assignment scores	In-class activity	Discussion activity
DeHoff et al., 2011	4	110				Four-year institution (public)	Exam scores, Final grades	Curriculum	Lab activities: cat dissection versus clay sculpting
Dobson, 2013	5	234				Four-year institution (public)	Exam, quiz, or assignment scores	Assessment	Ongoing retrieval assessments
Dobson & Linderholm, 2015	6	373				Four-year institution	Exam scores, not validated questionnaire	In-class activity	Self-testing strategies
Eleazer & Scopa Kelso, 2018	6	1,193		X		Four-year institution	Final grades	Curriculum	Flipped learning
Entezari & Javdan, 2016	4	66		X	X	Community college	Exam, quiz, or assignment scores	Curriculum	Flipped learning
Finn et al., 2017	6	626		X		Four-year institution (private)	Final grades, quiz scores	Curriculum	Integrating lab and lecture

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
FitzPatrick et al., 2011	6	421				Four-year institution (private)	Exam, quiz, or assignment scores	Assessment	Clicker questions
Fournier et al., 2017	5	444		X	X	Four-year institution (public)	Exam scores, final grades, not validated questionnaire	Assessment	Collaborative unit examinations
Fozzard et al., 2018	5	2,701		X		Four-year institution (public)	Exam, quiz, or assignment scores	Assessment	Multiple choice examinations
Gannon & Abdullahi, 2013	5	118				Community college	Exam scores, final grades	Assessment	Open note quizzes
Gopal et al., 2010	4	165				Four-year institution (public)	Exam, quiz, or assignment scores	Resource	Website resource
Green et al., 2006	4	652				Four-year institution	Exam, quiz, or assignment scores	Resource	LMS use
Griff & Matter, 2013	9	587				Multiple institutional contexts	Exam, quiz, or assignment scores, not validated questionnaire	Assignment	Adaptive online learning assignments
Guy et al., 2017	3	85	X	X		Four-year institution (public)	Assignment scores, final grades	In-class activity	Concept mapping

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

Citation	GA Score	Sample Size	Demographic Data Reported: Majors	Demographic Data Reported: Gender	Demographic Data Reported: Racial/ Ethnic Identity	Institutional Setting	Learning Outcome	Pedagogy Category	Specific Pedagogy Described
Guy et al., 2018	4	137	X	X		Four-year institution (public)	Final grades	Resource	Online resources
Harrison et al., 2001	5	Not reported				Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Lab activities: digital modeling and inquiry-based labs
Haspel et al., 2014	5	747				Community college	Exam, quiz, or assignment scores	Curriculum	Lab curriculum: clay modeling versus rat dissection
Higazi, 2011	3	88				Four-year institution (public)	Exam, quiz, or assignment scores	In-class activity	Digital microscopic histology
Hillhouse & Britson, 2018	6	556				Four-year institution (public)	Exam, quiz, or assignment scores	Resource	Smart phone microscope adapters
Hilvano et al., 2014	3	299				Four-year institution (public)	Not validated questionnaire	Assignment	Case studies
Hopper, 2011	3	12				Four-year institution (public)	Final grades	Supplemental Instruction	Concurrent enrollment study skills course
Hughes, 2011	3	132				Four-year institution (public)	Final grades, not validated questionnaire	Supplemental Instruction	Peer-assisted learning sessions

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	GA Score	Sample Size	Majors	Gender	Racial/ Ethnic Identity	Institutional Setting	Learning Outcome	Pedagogy Category	Specific Pedagogy Described
Hughes, 2011	3	132				Four-year institution (public)	Final grades, not validated questionnaire	Supplemental Instruction	Peer-assisted learning sessions
Hughes, 2018	4	215				Four-year institution (public)	Final grades	Supplemental Instruction	Peer-assisted learning sessions
Hurtt & Bryant, 2016	2	152				Four-year institution (private)	Exam, quiz, or assignment scores	Assignment	Writing assignments
Husmann et al., 2009	5	Not reported				Four-year institution	Exam, quiz, or assignment scores	Resource	Virtual microscopy
Hutchinson & Elbatarny, 2016	4	127	X			Four-year institution	Exam, quiz, or assignment scores	Resource	Printed histology atlas
Hutchinson et al., 2017	4	153	X			Four-year institution	Exam, quiz, or assignment scores	Resource	Printed gross anatomy atlas
Jensen, 1996	4	182				Four-year institution	Exam, quiz, or assignment scores, not validated questionnaire	Assessment	Cooperative quizzes
Johnston et al., 2013	8	499	X			Four-year institution	Final grades, exam grades	Resource	Online lecture videos
Krontiris-Litowitz, 2009	4	147				Four-year institution (public)	Exam, quiz, or assignment scores	Assessment	Collaborative quizzes

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
Lombardi et al., 2014	4	29		X		Four-year institution (public)	Not validated questionnaire	In-class activity	Out-of-class use of plastic models, organ dissection, or virtual dissection
Lunsford & Herzog, 1997	1	12		X		Community college	Exam, quiz, or assignment scores	Curriculum	Concept mapping
McDaniel & Daday, 2017	5	2247				Four-year institution (public)	Final grades	Curriculum	Case studies and electronic textbooks
Motoike et al., 2009	5	181	X	X		Community college	Exam scores, not validated questionnaire	In-class activity	Lab activities: cat dissection versus clay sculpting
O'Byrne et al., 2008	6	516	X			Four-year institution (public)	Exam scores, final grades	Resource	Online self-testing embedded within digital atlas
Owens & Moroney, 2017	7	263	X			Four-year institution (private)	Final grades	Supplemental Instruction	Pre-course and concurrent instructor-led supplemental instruction
Petto et al., 2017	4	162				Four-year institution (public)	Not validated questionnaire	In-class activity	Neural circuit modeling activity
Petzold et al., 2016	4	88				Four-year institution (public)	Exam, quiz, or assignment scores	In-class activity	Story-based writing activity

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
Rae, McGoey, et al., 2017	2	84	X			Four-year institution (public)	Not validated questionnaire	Resource	Cardiology pathology guide
Rae, Newman, et al. (2017)	2	84	X			Four-year institution (public)	Not validated questionnaire	Resource	Kidney pathology guide
Rathner et al., 2013	4	968				Four-year institution (public)	Final grades	Curriculum	Guided inquiry curriculum re-design
Reuter & Weiss, 2017	5	1,590				Four-year institution (public)	Final grades	Resource	Textbooks published by faculty
Rompolski et al., 2018	6	273	X			Four-year institution (private)	Exam, quiz, or assignment scores	Supplemental Instruction	Instructor-led review sessions
Rosli et al., 2017	4	165	X	X		Four-year institution (public)	Final grades	Curriculum	Flipped learning
Rudolph et al., 2018	5	178				Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Multiple assignments and non-compulsory video resources
Saltarelli et al., 2014	7	214		X		Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Lab activities: cadaver-based versus computer-assisted instruction

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
Salvage-Jones et al., 2016	7	1,320	X			Four-year institution	Exam, quiz, or assignment scores	In-class activity	Lab activities: labeling
Seeram, 2001	4	51				Community college	Not validated questionnaire	In-class activity	Video versus small group discussion sessions
Shaw & Almeida, 2018	5	118	X			Four-year institution (private)	Exam, quiz, or assignment scores	Assessment	Crib cards
Shoepe et al., 2015	5	165	X			Four-year institution (private)	Exam scores, final grades	Assignment	Digital project-based assignment
Smee & Cooke, 2018	4	1,958				Four-year institution (public)	Exam, quiz, or assignment scores	Assessment	Case study exam questions
Spiegel & Barufaldi, 1994	4	120		X		Community college	Validated questionnaire	Supplemental Instruction	Structured reading assignments
Steele, 2018	5	283				Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Lab curriculum: systemic and regional organization
Stein et al., 2006	3	283	X			Four-year institution	Exam, quiz, or assignment scores	Assessment	Clicker questions
Stencel, 1992	1	85				Community college	Not validated questionnaire	In-class activity	Guided problem-solving activity

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
Stetzik et al., 2015	5	185				Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Puzzle-based learning
Sturges et al., 2009	4	255	X	X		Four-year institution (public)	Exam scores, not validated questionnaire	In-class activity	Role play activity
Sturges et al., 2017	8	560	X	X	X	Four-year institution (public)	Final grades	Assignment	Study guide assignment
Sugrue et al., 2017	4	66				Four-year institution (public)	Validated questionnaire	Supplemental Instruction	Yoga workshop
Termos, 2013	3	161				Community college	Exam scores, validated questionnaire	Assessment	Clicker questions
Utz & Bernacki, 2018	3	238				Four-year institution (public)	Exam scores, not validated questionnaire	Assessment	Online self-assessment quizzes
Van Nuland et al., 2015	4	67		X		Four-year institution (public)	Exam, quiz, or assignment scores	Assessment	Competition based learning
Waters et al., 2005	5	136	X			Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Lab activities: cat dissection versus clay sculpting

Table B.1, continued

Generalizability Assessment (GA) of Quantitative Studies Evaluating Learning Outcomes

			Demographic Data Reported						
Citation	**GA Score**	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Learning Outcome**	**Pedagogy Category**	**Specific Pedagogy Described**
Waters et al., 2011	5	222				Four-year institution (public)	Exam, quiz, or assignment scores	Curriculum	Lab activities: cat dissection versus clay sculpting
Wolf et al., 2015	4	149	X	X		Community college	Exam, quiz, or assignment scores	In-class activity	Lab activities: spirometry
Zitzner, 2017	4	1,579	X			Four-year institution (private)	Exam, quiz, or assignment scores	Curriculum	Lab curriculum: guided modules

Table B.2

Included Studies Not Meeting Generalizability Assessment Criteria

Citation	Sample Size	Demographic Data Reported			Institutional Setting	Outcomes Measured	Pedagogy Category	Specific Pedagogy Described
		Majors	Gender	Racial/ Ethnic Identity				
Barton et al., 2018	61	X			Four-year institution (private)	Satisfaction	Curriculum	Cadaver-based learning curricula
Bentley et al., 2015	20	X	X		Community college	Satisfaction	Assignment	Inquiry-guided projects
Bevan et al., 2015	101	X			Not specified	Satisfaction outcome	Curriculum	Simulated patient activity
S. J. Brown et al., 2018	355		X	X	Four-year institution (public)	Learning and student engagement	Curriculum	Didactic lecture
Crisp et al., 2007	96				Four-year institution (public)	Satisfaction outcome	Assignment	Group webpage design project
Crowther et al., 2017	48				Four-year institution	Satisfaction outcome	In-class activity	Writing activity
Dunbar & Nichols, 2012	121				Four-year institution (public)	Empathy	Curriculum	History of anatomy and surface anatomy lessons
Dunn-Lewis et al., 2016	98				Four-year institution (private)	Learning and satisfaction	Resource	Commercial textbook resources
Ediger, 2017	49				Four-year institution (public)	Satisfaction outcome	Assignment	Interview-based written assignment

Table B.2, continued

Included Studies Not Meeting Generalizability Assessment Criteria

First Author (publication year)	Sample Size	Demographic Data Reported			Institutional Setting	Outcomes Measured	Pedagogy Category	Specific Pedagogy Described
		Majors	Gender	Racial/ Ethnic Identity				
Farkas et al., 2016	492	X	X		Four-year institution (public)	Learning and learning preferences	Curriculum	Didactic lecture and lab
Geuna & Giacobini-Robecchi, 2002	72	X	X		Four-year institution (public)	Satisfaction outcome	In-class activity	Brainstorming activities
Guy et al., 2015	202	X			Four-year institution (public)	Satisfaction outcome	Resource	Online interactive atlas
Hopper, 2016	59				Four-year institution (public)	Student engagement	Curriculum	Hybrid vs. in-person instruction
Jensen et al., 2002	5				Not specified	Lived experiences	Curriculum	Technology-rich course
Johnston & McAllister, 2008	104				Four-year institution	Satisfaction outcome	Curriculum	Laboratory exercises: dissections, clinical tests, and modeling
Johnston, 2010	189	X			Four-year institution (public)	Satisfaction outcome	In-class activity	Prosection exercise
Kuyatt & Baker, 2014	185		X		Community college	Perceived learning	Curriculum	Hybrid vs. in-person instruction
Mayner et al., 2013	26				Not specified	Learning and satisfaction	Curriculum	Problem-based learning

Table B.2, continued

Included Studies Not Meeting Generalizability Assessment Criteria

		Demographic Data Reported						
First Author (publication year)	**Sample Size**	**Majors**	**Gender**	**Racial/ Ethnic Identity**	**Institutional Setting**	**Outcomes Measured**	**Pedagogy Category**	**Specific Pedagogy Described**
Montayre & Sparks, 2017	60	X			Four-year institution	Satisfaction outcome	Curriculum	Compulsory laboratory curriculum
O'Connor & Britson, 2017	318	X			Four-year institution (public)	Attitudes toward the elderly, satisfaction	In-class activity	Lab activity: simulating arthritis
O'Drobinak & Woods, 2002	68				Not specified	Satisfaction outcome	In-class activity	Central nervous system lab activity
Ostrin & Dushenkov, 2016	280				Community college	Satisfaction outcome	In-class activity	In-class use of virtual microscopy and anatomy atlas
Ranaweera & Montplaisir, 2010	286				Four-year institution (public)	Learning outcome	Assessment	Drawing as formative assessment
Raynor & Iggulden, 2008	135	X			Four-year institution (public)	Satisfaction outcome	Resource	E-book supplement
Slominski et al., 2017	355	X	X		Four-year institution (public)	Learning	In-class activity	Drawing activity
Williamson & Lee, 2018	20				Four-year institution (public)	Satisfaction outcome	Assignment	Analogy-based pre-lab assignments
Yeom et al., 2017	20				Four-year institution (public)	Satisfaction outcome	Resource	Haptically-controlled computer gross anatomy models

Table B.2, continued

Included Studies Not Meeting Generalizability Assessment Criteria

First Author (publication year)	Sample Size	Demographic Data Reported			Institutional Setting	Outcomes Measured	Pedagogy Category	Specific Pedagogy Described
		Majors	Gender	Racial/ Ethnic Identity				
Yucha, 1995	17				Not specified	Satisfaction outcome	In-class activity	Improvisation activity

APPENDIX C

SELF-EFFICACY AND SCIENCE IDENTITY SURVEY

Chapter III Survey Metrics

Surveys 1 and 2

The following questions ask about your motivation for and attitudes about this class (Introduction to Anatomy and Physiology). Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions. If you think the statement is very true of you, select 7; if a statement is not at all true of you, select 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

- I believe I will receive an excellent grade in this class.
- I'm certain I can understand the most difficult material presented in the readings for this class.
- I'm confident I can learn the basic concepts taught in this class.
- I'm confident I can understand the most complex material presented by the instructor in this class.
- I'm confident I can do an excellent job on the assignments and tests in this class.
- I expect to do well in this class.
- I'm certain I can master the skills being taught in this class.
- Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

Please indicate how strongly you agree with each of the following statements about your experiences *in this course* (including labs, if applicable). Use the following scale to choose your responses:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

1. I received good grades on my assignments in this class.
2. My mind went blank and I was unable to think clearly when working on assignments.
3. Watching other students in class made me think that I could not succeed in Anatomy and Physiology.
4. When I came across a tough Anatomy and Physiology question, I worked at it until I solved it.
5. Working with other students encouraged and motivated me in this class.
6. I have usually been at ease in this class.
7. Listening to the instructor and other students in question-and-answer sessions made me think that I could not understand Anatomy and Physiology.
8. I found the material in this course to be difficult and confusing.
9. I enjoyed Anatomy and Physiology labs/activities.
10. My instructor’s demonstrations and explanations gave me confidence that I could solve Anatomy and Physiology-related problems.
11. I was rarely able to help my classmates with difficult Anatomy and Physiology problems.
12. My instructor encouraged me that I could use Anatomy and Physiology concepts to understand real life phenomena.

13. I usually didn’t worry about my ability to solve Anatomy and Physiology problems.
14. I had difficulty with the exams/quizzes in this class.
15. I am poor at doing labs/activities to explore Anatomy and Physiology questions.
16. The instructor in this course encouraged me to put forth my best efforts.
17. I rarely knew the answer to the questions raised in class.
18. Anatomy and Physiology makes me feel uneasy and confused.
19. I identified with the students in this class who did well on exams/quizzes.
20. I got positive feedback about my ability to recall Anatomy and Physiology ideas.
21. I got a sinking feeling when I thought of trying hard Anatomy and Physiology problems.
22. I learned a lot by doing my Anatomy and Physiology assignments/activities.
23. During this course, I admired my instructor’s understanding of Anatomy and Physiology.
24. In-class discussions and activities helped me to relax, understand, and enjoy my experience in this course.
25. My instructor’s feedback discouraged me about my ability to perform well on Anatomy and Physiology exams/quizzes.
26. It was fun to go to this class.
27. I could relate to many classmates who were involved and attentive in class.
28. No one in class has encouraged me to go on in science after this course.
29. I got really uptight while taking exams/quizzes in this class.
30. I can remember the basic Anatomy and Physiology concepts taught in this class.
31. Classmates who were similar to me usually had trouble recalling details taught in class.
32. My peers in this course encouraged me that I had the ability to do well on class projects/assignments.
33. I was attentive and involved in what was going on in class.

To what extent do you agree or disagree with the following statements?

Not at all 0 1 2 3 4 Very much so

- I see myself as a biology person
- My family sees me as a biology person
- My friends/classmates see me as a biology person
- My science instructors/teachers see me as a biology person
- I am confident that I can understand biology
- I can do well on exams in biology
- I understand concepts I have studied in biology
- I can overcome setbacks in biology
- Others ask me for help in biology
- I am interested in learning more about biology
- Topics in biology excite my curiosity
- I enjoy learning about biology

Survey 1 Supplemental Questions

How many credit hours are you enrolled in this semester?

Which of the following science classes have you taken before the Fall 2018 semester, either at UNC or at another institution? Select all that apply.

- ANT 130 - Introduction to Biological Anthropology
- AST 100 - General Astronomy
- AST 109 - The Cosmos
- BIO 100 - Exploring Biology
- BIO 105 - Exploring Biology Lab
- BIO 110 - Principles of Biology
- BIO 245 – Introduction to Human Anatomy and Physiology
- BIO 246 – Advanced Human Anatomy and Physiology
- BIO 265 - Life Science Concepts
- BIO 251 – Allied Health Microbiology
- CHEM 101 - Chemistry for Citizens
- CHEM 102 - Chemistry for Citizens Laboratory
- CHEM 111 - Principles of Chemistry I
- CHEM 111L - Principles of Chemistry I Laboratory
- CHEM 281 - Fundamentals of Biochemistry
- CHEM 281L - Fundamentals of Biochemistry Laboratory
- ENST 100 - Introduction to Environmental Studies
- ENST 225 - Energy and the Environment
- ENST 235 - Chemistry and the Environment
- ESCI 200 - Introduction to Environmental Earth Science
- ESCI 265 - Earth Science Concepts for Elementary Teachers
- FND 250 - Principles of Nutrition
- GEOL 100 - General Geology
- GEOL 110 - Our Geological Environment
- MET 110 - Our Violent Atmosphere
- MET 205 - General Meteorology
- OCN 110 - Our Ocean Systems
- OCN 200 - General Oceanography
- PHYS 106 - Introduction to Spaceflight
- PHYS 220 - Introductory Physics I
- PHYS 240 - General Physics I
- SCI 265 - Physical Science Concepts
- SCI 266 - Earth and Life Science
- SES 220 - Anatomical Kinesiology
- Other: [text entry]

Which of the following science classes are you taking this semester (Fall 2018)? Select all that apply.

- ANT 130 - Introduction to Biological Anthropology
- AST 100 - General Astronomy

- AST 109 - The Cosmos
- BIO 100 - Exploring Biology
- BIO 105 - Exploring Biology Lab
- BIO 110 - Principles of Biology
- BIO 245 – Introduction to Human Anatomy and Physiology
- BIO 246 – Advanced Human Anatomy and Physiology
- BIO 265 - Life Science Concepts
- BIO 251 – Allied Health Microbiology
- CHEM 101 - Chemistry for Citizens
- CHEM 102 - Chemistry for Citizens Laboratory
- CHEM 111 - Principles of Chemistry I
- CHEM 111L - Principles of Chemistry I Laboratory
- CHEM 281 - Fundamentals of Biochemistry
- CHEM 281L - Fundamentals of Biochemistry Laboratory
- ENST 100 - Introduction to Environmental Studies
- ENST 225 - Energy and the Environment
- ENST 235 - Chemistry and the Environment
- ESCI 200 - Introduction to Environmental Earth Science
- ESCI 265 - Earth Science Concepts for Elementary Teachers
- FND 250 - Principles of Nutrition
- GEOL 100 - General Geology
- GEOL 110 - Our Geological Environment
- MET 110 - Our Violent Atmosphere
- MET 205 - General Meteorology
- OCN 110 - Our Ocean Systems
- OCN 200 - General Oceanography
- PHYS 106 - Introduction to Spaceflight
- PHYS 220 - Introductory Physics I
- PHYS 240 - General Physics I
- SCI 265 - Physical Science Concepts
- SCI 266 - Earth and Life Science
- SES 220 - Anatomical Kinesiology
- Other: [text entry]

Have you taken BIO 245 (Introduction to Anatomy and Physiology) at UNC before?

- Yes
- No

[If yes] Which semester did you take BIO 245 (Introduction to Anatomy and Physiology)

- Summer 2018
- Spring 2018
- Fall 2017
- Summer 2017
- Spring 2017
- Other: [text entry]

[If yes] What letter grade did you receive in BIO 245 (Introduction to Anatomy and Physiology)?

- A
- B
- C
- D
- F
- I withdrew (W)
- Prefer not to say

Have you taken an introductory anatomy and physiology class at another institution before?

- Yes
- No

[If yes] Where did you previously take an introductory anatomy and physiology class?

[If yes] Which semester did you take an introductory anatomy and physiology class?

- Summer 2018
- Spring 2018
- Fall 2017
- Summer 2017
- Spring 2017
- Other: [text entry]

[If yes] What letter grade did you receive in this introductory anatomy and physiology class?

- A
- B
- C
- D
- F
- I withdrew (W)
- Prefer not to say

Survey 2 Supplemental Questions

How many credit hours did you complete this semester?

What letter grade do you expect to receive in BIO 245 (Introduction to Human Anatomy and Physiology)?

Do you anticipate taking BIO 245 (Introduction to Human Anatomy and Physiology) again in the future?

- Yes
- No
- I don’t know
- Prefer not to say

Will you enroll in BIO 246 (Advanced Human Anatomy and Physiology) in the future? Why or why not?

- Yes, because [text entry]
- No, because [text entry]
- I don’t know
- Prefer not to say

What is your gender?

[enter response here]

Which of the following best represents your racial or ethnic heritage?

- Non-Hispanic White or Euro-American
- Black, Afro-Caribbean, or African American
- Latino or Hispanic American
- East Asian or Asian American
- South Asian or Indian American
- Middle Eastern or Arab American
- Native American or Alaskan Native
- Multiracial
- Other
- Prefer not to say

What is your current classification?

- Freshman
- Sophomore
- Junior
- Senior

What is your major?

[enter response here]

APPENDIX D

REMEDIATION INTERVIEW PROTOCOL

Interview Protocols

Interviews will be conducted at a mutually agreed upon location on-campus at UNC. At the beginning of the interview, Mrs. Royse will review the consent form with the participant to reiterate the purpose of the study, elaborating on the purpose of the study to specifically examine student persistence when retaking anatomy and physiology courses. The interview should last between 30-45 minutes.

Interview Questions

Interview topics will consist of questions about motivations for retaking the course, learning strategies and how they may have changed. For conversational purposes, “A&P” will be used in place of “BIO 245” or “Anatomy and Physiology.”

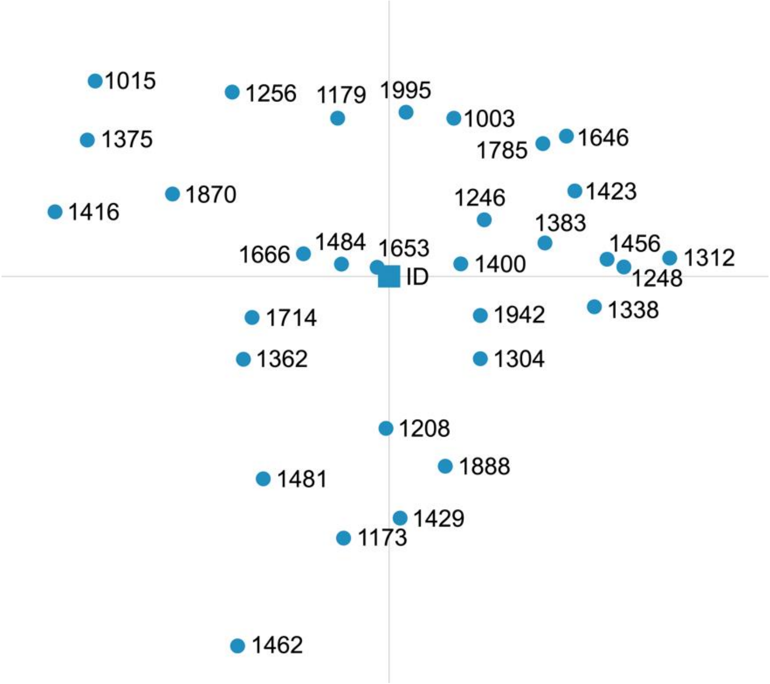
- Visualize your future career goal or next educational goal. Describe it to me. What is compelling about it? Why did you choose it?
- Keeping sight of your career/educational goals, how does A&P relate to your path to realizing that goal?
- On the pre-test, you indicated that you had taken A&P before. What experiences informed your decision to enroll in the course again?
- What attributed to or affected your performance in A&P last time you took the course? Describe how those factors relate to your performance now.
- Imagine you have an A&P test in seven days. How do you prepare? How does your strategy now compare to your strategy the last time you took the class?
- Imagine you are now taking the A&P test, using your current prep strategy. Run me through your mental narrative as you answer questions. How do you approach them? What happens when you come across one you are unsure of?
- How would you describe who a “biology person” is?
- How do you see your identity manifested in your coursework? How do you see it manifested in A&P? How do you see it manifested in your career goals?

APPENDIX E

EPISTEMIC NETWORK ANALYSIS PLOTS

Figure E.1

Individual Centroid Coordinates in ENA Model



Note. Centroids labeled by Participant ID number.

Figure E.2

Individual Networks for All Participants (n = 31)

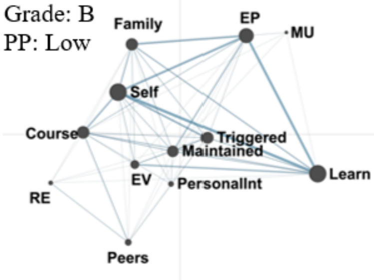
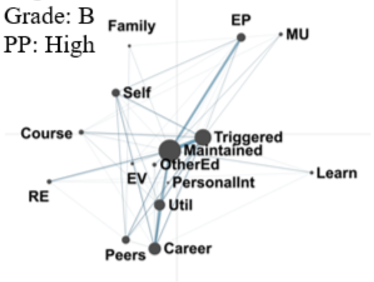
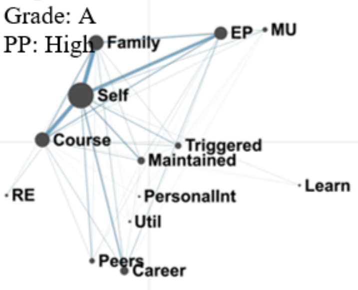
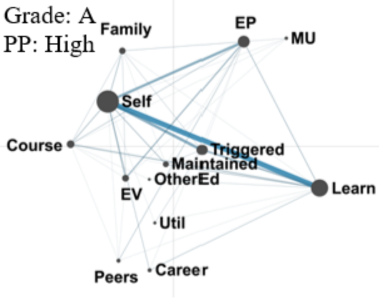
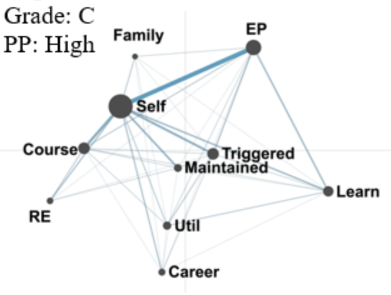
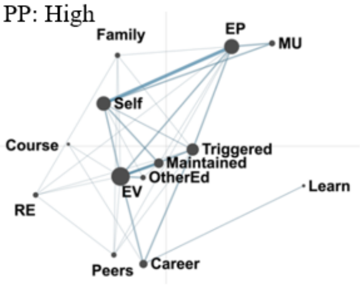
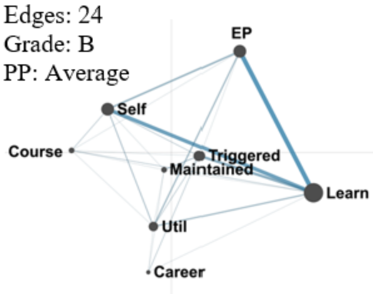
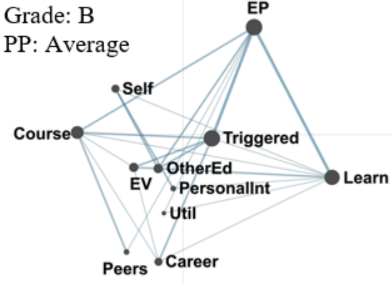
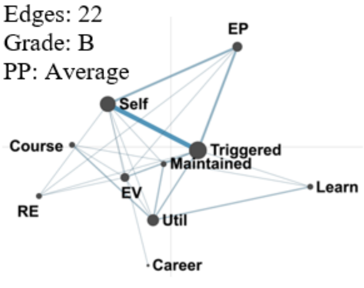
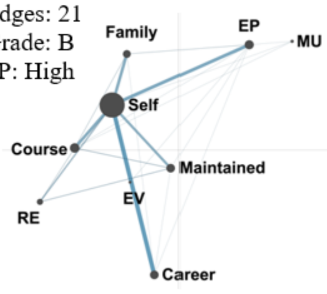
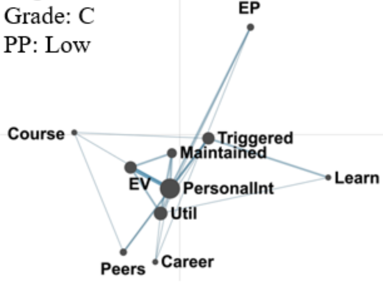
[ID Number] Edges: [# Edges in Network] Grade: [Unit Exam Average] PP: [Level of Participation Points]	1003 Edges: 53 Grade: B PP: Low 	1481 Edges: 53 Grade: B PP: High 
1015 Edges: 51 Grade: A PP: High 	1785 Edges: 42 Grade: A PP: High 	1179 Edges: 38 Grade: C PP: High 
1666 Edges: 32 Grade: A PP: High 	1248 Edges: 24 Grade: B PP: Average 	1304 Edges: 23 Grade: B PP: Average 
1653 Edges: 22 Grade: B PP: Average 	1375 Edges: 21 Grade: B PP: High 	1173 Edges: 20 Grade: C PP: Low 

Figure E.2, continued

Individual Networks for All Participants (n = 31)

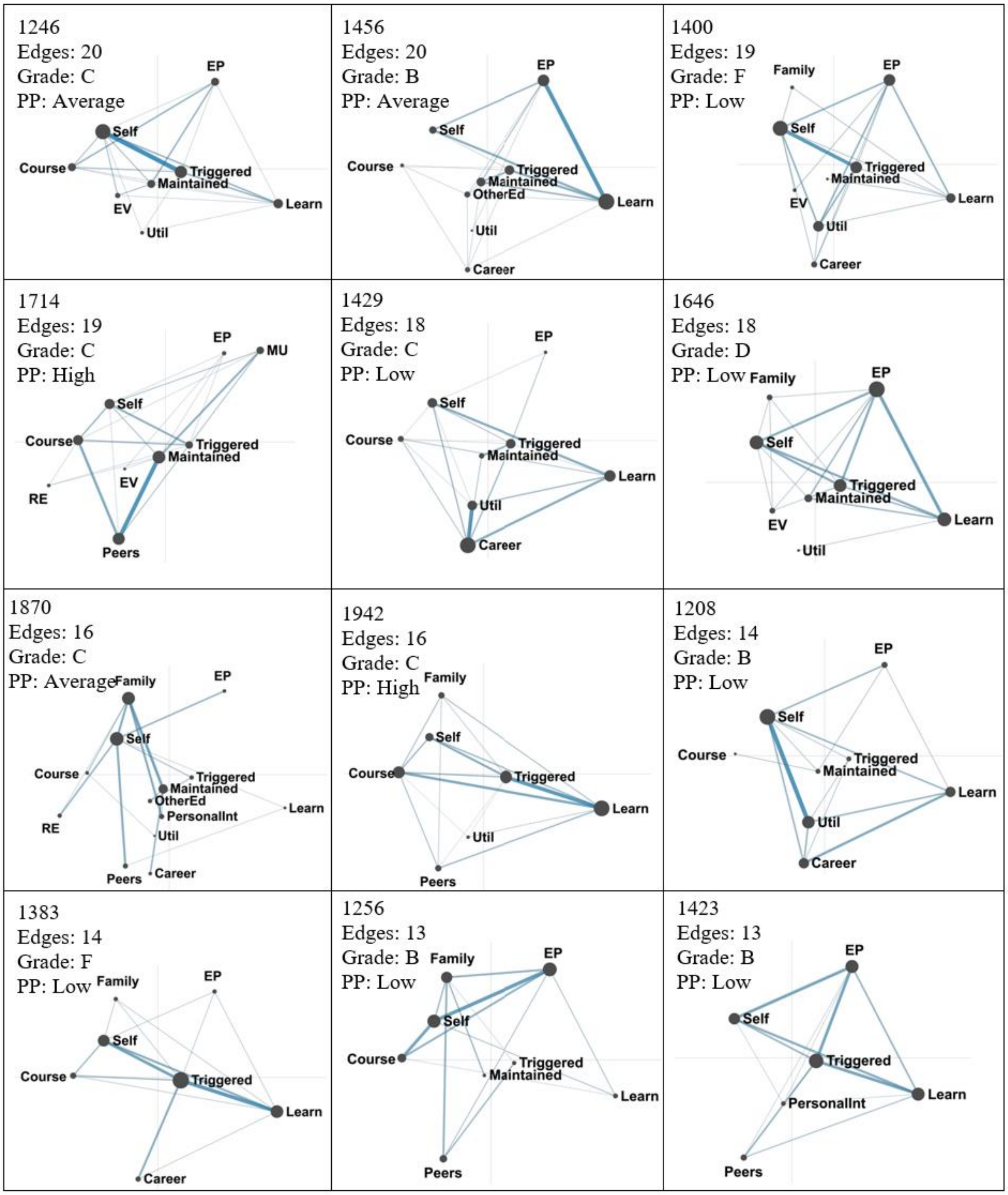
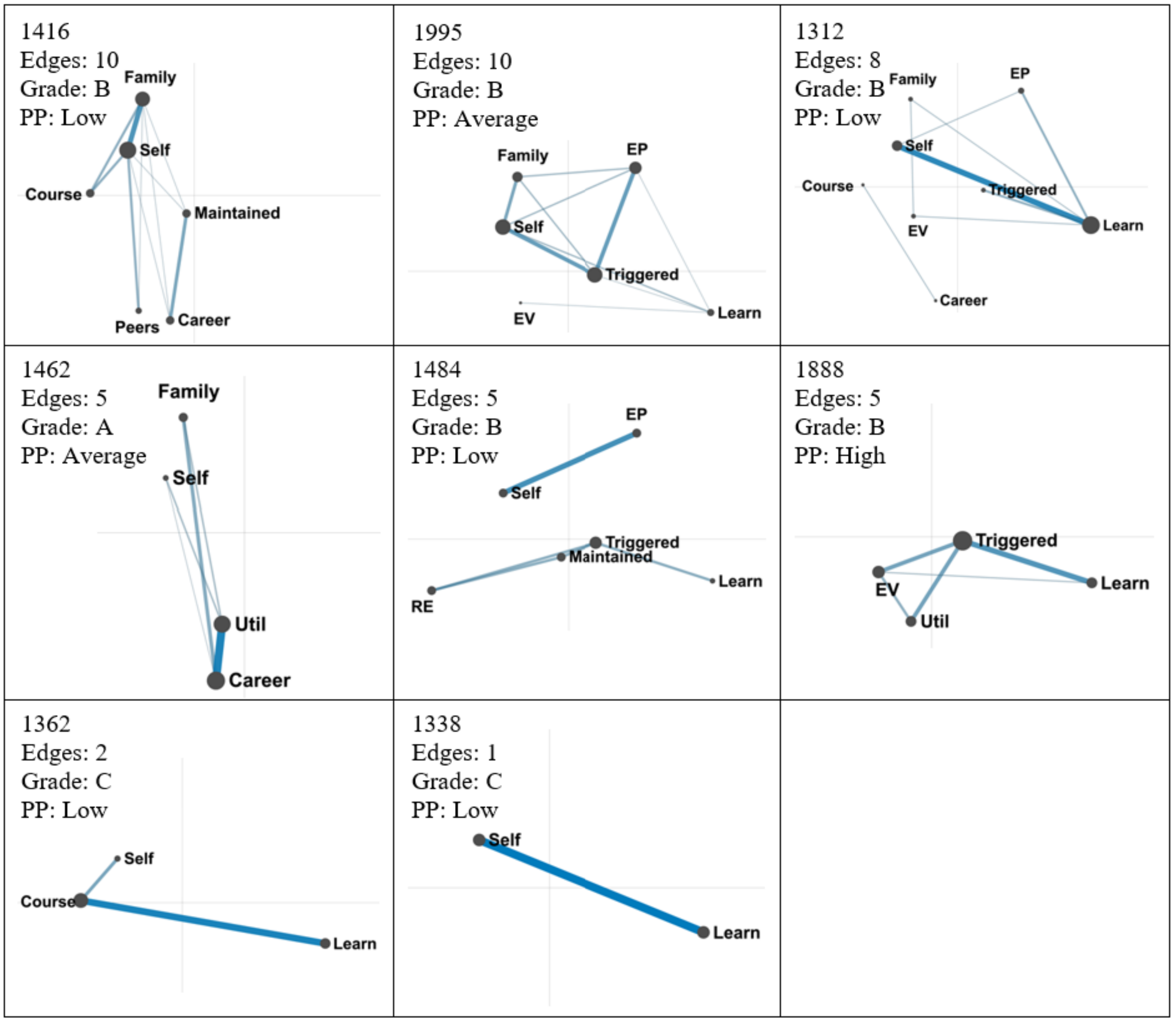


Figure E.2, continued

Individual Networks for All Participants (n = 31)



Note. Participants arranged from greatest to fewest number of edges in their individual networks.