DISSERTATION

PREDICTORS OF LEARNING OUTCOMES AMONG STUDENTS IN NUTRITION SCIENCE COURSES AT COLORADO STATE UNIVERSITY

Submitted by

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ABSTRACT

PREDICTORS OF LEARNING OUTCOMES AMONG STUDENTS IN NUTRITION SCIENCE COURSES AT COLORADO STATE UNIVERSITY

Overview

This dissertation is a summary of exploratory research to assess predictors of learning outcomes (academic background, conceptions of subject, motivations for studying, and approaches to learning) among students taking two undergraduate nutrition science courses at CSU—*Human Nutrition* (Course 1) and *Integrative Nutrition & Metabolism* (Course 2). It was comprised of three studies.

Introduction

There is a global need for experts trained in nutrition with an integrationist approach to health sciences and equipped to understand complex issues in health and disease. Yet, many students in nutrition sciences courses are not learning at a mastery level and often lack the knowledge and ability to integrate what they have learned to apply it to more advanced courses and their careers.

Key factors influencing a student's approach to learning and performance outcomes in a course include their academic background, motivations for learning the subject, conceptions of the subject, and approaches to learning. Pilot data from preliminary research performed during a course re-design project at Colorado State University (CSU) indicate many students begin nutrition science courses with inadequate prior knowledge from prerequisite courses, lack

autonomous motivations, exhibit *fragmented* conceptions of the science of nutrition, and adopt *surface*, rather than *deep*er, more meaningful approaches to learning.

Methods

Exploratory mixed-methods research was performed to assess academic background, motivations for studying nutrition, conceptions of the discipline, and approaches to learning among students in Course 1 (*Human Nutrition)* and Course 2 (*Integrative Nutrition & Metabolism*). It was comprised of three studies. The first was an analysis of academic and demographic data for 1,739 students, who had completed Course 1 only (n=1,377) or both Course 1 and Course 2 (n=362) between 2010-2016, to identify and evaluate relationships with in-class exam performance. Studies 2-3 were analyses of semi-structured interviews with students who had completed Course 1 only (n=12) or both Course 1 and Course 2 (n=27) between 2012-2015. Each student reflected on their experiences before and after the course(s) they completed, including their motivations for studying nutrition, conceptions of nutrition as a discipline, and approaches to learning. Transcripts were inductively coded and discrete categories of motivations, conceptions, and approaches were developed using phenomenography. Transcripts were re-analyzed using focused coding, and each student was categorized for each domain. Statistical tests were conducted to evaluate the strength of relationships among academic background variables, motivations, conceptions, approaches, and learning outcomes.

Results

Pre-course GPA, grades in prerequisite courses, and scores on a prior knowledge test for Course 1 were positively correlated with in-class exam performance. Pre-course GPA was the best predictor for both courses, explaining 51.9% and 43.9% of the score variance in Course 1 and Course 2, respectively. Alone, demographic variables were poor predictors of performance.

First-generation status was negatively correlated with performance. Among students interviewed, 100% indicated having an intrinsic interest in learning nutrition before Course 1. However, when taking upper-level nutrition science Courses 1 and 2, 100% suggested being driven to some extent by extrinsic rewards, and only 53.8% and 63% of students suggested having *autonomous* motivations for studying the specific material covered in Courses 1 and 2, respectively. At the start of Course 1, 87.2% of students had a *fragmented* conception of nutrition as a discipline; 76.9% adopted a *surface* approach to learning. Most (82.4%) of the students with a *fragmented* conception of nutrition science adopted a *surface* approach to learning. For Course 2, 52% began with a *coherent* conception of nutrition as a science, and most (81.5%) adopted a *deep* approach to learning in the course. Statistically significant relationships were identified among motivations, conceptions, and approaches to learning for Course 1. In both Course 1 and 2, *coherent* conceptions, *autonomous* motivations, and *deep* approaches were associated with significantly higher mean grades.

Conclusions and Implications

Previous academic achievement and prior knowledge provide students a critical foundation for success in upper-level courses in nutrition science. Students develop more *coherent* conceptions of nutrition as a science, *autonomous* motivations for learning nutrition, and *deep* approaches to learning nutrition as they progress through their courses, attempting to meet academic demands. These developmental changes are associated with positive learning outcomes. Efforts should be made to support and increase students' development of cognitive prerequisites, such as prior knowledge from foundational sciences, *coherent* conceptions of nutrition as a science, and *autonomous* motivations and *deep* approaches for learning nutrition earlier in their academic program.

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PREFACE

PREDICTORS OF LEARNING OUTCOMES AMONG STUDENTS IN NUTRITION SCIENCE COURSES AT COLORADO STATE UNIVERSITY

This dissertation is written in journal article format. Chapter 1 is a brief literature review and project overview. Chapters 2–4 are primary research papers to be submitted for publication in the near future. Chapters 3–4 describe studies completed in parallel using the same methods and sample to answer different research questions, and there are several references between them to avoid duplication.

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CHAPTER 1: NEED FOR EXPERTS IN NUTRITION SCIENCE

Overview/Problems

There is a critical need for experts in nutrition who understand science in a broad, integrative, and trans-disciplinary way. Many nutrition professionals enter the field with a B.S. degree in nutrition science; yet, there are learning gaps in their undergraduate science education. In addition, we are not currently graduating a sufficient number of nutrition students who are experts with the skills to solve nutrition-related national health problems. A review of the literature and findings from a pilot study will be discussed, justifying the dissertation studies described in subsequent chapters.

Broader Issues in Public Health

Over recent decades as people have adopted a Western diet and a less physically active lifestyle, there has been a global increase in the prevalence and incidence of chronic, non-communicable diseases such as cardiovascular disease, type 2 diabetes, and cancer, as well as other diet- and lifestyle-related metabolic health issues,[1,2] which has been described as a global pandemic.[2,3] For example, the prevalence of obesity has been increasing since the 1970s,[2] across socioeconomic groups and education levels, and affecting even the most highly educated professionals in nutrition and medicine.[4] Although most diet and lifestyle risk factors are modifiable and many of these diseases are avoidable, these morbidity and mortality trends are expected to continue.[5] Lifestyle-related diseases will impact millions of individuals, not only in developed countries like the United States, but also in developing nations where individuals are suffering from the burdens of chronic diseases simultaneous to food shortages that result in undernutrition, sometimes in the same household.[2]

For the first time in medical history, life expectancy in the United States is decreasing.[2] Experts have predicted that by midcentury, pediatric obesity may shorten life expectancy in the U.S. by two to five years.[6] Recent evidence suggests that adolescents with type 2 diabetes are more likely to die premature deaths, and after other lifestyle factors are considered, obese adolescent girls have a two to three times higher risk of dying by middle age.[6] Also, chronic diseases have a negative impact on quality of life. For example, overweight and obese children also suffer from various social and psychological problems, including negative self-esteem and feelings of chronic rejection, and many withdraw from interaction with peers.[7] They have higher rates of disordered eating, depression, anxiety,[6,7] and stigmatization.[8] They also have poorer academic performance,[9] are less likely to complete college, more likely to live in poverty as adults;[6] and rate their quality of life lower than kids undergoing chemotherapy for cancer treatment, due to negative body image and social pressure.[10] The economic burden is also high. There are increased direct costs for healthcare, with more than half of the expenditures incurred by individuals covered by publicly-funded health care programs, as well as indirect costs, due to reduced productivity, work absenteeism, and early retirement.[11]

Public health experts have argued that it is time to change our approach.[12] In a special diabetes issue published in the Lancet in 2010, editors suggested "The fact that type 2 diabetes, a largely preventable disorder, has reached epidemic proportion is a public health humiliation… Solving broader issues in public health will require a strong, integrated, and imaginative response."[12] Yet, chronic metabolic diseases and their determinants are complex and multifactorial, including issues such as appetite regulation and energy metabolism, and involving genetics, physiology, biochemistry, neuroscience, nutrition, food science, and environmental, psychosocial, and cultural factors, that influence food intake and energy expenditure. The future of healthcare and advising patients about health will be a difficult task.[13] Recent literature has suggested health professionals and scientists must move away from molecular reductionism toward understanding the complexity of biological systems in an integrative way.[14–16]

Related Issues in Science Education

There is a pressing need to improve the nature and quality of undergraduate science education[17] to better prepare students to understand the complexity of biological systems,[14,16] synthesize key concepts across their degree program, build connections among scientific disciplines and themes that span them,[18] and become workers and leaders who solve problems.[1,4,5] There has been a decline in the proportion of college graduates with STEM degrees in the past decade.[17] In early 2012, the U.S. President's Council of Advisors on Science and Technology (PCAST) published an executive report describing the need to produce one million more STEM graduates than expected by 2022—an annual increase of 34% over the rates at the time.[17] The basis of this need was to fill a projected one million jobs and to remain competitive globally.[17] Furthermore, broadly increasing science literacy among Americans and building a skilled workforce are important for preventing continued widening of economic and demographic gaps.[17]

Recent literature has also highlighted learning needs among university science students, who often lack foundational knowledge from prerequisite courses (or the ability to build on it) during more advanced courses in their major.[17,19–24] For example, in 2005, Wieman & Perkins questioned how successfully we are educating all students in science.[19,25] Handelsman, et al. suggested the data indicate we are not where we want to be—too many undergraduates in our courses are not learning the science.[19,26] In 2008, Hailikari and Katajavuori described a common problem faced by instructors in higher education, in which "students lack important prior knowledge and skills needed when they enter the more advanced courses in their curriculum."[22] Similarly, at the 2016 Experimental Biology, Mini-symposium: *Innovations in undergraduate, graduate, & medical nutrition education*, Thalacker-Mercer and Vanderlan stated the following about students taking a core nutrition science course at Cornell University, entitled *Regulation of Macronutrient Metabolism*: "Students do not come to class prepared to build on or apply foundational knowledge, expecting to receive first exposure to course material in lecture… Further, students then learn the material in preparation for assessments. This type of learning strategy minimizes both understanding and opportunities to apply knowledge in lectures and discussions; students are unable to appropriately apply course materials in class discussions. Evidence indicates that university students are not studying in a way that would support development of these skills."[21] In summary, many students, even at top universities in the world, are not adopting *deep*, meaningful approaches to learning in their courses.

The issues described above are particularly problematic for students in nutrition, which has been described as a "uniquely integrative science field"[16] that "offers great hope" for

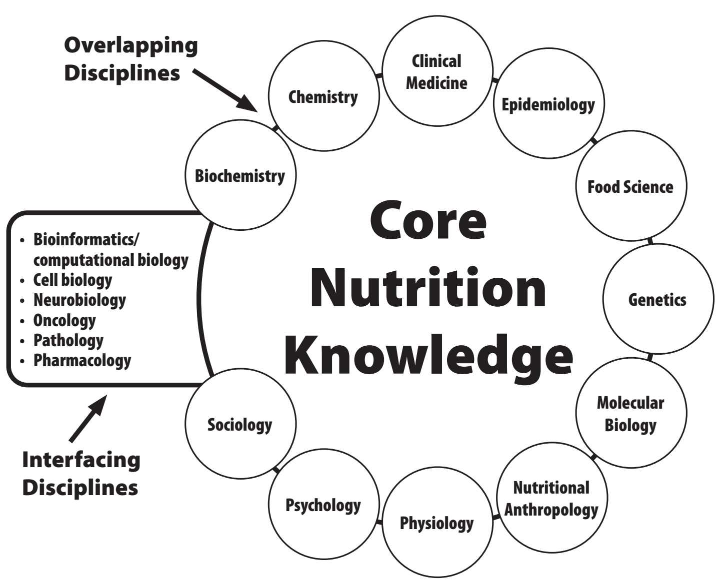

Figure 1.1: Core Nutrition Knowledge. Adapted from Allen et al.[27]

improving health.[16] Nutrition bridges core concepts in biology, chemistry, and physiology, pathology, genetics, and many other disciplines, and requires translation of complex scientific areas from the molecular level to whole body homeostasis,[27] to applications in health sciences, which involve biology, behavior, and the environment (Figure 1.1).[16]

In nutrition science courses, students build on basic concepts about metabolism from foundational science courses to understand more complex details about nutrient metabolism. For example, a student completing an intermediate course in nutrition science should be able to describe the detailed process by which the nutrients in food provide the body a source of energy for cellular work. To do this, the student must be familiar with the food sources of the nutrients, the molecular structure of the individual nutrients and their polymers, the physiology of nutrient digestion and absorption in the gastrointestinal tract, circulation to various tissues in the body, transport into cells, and use in metabolic pathways. They must also be able to apply an understanding of how these processes are regulated in the body by the nervous and endocrine systems across different metabolic states and systemic perturbations (including feeding, fasting, starvation, and exercise) and to various health and disease scenarios. This requires a foundational understanding of food science, cellular and molecular biology, physiology, as well as general, organic, and biochemistry. It has become increasingly important to have individuals trained in nutrition and dietetics who are able to communicate across disciplines, integrating and translating these science fields.[16]

Nutrition Science Courses at Colorado State University

Most students in Food Science and Human Nutrition (FSHN) at Colorado State University (CSU) enroll with an expressed interest in becoming practitioners (e.g., dieticians) or researchers.[20] To complete a degree in FSHN, students must demonstrate a strong background in basic and applied sciences.[20] At the heart of the degree is the expectation that students learn not only about human behavior and food choices, but about nutrient metabolism.[20] A student completing a degree in nutrition should be able to communicate across disciplines, translating science from the molecular level to whole body homeostasis, to behavioral and environmental issues, and ultimately, to solve problems[5,20,28,29] related to the complex diet- and lifestyle-related chronic, metabolic diseases that burden public health and the economy.[1–3,5,12,13,16,20,28,29]

Pivotal in the FSHN undergraduate major is FSHN 350 (*Human Nutrition*). It is the first upper-level nutrition science course in the program, a rigorous three-credit science class focused on providing students a foundation for understanding the metabolism of macro- and micronutrients, the physiological basis underlying dietary recommendations for human health, nutrients and dietary requirements for physical well-being, and evaluation of various diets.[20] FSHN 350 or an equivalent is required as a prerequisite for approximately 20 (graduate and undergraduate) courses in FSHN. It has an annual enrollment of nearly 300 students, mostly juniors and seniors.[20] Students must grasp the concepts covered in FSHN 350 to be successful in nearly all upper division nutrition courses in the department.[20] For example, FSHN 470 (*Integrative Nutrition & Metabolism*) builds on the foundation laid by FSHN 350.[20]

In early 2013, FSHN 350 instructors assessed the current state of the course and its students. They indicated the following: Most students do well—a good percentage of students earn “A” grades in these courses, and the percentage of students who pass the dietetics registration exam is high.[20] Yet, student performance on tests and final grades indicate a bimodal distribution, with a significant portion of students earning “D” or “F” grades, often despite the students indicating they spend a substantial amount of time studying.[20] Also, instructors reported that many students do not learn the material at a mastery level, do not adequately retain an understanding of many important concepts covered in FSHN 350, and are unable to integrate what they have learned to apply it to more advanced courses.[20] As such, professors who teach upper-level FSHN courses (e.g. FSHN 470) must back up to review foundational concepts.[20] An important factor faced by FSHN 350 instructors seemed to be the broad range of prior knowledge students have when entering the course, including material from prerequisite courses in biology, general and organic chemistry, and physiology.

High-quality instruction is a major thrust of the FSHN department in preparing an academically and demographically diverse student population for professional careers focused on improving the nutritional status and reducing the burden of disease within the human population. Instructors and I embraced the opportunity to submit a proposal to The Institute for Learning and Teaching (TILT) at CSU to redesign FSHN 350. This required us to assess and define the course needs and gaps in learning and set goals for closing them.

The project was funded June 2013, with a goal of incorporating new instruction—using existing university resources to integrate a collection of course-appropriate, learning-centered instructional strategies proven successful in increasing student engagement and critical thinking, both in and out of the classroom. Ideas from instructional designers at TILT and instructors in FSHN and other science departments at CSU were included.

While developing new instruction with instructors and staff at TILT over the next year, pilot exploratory research was performed. This included an in-depth review of course artifacts (syllabi, topics covered, learner objectives, assignments, etc.) and student assessments, persistent (daily) participation in course activities, observation of patterns of behavior among students and instructors, and interaction with them in a variety of scenarios (one-on-one and small group study sessions, weekly recitations, class lectures, and review sessions), and many informal interviews of students and instructors. Discussions included details of nutrition science and all aspects related to each course, instructors, course materials, study methods, career goals, and other academic and extracurricular activities. These experiences were documented in a research journal as field notes, then used later for reflection and expansion into more in-depth research memos. This process was continued through the period of data collection in 2016.

Evidence obtained from this research confirmed anecdotal information from professors—that many students enter FSHN 350 with inadequate prior knowledge from prerequisite courses and adopt *surface* approaches to learning that are insufficient to master the material or integrate what they have learned to apply to more advanced courses in nutrition sciences or careers as nutrition professionals. The following also became more apparent. Based on students' descriptions of their experiences—learning activities in FSHN 350 and associated outcomes seemed to predict performance in FSHN 470. Students who completed FSHN 350 using *surface* learning approaches were not prepared to apply concepts from FSHN 350 to topics covered in FSHN 470. They had not developed the necessary cognitive prerequisites—many lacked an understanding of key concepts covered in FSHN 350 and other prerequisite science courses. Many also had *fragmented* conceptions of the science of nutrition or inaccurate or vague ideas of what to expect during each course and/or were surprised by the scientific rigor of the material covered in one or both courses. FSHN 470 was the source of much anxiety and frustration for these students. Even though students taking FSHN 470 have advanced prerequisite courses in human nutrition and biochemistry, and nearly all were seniors intended to graduate at the end of same semester or the following semester, several specifically suggested being worried about being able to pass the course and graduate on time. Why were they so unprepared? How were they able to complete FSHN 350 and other advanced courses using *surface* approaches to learning, often with A or B grades, yet be unable to succeed in FSHN 470, the course that required them to integrate and apply what they learned?

Many factors influence a student's learning and performance in a course, including prior academic knowledge, experience, self-efficacy, motivations, conceptions of the topic, approaches to learning, participation in learning and engagement programs or other co-curricular activities; as well as their program of study, previous courses they have taken, and their previous academic success. There is also much variation among students.

To address the learning issues described above, more rigorous research was necessary to understand the unique characteristics of learners in nutrition science courses at CSU. Chapters 2-4 of this document describe three studies that were performed as part of an exploratory mixed-methods analysis of learners in nutrition science courses at CSU to assess their knowledge, beliefs, and behaviors related to learning and performance in these courses. This included the development and implementation of two research instruments—1) a prior knowledge test deployed at the beginning of FSHN 350 (2015-2016) and 2) a semi-structured interview for students completing FSHN 350 and 470, related to their motivations for studying nutrition, their conceptions of nutrition as a science, and their approaches to learning. An exploratory quantitative analysis of academic and demographic data from 1,739 students in upper-level nutrition science courses at CSU from fall semester 2010-spring 2016 was also completed. The overarching objective of these studies was to assess these data, including several factors previously demonstrated to influence learning in other disciplines, to determine what predicts academic performance among students in FSHN 350 and 470.

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CHAPTER 2: ACADEMIC BACKGROUND PREDICTS STUDENT EXAM PERFORMANCE IN NUTRITION SCIENCE COURSES.

CHAPTER OVERVIEW

Background

There is a global need for nutrition professionals with an integrationist approach to health sciences and who are equipped to solve complex nutrition-related health issues. Yet, many students in nutrition sciences courses are not learning at a mastery level. They often lack the knowledge and ability to integrate what they have learned to apply it to more advanced courses in nutrition sciences or careers as nutrition professionals.

Methods

We performed an exploratory quantitative analysis of academic and demographic data from 1,739 students (71% female, 96% undergraduate, 21% first generation) in upper-level nutrition science courses at Colorado State University (CSU) from fall semester 2010–spring 2016. We assessed relationships among academic aptitude, prior knowledge, demographics, and in-class exam performance for students who completed Course 1 (*Human Nutrition*, n=1,265) only or both Course 1 and Course 2 (*Integrative Nutrition & Metabolism*, n=465).

Results

Academic aptitude and prior knowledge significantly predicted scores on in-class exams in both Course 1 and Course 2. Pre-course GPA was the best predictor, with correlation coefficients of .671 and .655, which explained 51.9% and 43.9% of the variance in exam scores for Courses 1 and 2. Grades in prerequisite science courses were also strong predictors for both courses. Alone, demographic variables were poor predictors of performance. First-generation status was negatively correlated with performance.

Conclusion

Previous academic success and prior knowledge developed during more basic courses provide students a critical foundation for success in upper-level courses in nutrition science. Continued efforts should be made to support and increase development of cognitive prerequisites among students early in their academic program.

INTRODUCTION

There is a pressing need to improve undergraduate education[1] in nutrition science—a uniquely integrative field[2] that bridges core concepts in biology, chemistry, and physiology.[3] A student completing a degree in nutrition should be able to synthesize complex scientific concepts across their degree program[2,4] to communicate across disciplines and themes that span them,[5] translating science from the molecular level to whole body homeostasis, to behavioral and environmental issues,[2] and ultimately, to solve problems[1,5,6] related to the complex diet- and lifestyle-related chronic, metabolic diseases that burden public health and the economy.[7–9] Yet, there are learning gaps among students in foundational sciences courses, including nutrition.[6,10–13] Many students enter these courses with inadequate prior knowledge (PK) from prerequisite courses, lack intrinsic motivations, exhibit *fragmented* conceptions of the subject of nutrition, and adopt *surface*, rather than *deep*er approaches to learning that are necessary to master the material, integrate what they have learned, and apply it to more advanced courses in their major.[6,10,12–15]

Learning and Performance

Many factors influence a student's learning and performance in a course, including prior academic knowledge, experience, self-efficacy, motivations, conceptions of the topic, their approaches to learning, participation in learning and engagement programs or other co-curricular activities; as well as their program of study, previous courses they have taken, and the grades they have achieved in those courses. Previous research across fields and class levels (from elementary to graduate school) has demonstrated that academic background (general academic aptitude and PK of the course material) strongly predicts academic performance.[16–18]

Students enter the university with diverse academic skills. Performance on standardized achievement tests (SAT and ACT scores) and high school grade point averages (GPAs) and class rankings represent measures of general student aptitude[17] and have been correlated with academic performance among university students.[19] High-level performance in specific academic areas is termed "specific academic aptitude." Cumulative college GPA and GPA in prerequisite science courses are even more specific measures of students' abilities to perform at a university level and on related subject material. Outcomes also vary among demographic groups. For example, compared with students whose parents were college graduates, first-generation students tend to have lower GPAs throughout their enrollment in college.[20] These differences are observed across diverse academic areas.[20] This is important for nutrition courses at Colorado State University (CSU) because first-generation students comprise approximately 20% of the enrollment. There are also gender-related performance gaps at CSU. Females have higher high school grades, increased enrollment in college, better performance in college courses, higher GPAs, and complete college degrees at higher rates. These differences persist after controlling for key factors, including college quality and major.[21] These are important considerations since the dietetics profession is female-dominated, and approximately 70% of nutrition majors at CSU are female.

Prior Knowledge (PK)

PK is a key factor in student achievement, as it is integral to acquisition of knowledge and construction of new understanding, as well as capacity to apply higher-order cognitive problem-solving skills.[14,22–29] Many learning theories and psychological models in education consider PK to be critical for acquiring new knowledge,[29] and many consider it the most important factor influencing learning and student achievement.[23] Furthermore, PK and general aptitude are associated with one another.[17] For example, students with higher aptitude are more likely to learn and retain information, increasing their knowledge.[17] Individual differences in PK explain between 31% and 64% of the variance in learning domain-specific content.[29] Most courses in higher education have prerequisites to ensure that background knowledge is adequate to facilitate learning new subject material, as it would be difficult or impossible without PK in the subject areas.[29]

There are a variety of explanations of how PK influences learning of new information.[29] Both subject-specific knowledge and the type of knowledge (e.g., declarative versus procedural) influence student achievement.[14,23,30] Declarative knowledge is the accumulation of facts and concepts.[14,27] It has been defined as “knowing that” and mainly includes skills to integrate new and existing knowledge—understanding concepts and their inter-relationships, classifying, and comparing information.[14,27] Conversely, procedural knowledge is more about “knowing how” and includes skills to apply knowledge, including problem-solving, and producing and implementing information at a higher level.[14,27] Students with *deep*er procedural knowledge from previous courses tend to obtain higher grades in advanced courses.[31]

In general, having PK of a topic facilitates a student's comprehension and learning of that topic. Students enter the first upper-level nutrition science course at CSU, *Human Nutrition,* having taken courses in biology, general and organic chemistry, physiology. Many have taken an introductory course in nutrition and biochemistry, and most are juniors or seniors with considerable knowledge on these topics. There is a broad range and depth of PK, but it is evident that many students do not retain adequate procedural knowledge of foundational concepts from past courses. Often students fail to recognize the relevance of the prerequisite courses in basic sciences while enrolled and use minimal, *surface* approaches to learning in these courses.

PK can bias how people respond to new information, and incorrect, inadequate, or *fragmented* PK or misconceptions about a topic can hinder learning.[14,30] This is especially pertinent in the field of human nutrition, which is relevant to everyday life and a hot topic in the popular media, where coverage is often inaccurate, incomplete, oversimplified, exaggerated, and nonscientific, focusing on the newest fad diets, controversies, and debates. When students have inadequate procedural PK, and/or their conceptions of nutrition are more congruent with coverage in the media, their approaches to learning may be negatively impacted in *Human Nutrition*, which mainly focuses on the detailed science of micro- and macro-nutrient metabolism. Learning and performance in subsequent advanced nutrition courses (e.g., *Integrative Nutrition & Metabolism,* the second upper-level nutrition science course at CSU) may be hindered as well. This is particularly relevant for students preparing for careers in nutrition. Nutrition professionals cannot rely on simple rote learning and memorization. The information in the field is constantly changing and there are many controversies, even among nutrition scientists. This requires today's nutrition professionals be able to self-learn, integrate, and apply knowledge to complex health and disease scenarios.

Nutrition, a has been described as a "uniquely integrative science field" that "offers great hope" for improving health.[2]" However, there is a paucity of data in the research literature regarding performance in upper division nutrition courses. There is a strong need, therefore, for research studies to evaluate the relationships among academic and demographic variables and achievement in nutrition science. Moreover, there is a need to assess and to capture the preexisting differences in the academic and demographic backgrounds of students taking nutrition science courses to determine those variables related to performance in these courses. Instructors can take what they learn into account when developing curricula and fine-tune their teaching methods to account for gaps in PK and differences among students.[30] This may ultimately enhance student learning in nutrition science.[30]

The purpose of this study was to assess how student academic background (aptitude and PK) and demographic variables predict in-class exam performance in two nutrition science courses taught at one institution: *Human Nutrition* and *Integrative Nutrition and Metabolism*, henceforth called "Course 1" and "Course 2." We hypothesized that scores on aptitude tests, GPA, grades in prerequisite courses, and scores on a PK test (particularly understanding scores) would significantly and positively predict student performance on in-class exams in Course 1 and Course 2.

METHODS

We analyzed data for students taking nutrition science courses at Colorado State University. The sample included 1,739 students completing undergraduate nutrition science courses at Colorado

State University (CSU) fall semester 2010–spring 2016. Students had completed either Course 1 (n=1,377) only or both Course 1 and Course 2 (n=362). Of these students, 499 completed the PK test for Course 1 (2015-2016) described below, and 362 of those students also completed Course 2. The university Center for the Analytics of Learning and Teaching provided data for gender, computed index scores (calculated using a combination of high school GPA or high school rank percentage combined with ACT or SAT score), first-generation status, class level, major, instructor, cumulative GPA achieved prior to each course, grades in prerequisite courses, and final grades in each course. Instructors provided students' individual exam scores and final grades as percentages. Then, following guidelines for data management from the university Institutional Review Board to ensure students' privacy and confidentiality and minimum exposure to risk, a third party matched student data from these two sources, assigned each student a unique code, and removed all other identifying information. Data were maintained in an Excel (Microsoft, Inc., Redmond, WA) spreadsheet.

Courses Studied

Both Course 1 and Course 2 are primarily lecture-based, generally taught in large classrooms or small auditoria, with fewer than 75 students/section. Instructors used slide presentations of new content (and some discussions), and during the year, taught three times a week for 50 minutes/session. The focus of lectures was to prepare students for material covered on in-class exams.

Course 1 is the first upper-level nutrition science course in the nutrition major. Two sections of the course are taught in both fall and spring semesters, and one section is taught in the summer. It is a rigorous three-credit, 300-level science class with pre-requisites of general and organic chemistry, biology, and physiology and with an annual enrollment of approximately 300 students, mostly juniors and seniors. The course objectives are focused on providing students a foundation for understanding the metabolism of macro- and micronutrients, the physiological basis underlying dietary recommendations for human health, nutrients and dietary requirements for physical well-being, and evaluation of various diets and dietary intake patterns.[6] This course is a pre-requisite for all other upper-division nutrition courses in the major, and thus students must grasp the concepts covered to be successful in these other courses.[6] During the study, students were expected to complete a variety of assessments, including 3-5 in-class exams and up to 20 short in-class or online quizzes and other small projects, with some variation, depending on the instructor. In-class exams comprised 75-85% of the final course grade.

Course 2 is the capstone nutrition science course for the major and builds on the foundation laid by Course 1. It is the most demanding nutrition science course in the department's undergraduate program, with a strong focus on regulation of metabolism. Students must synthesize complex information from nutrition biochemistry, endocrinology, molecular biology, and human physiology, and in many cases also apply these details to a diet or health scenario. Historically, the grade for this class has been based solely on in-class exam scores. More recently, instructors have included take-home quizzes and writing assignments as component of each exam.

Table 2.1. Descriptive Statistics for Student Background (Total N=1739)

Characteristic		**N (%)**
Gender	Female	1229 (71)
	Male	510 (29)
Major	Food Science and Human Nutrition	574 (33)
	Health and Exercise Science	908 (52)
	Other	257 (15)
Class Level	Undergraduate	1664 (96)
	Graduate	75 (4)
First Generation	Yes	373 (21%)
	No	1366 (79%)

Student Background

During the period of this study, most students were undergraduates (96%) and female (71%); were majors in Food Science and Human Nutrition (33%), Health and Exercise Science (52%), and other fields (15%, mainly other biological sciences); and first-generation students comprised 21% of the sample (Table 2.1). Most students in the sample completed the two prerequisite courses for Course 1—physiology (87.6%) and organic chemistry (89.4%), and the average GPA of students entering the course was a 3.16 (Table 2.2).

Table 2.2. Other Student Academic Variables

Academic Variable (Max Score)	N	Mean
Computed Index (146)	1257	117.4±11.2
Grade: Organic Chemistry (4)	1555	2.74±.91
Grade: Physiology (4)	1523	2.95±.92
Grade: Biochemistry (4)	1532	2.89±.95
Pre-Course GPA: Course 1 (4)	1597	3.16±.62
Pre-Course GPA: Course 2 (4)	396	3.32±.46

Instructors

Seven instructors taught the two courses—four taught Course 1, one taught Course 2 only, and two taught both courses (Table 2.3). Within each course, materials were consistent from one instructor/section to the next, but there was some variation in instruction, including aspects of classroom presentation and assessments.

Table 2.3. Instructors by Course and Number of Students

Instructor:	Course 1	Course 2
1	0	49
2	350	0
3	537	0
4	409	91
5	49	0
6	325	225
7	69	0
Total:	1739	365

Prior Knowledge (PK) Test

In 2015, we began administering a content-oriented PK test among students taking Course 1—at the beginning of the course—to assess knowledge of concepts foundational to Course 1 and to determine whether the scores on the test predict performance on in-class exams. To develop an appropriate assessment of PK, we surveyed course materials from Course 1 and from prerequisite courses including biology, general chemistry, organic chemistry, physiology, and the departmental course in introductory nutrition. Next, we developed questions over topics in biology, chemistry, physiology, and nutrition that are foundational to Course 1. To ensure content validity, we solicited input from subject experts (nutrition instructors and graduate students) who examined the content of the test and provided feedback through multiple cycles of revision. The test was found to have high content validity for assessing PK in topics covered in the class. The final version of the test had 60 multiple choice questions, each with five potential answer choices. The first 30 were "remembering" questions, and the next 30, "understanding" questions (categorized based on whether they reflected learning at the first or second level of Bloom's Taxonomy, which are termed "remembering," and "understanding," respectively).[32] Within each set of 30 questions, there were 10 questions from each of the main topic areas foundational to Course 1: 1) biology and chemistry, 2) physiology, and 3) introductory nutrition—for a total of 20 questions from each topic area. We deployed the test as a 45-minute PK assessment performed online within the first two days of class. All eligible students completed the test. We scored questions as dichotomous variables, where each question was either correct or incorrect. For each correct answer to an item, participants received one point, otherwise they received zero. Each student received a "remembering" and an "understanding" score (each out of 30 points); "biology/chemistry," "physiology," and "nutrition" scores (each out of 20 points); and a "total" score (out of 60 points) (Table 2.4). After deploying and scoring it, the objective reliability (internal consistency) of the instrument was assessed, using the Kuder-Richardson Formula 20 (KR-20) as the statistical measure of internal consistency. Response data (1 or 0) were entered into a formula that provides the KR 20 reliability coefficient for the single PK test. The reliability of internal consistency (KR-20) was 0.811—above 0.8, the minimal acceptable value to be considered a reliable instrument. This is a relatively high internal consistency, e.g., compared with other studies[16] and particularly considering the heterogeneity of test items among sections and large differences in students' scores across topic areas with relatively higher scores in biology/chemistry versus physiology or nutrition. Scores on the PK test were not included with the course exams in determining final grades.

Table 2.4. Student Course Performance – Exam Scores

Exam Score (out of 100)	N	Mean	SD
Course 1 Exam 1	1238	80.57	14.495
Course 1 Exam 2	1236	78.86	15.977
Course 1 Exam 3	1232	76.53	15.821
Course 1 Exam 4	1168	79.64	15.529
Course 1 Exam 5	480	76.63	17.913
Composite Course 1 Exams	1238	80.4	11.6
Course 2 Exam 1	362	75.95	17.782
Course 2 Exam 2	362	79.11	16.198
Course 2 Exam 3	362	84.48	20.818
Composite Course 2 Exams	362	79.86	11.7

In-Class Exam Scores

For the exams used for determination of student grades, a composite in-class exam score was calculated for each student in each course by adding the total points earned on all in-class exams and dividing by the total points possible. This was used as the main outcome variable in analyses because in-class exam scores were the most substantial contributor to overall course grade in each course and performance on in-class exams was the representative assessment of students' understanding of course material, at the level covered in class lectures.

Final Course Grades

Students' final course grades (as a percentage) were also used as dependent variables. These were calculated for each student in each course by adding the total points earned on all assessments and dividing by the total points possible.

Analyses

SPSS version 24 (IBM, Inc., Chicago, IL) was used for all analyses. Independent samples t-tests were performed to identify differences among variables by gender or first-generation status. A Spearman's rank-order correlation was calculated to assess whether there were statistically significant associations among computed index score, grades in prerequisite courses, GPA prior to each course, PK test scores, and composite exam score and grade in each course. Stepwise multiple regression analyses were performed to investigate how well students' composite score on in-class exams in each course could be predicted from several independent variables and the relative contribution of each predictor to the explanation of variance. Coefficients of determination (R^2) were calculated for statistically significant correlations and are displayed in Tables 2.8-2.9.

RESULTS

In-class exam scores

Each term, there were up to five in-class exams for Course 1, and three in-class exams for Course 2. Group mean scores on exams include all students completing each test from 2010-

2016. These scores ranged from 76.63-80.57 for Course 1, and 75.95-84.48 for Course 2, and mean composite scores were 80.4 and 79.9, respectively for the two courses (Table 2.4).

Prior Knowledge Tests

Mean on the PK test for Course 1 are displayed in Table 2.5, including "remembering" and "understanding" scores (each out of 30 points), "biology/chemistry," "physiology," and "nutrition" scores (each out of 20 points) and "total" score (out of 60 points). The mean total score was 38.0 points. There were broad differences in PK, with total scores ranging from 12-57. The mean score on remembering questions was 20.4

Table 2.5. Student Performance on Prior Knowledge Test for Course 1 (n=499)

Type of Prior Knowledge	Possible	Range	Mean±SD
Biology/Chemistry	20	5-20	14.82±2.6
Physiology	20	2-19	11.45±3.2
Nutrition	20	0-20	11.8±3.1
Remembering (all topics)	30	9-30	20.4±4.1
Understanding (all topics)	30	0-29.4	17.64±4.4
Total Score	60	12-57	38.05±7.2

(range = 9-30). This was 15.6% higher than the mean score on understanding questions, which was 17.6 (range = 0-29). Students' knowledge of biology and chemistry was the highest, with the mean score of 14.8 compared with mean scores of 11.4 and 11.7, for physiology and nutrition questions, respectively (Table 2.5).

Analyses

Compared with male students, female students had statistically significantly higher mean Computed Index scores (118.7 vs. 114.2*), GPAs when entering both Course 1 (3.21 vs. 3.05*) and Course 2 (3.35 vs. 3.13*) (Table 2.6). There were no significant differences between genders for grades in organic chemistry, physiology, or biochemistry, or total scores on the PK test.

However, female students had lower PK scores for understanding (17.3 vs 18.4*), biology/chemistry (14.6 vs 15.3*), and physiology (11.3 vs 11.9*), although these gender-related differences were small (Table 2.6). Females had a higher mean composite in-class exam score for Course 1 (80.8 vs 79.3*) (Table 2.6). Females also had higher mean scores on all in-class exams and overall grade in Course 1. In fact, Male students' mean scores were statistically* higher on only one assessment—in-class exam 3 in Course 2, the comprehensive final exam.

Table 2.6. Student Performance and Differences by Gender and Generation

		Gender			Generation		
Variable (max)	All	F	M	Mean Dif	>1st Gen	1st Gen	Mean Dif
Computed Index (146)	117.4±11.2	118.7	114.2	4.51*	118.1	114.9	3.161**
PK: Remembering (30)	20.4±4.1	20.3	20.6	-.304	20.6	19.8	.678
PK: Understanding (30)	17.64±4.4	17.3	18.4	-1.04*	17.9	16.8	1.07*
PK: Biology/Chemistry (20)	14.82±2.6	14.6	15.3	-.736*	14.9	14.4	.496
PK: Physiology (20)	11.45±3.2	11.3	11.9	-.678	11.6	10.8	.852*
PK: Nutrition (20)	11.8±3.1	11.8	11.7	.093	11.9	11.5	.391
PK: Total (60)	38.0±7.2	37.7	39.0	-1.34	38.4	36.7	1.746*
Grade: Organic Chemistry (4)	2.74±.91	2.75	2.71	.0363	2.78	2.59	.191**
Grade: Physiology (4)	2.95±.92	2.96	2.94	.026	3.01	2.72	.304**
Grade: Biochemistry (4)	79.86±.95	2.61	2.61	.007	2.93	2.75	.189**
GPA: Pre-Course 1 (4)	3.16±.62	3.21	3.05	.159*	3.18	3.08	.099**
GPA: Pre-Course 2 (4)	3.32±.46	3.35	3.13	.216*	3.35	3.22	.123*
Exams: Course 1 (100)	80.40±11.6	80.84	79.3	1.65*	80.98	78.33	2.650**
Exams: Course 2 (100)	79.86±11.7	79.76	80.53	-.306	80.8	76.71	4.091*

**p<.05, **p<.01*

First-generation students had statistically lower computed index scores (114.9 versus 118.1**), lower PK scores (total and all sub-scores)—and significantly lower scores for understanding (17.3 vs. 18.4*), biology/chemistry (14.6 vs. 15.3*), physiology (11.3 vs. 11.9*), and total (36.7 vs. 38.4*), significantly lower grades in organic chemistry (2.59 vs. 2.78**), physiology (2.72 vs. 3.01**), and biochemistry (2.75 vs. 2.93**), lower GPAs when entering both Course 1 (3.08 vs. 3.18*) and Course 2 (3.22 vs. 3.35*), and statistically lower mean scores on all in-class exams in Course 1 and two of three exams in Course 2, with a statistically lower mean composite exam scores in both Course 1 (78.33 vs. 80.98**) and Course 2 (76.71 vs. 80.8*) (Table 2.6). Correlations among predictor and outcome measures were calculated (Table 2.7). As hypothesized, composite exam scores in both courses were positively correlated with predictors (computed index, grades in prerequisite courses, pre-course GPA, PK total score and all sub-scores (remembering, understanding, biology/chemistry, physiology, nutrition) and overall course grade. None of the PK sub-scores, though, were *better* predictors than the others.

The first multiple regression analysis for Course 1 included data for 399 students who completed Course 1, prerequisite courses in physiology and organic chemistry, and the PK test, and assessed the following predictor variables, in order: pre-course GPA, grade in physiology, grade in organic chemistry, and PK total score (Table 2.8). Since the PK test was not implemented until 2015, additional analyses were performed without including the PK variable, enabling a larger sample of data (n=965) to be analyzed. The correlation coefficient (*R*) resulting from the analysis indicated a relatively strong correlation (R = .721) between pre-Course 1 GPA and composite exam score in Course 1. Alone, pre-Course 1 GPA predicted 51.9% of the variance in Course 1 exam scores. Each stepwise addition to the model of independent variables (grade in physiology, grade in organic chemistry, and PK total score) strengthened the correlation, with an increase in R^2 of .027, .018, and .009 for steps 2, 3, and 4, respectively. With all predictors simultaneously, 57.5% of the variance in composite in-class exam scores could be predicted (Table 2.8). The second multiple regression analysis for Course 1 included data for 956 students who completed Course 1 and prerequisite courses. Considered together, these variables accounted for 49.8% of composite in-class exam scores.

Table 2.7: Intercorrelations Among Predictor and Outcome Measures: Course 1 (n=392-1262) and Course 2 (50-362)

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Computed Index	—	.366**	.408**	.572**	.116*	.253**	.258**	.178**	0.086	.224**	.409**	.418**	.332**	.571**	.285**	.300**
2 Grade: Organic Chemis	—	—	.544**	.679**	.229**	.202**	.223**	.254**	.130**	.250**	.544**	.540**	.509**	.698**	.536**	.479**
3 Grade: Physiology	—	—	—	.703**	.260**	.299**	.311**	.330**	.164**	.332**	.604**	.595**	.547**	.751**	.539**	.524**
4 GPA: Pre-Course 1	—	—	—	—	.280**	.250**	.256**	.291**	.183**	.308**	.671**	.679**	.597**	.936**	.580**	.554**
5 PK: Remembering	—	—	—	—	—	.460**	.577**	.663**	.750**	.840**	.316**	.317**	.267**	.406**	.449**	.447**
6 PK: Understanding	—	—	—	—	—	—	.704**	.736**	.611**	.854**	.371**	.361**	.259**	.304*	.360*	.333*
7 PK: Biology/Chemistry	—	—	—	—	—	—	—	.472**	.422**	.751**	.358**	.347**	.286**	.320*	.367**	.355*
8 PK: Physiology	—	—	—	—	—	—	—	—	.477**	.824**	.350**	.354**	.255**	.364**	.436**	.424**
9 PK: Nutrition	—	—	—	—	—	—	—	—	—	.799**	.245**	.238**	.185**	.299*	.351*	.335*
10 PK: Total	—	—	—	—	—	—	—	—	—	—	.394**	.389**	.302**	.360**	.432**	.410**
11 Exam Mean: Course 1	—	—	—	—	—	—	—	—	—	—	—	.986**	.611**	.665**	.602**	.542**
12 Grade: Course 1	—	—	—	—	—	—	—	—	—	—	—	—	.616**	.653**	.600**	.549**
13 Grade: Biochemistry	—	—	—	—	—	—	—	—	—	—	—	—	—	.667**	.567**	.515**
14 GPA: Pre-Course 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.655**	.623**
15 Exam Mean: Course 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.892**
16 Grade: Course 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 2.8. Regression Analysis for Statistically Significant Predictors of Exam Scores in Course 1 (n=399)

Step Independent Variables	R	R^2	Adjusted R^2	Std. Error of Estimate
1. Pre-Course 1 GPA	.721	.521	.519	7.468
2. Grade in Physiology	.740	.548	.546	7.725
3. Grade in Organic Chemistry	.753	.566	.563	7.120
4. Prior Knowledge Test Score	.758	.575	.571	7.057

The multiple regression model for Course 2 included data for 215 students completing Course 2 and its prerequisites: Course 1 and biochemistry, and included the following predictor variables, in order: pre-course GPA, grade in Course 1, and grade in biochemistry. Pre-Course 2 GPA (which includes the grade achieved in Course 1) accounts for approximately 43% of the variance in composite in-class exam scores in Course 2 and stepwise addition of other independent variables (grades in Course 1 and biochemistry) strengthen this relationship with approximately 53% of the variance in composite exam scores explained when all three predictors are included (Table 2.9).

Table 2.9. Regression Analysis for Statistically Significant Predictors of Exam Scores in Course 2 (n=215)

Step Independent Variables	R	R^2	Adjusted R^2	Std. Error of Estimate
1. Pre-Course 2 GPA	.656	.431	.426	8.835
2. Grade in Course 1	.718	.516	.512	8.164
3. Grade in Biochemistry	.729	.531	.525	8.054

DISCUSSION

The purpose of this study was to explore relationships among students' academic background and their performance in nutrition science courses. The results supported our hypothesis and demonstrated that students were more likely to obtain higher grades on in-class exams, if they began the course with higher academic aptitude and PK. Both *general* academic aptitude (represented by computed index scores) and *specific* academic aptitude (represented by grades in prerequisite courses and pre-course GPA) were significantly positively correlated with in-class exam scores (in Course 1 and 2). However, *general,* compared to *specific* academic aptitude was a poorer predictor of performance in either course, and this was particularly true for Course 2—the more advanced course. These results are consistent with literature indicating domain-specific knowledge is a better predictor of learning and performance than general ability.[33]

Of the measures of *specific* academic aptitude, pre-course GPA was the best predictor of performance on in-class exams for both courses. Grades in Course 1 prerequisites (physiology and organic chemistry) were strong predictors of performance in both courses as well. Performance in Course 2 was also predicted by grades in its prerequisites (Course 1 and biochemistry), which were also strongly positively correlated with one another. These data are consistent with studies demonstrating that previous academic success predicts future academic success,[25,27,31] and that during introductory courses, students develop knowledge, skills, and competencies, collectively termed "cognitive prerequisites," for success in more advanced courses.[33] According to Neumann,[34] this is particularly true in hard, applied sciences because development of knowledge is sequential, hierarchical, and cumulative. The knowledge developed during earlier stages of a student's studies consists mainly of established facts and theories, while more advanced understanding occurs in later stages and requires an integration of that knowledge.[34]

As expected, students' performance in Course 1 was predicted by PK of Course 1 content. Total PK score and sub-scores (remembering, understanding, biology/chemistry, physiology, nutrition) were all significantly positively correlated with Course 1 (and Course 2) composite exam scores. Total PK score was the best predictor. None of the sub-scores were much better predictors than the others, which was inconsistent with our hypothesis that higher performance in Course 1 would be better predicted by *understanding* vs. *remembering* scores. The basis for this prediction was the idea that understanding scores better represent procedural PK (ability to integrate and apply knowledge), while remembering scores represent declarative PK (knowledge of facts and meaning of concepts). Previous studies have shown procedural PK to be a better predictor of student performance in courses in mathematics and pharmaceutical science[14,30,31]—yet relationships between PK and performance differed by course—depending on the nature of the course. For some courses, students' success on questions that tested their ability to apply knowledge was a better predictor of performance, while in other courses, their ability to integrate knowledge was a better predictor.[31] For the PK test we developed and deployed before Course 1, students who earned high total PK scores tended to also have high scores on both understanding and remembering questions and high scores on in-class exams in Course 1. This was not surprising because the content on the PK test was directly relevant to Course 1 content and the in-class exams for Course 1 contained a combination of different types of questions, requiring factual knowledge, understanding, and some integration, with some variation among instructors. Scores on the PK test were also positively correlated with grades in prerequisite courses. In the current study, PK *should* be highly related to previous study success, since the PK test was designed to assess knowledge of content foundational to Course 1 that would have been covered in prerequisite courses.

CONCLUSION AND IMPLICATIONS

Educators aim to promote high-quality learning and outcomes to support academic scholarship. In the field of nutrition, educators seek to prepare health professionals who are equipped to address complex health issues like obesity and cardiometabolic disease, yet little educational research has been conducted regarding the academic preparation of future nutrition professionals. This exploratory study confirms findings from past research in other disciplines, which demonstrated how important PK and academic success in foundational courses are in predicting success in more advanced courses. Thus, the present study contributes to the research literature by documenting these relationships in nutrition science. This is useful information for academic programs in nutrition because this study confirms how important it is for students to develop cognitive prerequisites in basic sciences—biology, chemistry, and physiology—to succeed in courses in nutrition science. Additionally, this study highlights the importance of structuring a curriculum to support learning outcomes in basic courses, to ensure students begin developing an integrated knowledge base early.

Instructional reform in nutrition science could also include dialogue among instructors from different departments, including chemistry, biology, and nutrition to ensure that appropriate information is covered in a curriculum, from basic to advanced courses. Moreover, a collaborative effort among instructors may ensure students are developing and retaining necessary knowledge and skills, during foundational courses to succeed in more advanced courses. Within a department, support could be added to existing courses, beginning at the freshman level, to ensure all students develop *deep* understanding of material and are prepared for success in subsequent courses in their academic program and in their careers. In particular, efforts should be made to reach individuals and/or populations with a history of academic underperformance. For example, in this study, first-generation students had lower mean computed index scores, GPAs, grades in prerequisite courses, and on exams and final grades for courses 1 and 2. It is crucial to identify and address deficiencies and provide appropriate support early in the sequence of courses.

These data may also be interesting from an instructional design view. Instructors may assess classroom instructional methods and other learning experiences in foundational courses to ensure evidence-based practices are being used. Instructors may also benefit from using PK assessments and the results to understand students' knowledge at the beginning of each course and to help make students aware of what they know and don't know.[35] Instructors then receive feedback that helps them modify instruction and students become more familiar with the material. For example, instructors can provide students feedback on test items, which may guide their study for the course. Thus far, students who have completed the PK test for Course 1 have received guidance about each question, with references to the course textbook. Additionally, a PK test helps to set expectations for both students and instructors.

Just as it is important to evaluate students' aptitude and knowledge at the beginning of each course, it is critical to assess their approaches to learning and individual differences in beliefs that may influence their approaches to learning and performance in the courses. Subsequent chapters will focus on additional studies performed to learn more about students' beliefs and behaviors related to learning in nutrition science, including factors that interested them in nutrition, their conception of nutrition as a science, things that motivate them to study for classes, their approaches to learning in nutrition and related science courses, and their perceptions related to the effectiveness of these methods. Performing a more detailed learner analysis will provide data for development of detailed profiles of learners that can be used for instructional and curricular improvements.

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CHAPTER 3: DIFFERENCES IN STUDENTS' MOTIVATIONS TO STUDY NUTRITION AND THEIR APPROACHES TO LEARNING NUTRITION SCIENCE

CHAPTER OVERVIEW

Background

There is a global need for nutrition professionals with an integrationist approach to health sciences. Yet, many students in nutrition sciences courses are not learning at a mastery level. They exhibit more *controlled* forms of extrinsic motivation, and adopt *surface* rather than *deep*, more meaningful approaches to learning that are necessary to integrate what they have learned and apply it to their more advanced courses in nutrition sciences and careers as nutrition professionals.

Methods

We performed an exploratory analysis of interviews of 39 students (82% female, 85% undergraduate, 10% first generation) in upper-level nutrition science courses at Colorado State University (CSU) spring semester 2012–spring 2015 to explore their motivations for studying nutrition and their approaches to learning in Course 1 (*Human Nutrition*, n=12) or both Course 1 and Course 2 (*Integrative Nutrition & Metabolism*, n=27). We developed categories of motivations and approaches using phenomenography, categorized participants for each variable, and assessed relationships among motivations, approaches, and performance.

Results

Among students interviewed, 100% indicated having an intrinsic interest in learning nutrition as a subject before Course 1. However, when taking upper-level nutrition science Courses 1 and 2, 100% suggested being driven to some extent by extrinsic rewards, and only

53.8% and 62% of students suggested having *autonomous* motivations for studying the specific nutrition science topics covered in Courses 1 and 2, respectively. Also, 76.9% adopted a *surface* approach to learning in Course 1, while 81.5% adopted a *deep* approach to learning in Course 2. Statistically significant relationships were identified between students' motivations and approaches to learning for Course 1. In both courses, groups of students with *autonomous* motivations and/or *deep* approaches achieved statistically significantly higher mean grades.

Conclusion

Alone, the orientation of a student's motivation did not predict their approach to learning for these courses. In Course 1, students who adopted a *surface* approach to learning tended to have *controlled* motivations for studying nutrition, while students who adopted a *deep* approach to learning tended to have *autonomous* motivations. Yet these relationships differed between Courses 1 and 2, and students' adoption of an approach to learning seemed to be influenced more by the specific course demands. How instructors and programs can intervene to address gaps in students' motivations for studying nutrition and approaches to learning will require further investigation.

INTRODUCTION

Overview

In recent decades, there has been an increased global prevalence of obesity and diet- and lifestyle-related cardiometabolic diseases.[1–5] To address these complex issues, we must educate more experts in the integrative science of nutrition.[6–8] These individuals will need a broad understanding of science and the ability to communicate across disciplines, translating from the molecular level to whole body homeostasis, to behavioral and environmental issues.[6–10] Yet, nutrition is complex, bridging core concepts in biology, chemistry, and physiology, pathology, genetics, and many other disciplines.[7,11] Instructors at Colorado State University (CSU) have suggested that many undergraduate students studying nutrition do not master the material in their core courses, failing to develop cognitive prerequisites to integrate what they have learned and apply it to more advanced courses in their major or careers as nutrition professionals.[6] Similarly, Thalacker-Mercer and Vanderlan said students in a core nutrition science course at Cornell University "come to classes unprepared to learn or contribute in a way that would support development of important skills."[12] These are not isolated issues; learning gaps in undergraduate science education have been reported by many others.[13–16]

Approaches to learning

In any course of study, a student's outcomes are influenced by their approaches to learning.[17] Students who adopt a *surface* approach to learning in a course attempt to cope with class requirements and instructor expectations by acquiring and memorizing isolated details they expect to appear on a test.[18–20] They do not reflect on purpose or strategy, relate new and prior knowledge, or connect the details to real life.[18–20] In class, they often struggle to make sense of the material or participate. They feel undue pressure and worry about their work (which impairs memory formation).[20] They do not develop understanding and have poorer long-term learning outcomes.[18–20] In contrast, students who adopt a *deep* approach to learning are more active in learning and use a full range of activities to develop understanding.[18–20] These often include behaviors practiced by *surface* learners (e.g. memorizing), as well as reflecting, seeking and identifying patterns, critically examining and incorporating evidence, integrating new and prior knowledge, and relating what they learn to everyday experiences.[20,21] These students are interested in the course content and motivated to learn.[20] They focus on making meaning and developing intellectually.[20] They develop a better understanding of content, remember more, and have better long-term learning outcomes.[18–20]

Students may vary considerably in how they approach learning the same phenomenon, concept, or principal. One student may use either *surface* or *deep* or both approaches to learning, depending on a number of factors, including assessment characteristics.[20,22,23] Approaches tend to be exclusive, e.g. *surface* or *deep*, for a task, but these are not stable traits and some students may switch between approaches, even within a single class. Students may also adopt strategic study approaches to balance time, learning, and performance.[22] These students are methodical and organized in their study, reflective on assessment performance, and motivated by achievement.[24] A student's academic performance tends to correlate negatively with *surface* approaches and positively with *deep* or strategic approaches to learning.[20,22,23,25]

Motivations

Surface and *deep* approaches to learning, and the key factors that seem to encourage or discourage the adoption of one versus another, have been described, compared, and contrasted.[26] Student factors, such as motivations, are considered to be an important influence on a student's adoption of an approach to learning and their learning outcomes.[20,26,27] Students' motivations may vary in amount, i.e. a student may be more or less motivated to study a subject. Although, this is the focus of many theories of motivation in psychology,[28] educational researchers have suggested the orientation of motivation is more important and provides more information about underlying reasons for behavior.[29] Motivation is also not a stable personality trait, and a student's (amount and orientation of) motivation may vary depending on the learning context and subject.

For more than a century, researchers have highlighted the importance of assessing intrinsic and extrinsic motivation related to academic learning and performance.[27,29,30] Intrinsic motivation is about engaging in a task, like studying, for the rewards inherent in the task, such as interest in the subject. Intrinsic motivation has been associated with higher quality learning and creativity.[29] Extrinsic motivation is engaging in a task for the rewards outside of the task, such as grades, affirmation from other people, or to avoid embarrassment or punishment.[29] Historically, the two types of motivation have been contrasted and intrinsic motivation has been considered the superior orientation that should be promoted among students.[31]

Motivations and approaches

Fransson tested relationships between motivations and approaches to learning, and suggested that students adapt their approaches to learning depending on what they believe is required of them.[27] In general, a *surface* approach to learning was correlated with extrinsic motivation, while a *deep* approach was linked to intrinsic motivation.[27] Students were more likely to adopt a *deep* approach when course content was relevant to their interests and a *surface* approach to learning when it was irrelevant or if they were anxious or perceived some performance-related consequence.[27] If the student was extrinsically motivated and believed specific instructional materials were important for a graded assessment, they would adopt a *surface* approach, and focus efforts on memorizing that topic, excluding others.[27] These behaviors occurred even among students inherently interested in the topic and learning it.

Ames and Archer also related students' motivations and approaches to learning.[32] Their work suggests social conditions influence the approach students adopt and students are more likely to adopt a *deep*, mastery focus when realistic/challenging goals, absolute standards, participation, and self-efficacy are promoted.[32] This is consistent with self-determination theory (SDT), which suggests an individual with an *autonomous* focus is more likely to approach and respond to learning tasks with a mastery orientation, have a better attitude about the subject or class, and select more challenging tasks that foster learning.[29]

Table 3.1. The Self-determination Continuum. Modified from Ryan and Deci.[29]

Type of Motivation	Amotivation	*Controlled*		*Autonomous*		
		Extrinsic		Extrinsic		Intrinsic
Type of Regulation	Non-regulation	External	Introjection	Identification	Integration	Internal
PLOC	Impersonal	External	Somewhat External	Somewhat Internal	Internal	
Processes	Lack of intentionality and personal causation	Compliance to extrinsic rewards or punishment	Focus on approval from self or others	Endorse, accept value of activity	Synthesis congruence of goals	Inherent interest, enjoyment, satisfaction
	Non-self-determined	← SDT CONTINUUM →				Self-determined

Self-determination theory

SDT is focused on factors that promote different types of motivation.[29,33] According to SDT, people have three fundamental psychological needs for health, wellbeing, and optimal functioning—competence, autonomy, and relatedness.[33] Meeting these needs, particularly perceived autonomy and competence, facilitates interest and intrinsic motivation.[33] To maintain or enhance intrinsic motivation, having a sense of competence or self-efficacy alone is insufficient without a sense of autonomy.[29] Many have discussed this issue using the attributional concept of perceived locus of causality (PLOC), where each individual exists on a continuum from external to internal PLOC.[29,31,33–36] Someone with an external PLOC (EPLOC) believes outside forces dictate their behavior and compliance is required to avoid negative consequences, while someone with an internal perceived locus of causality (IPLOC) believes their behavioral choices are made *autonomous*ly, for reasons of personal interest and valuing the activity.[29,33–36]

SDT makes further distinctions within different types of motivation, on a continuum from non-self-determined to self-determined behavior, across six categories of regulation (Table 3.1).

The first is *amotivation* (non-regulation), where the person does not take any actions or are just going through the motions. They do not value the activity, feel competent or *autonomous*, or expect any desired outcomes, and they have an impersonal PLOC.[29] For example, a student may not be sure why they have selected a particular academic program and do not have specific plans for what to do with the degree. It is possible they do not perform any learning activities. While *amotivation* is categorized by *lack* of motivation, the remaining categories are characterized as *controlled* or *autonomous* and by type of motivation (extrinsic vs intrinsic), regulation, PLOC, and associated processes. There are four sub-categories of extrinsic motivation, from external regulation and EPLOC to integration and IPLOC (Table 3.1).[29]

***Controlled* motivation**

External regulation is *controlled*, extrinsic motivation with behavior driven by meeting an external demand, such as compliance to rewards or punishments, and an EPLOC.[29] For example, a student may study or do assignments to avoid confrontations from parents or instructors or, a student may join a pre-med major to get into medical school to be a physician because of pressure from family to choose this particular path. The second *controlled* category is *introjection*. An individual in this category is someone who is just beginning to have an internalized view and value the activity.[29] For example, a student starts to see the value of studying a subject. This individual may not have fully accepted it as their own but studies to avoid guilt or anxiety or to attain goals related to ego or pride. This student may attend class to avoid feeling like a bad person.

***Autonomous* motivation**

According to SDT, when someone moves from *introjection* to the next type of extrinsic motivation on the SDT continuum, *identification*, they also make an important shift—from *controlled* to *autonomous* motivation. They begin to value the activity or task as personally important, i.e. it is more internalized. A student with identified regulation may take an extra science course to better understand the topic or willingly spends extra time studying because it is important for the future. The most *autonomous* form of extrinsic motivation is *integrated* regulation. Here the person is identified with the importance of behavior but also integrates those identifications with their other values (is even more internalized). It is still *extrinsic*, not *intrinsic* motivation, and it is possible for a student to be in this stage without having an inherent interest in the subject or activity being performed yet has goals congruent with the goals of the activity.

The final category on the SDT continuum is intrinsic motivation, where the individual is fully *autonomous*, and motivation is completely internalized. An intrinsically motivated learner tends to adopt a *deep* approach to learning, and they may enjoy the activity so much they lose track of time. A common goal among educational researchers and instructors has been to promote intrinsic motivation in an educational setting, e.g. by supporting students' psychological needs for competence, autonomy, and relatedness.[33] This may also facilitate internalization and integration of values among extrinsically motivated students, which may help move them from an external regulation toward an integrated regulation. Further, it is possible for someone to have both intrinsic and extrinsic motivation, but each exists on a separate continuum. An individual may be high or low on intrinsic or extrinsic motivation or both. For example, a student may enjoy studying a topic and also engage in the task of studying it for external rewards. There is much evidence that *autonomous* extrinsic motivation is positively associated with engagement, persistence, learning, and other beneficial outcomes, and a student with a combination of intrinsic motivation and *autonomous*, integrated extrinsic motivation has been shown to result in high-quality academic outcomes.[29]

Based on preliminary discussions with students in two nutrition science courses at CSU, *Human Nutrition* (Course 1) and *Integrative Nutrition & Metabolism* (Course 2), and pilot data, many students enter these courses with little or no academic or professional experience in nutrition, have inadequate prior knowledge from prerequisite courses, exhibit *fragmented* conceptions of nutrition as a science, and adopt *surface*, rather than *deep*, more meaningful approaches to learning it. The students who seem to develop the most integrative understanding of nutrition as a science are those who are motivated to study due to an intrinsic interest in human physiology and a goal of improving health, for themselves and others. Empirical data are needed to confirm this, though. Since a student's motivations are known to influence their approaches to learning and learning outcomes, we sought to explore and analyze students' motivations for studying in their nutrition science courses and their associated goals for their academic training and careers. To our knowledge, there have been no studies of these issues and there is a strong need for research regarding students' motivations for studying nutrition science and their approaches to learning in university-level nutrition courses.

Therefore, in this study we sought to answer the following research questions: (i) What are students in two upper-level nutrition science courses motivations for studying nutrition science; (ii) What do they consider ideal learning and performance outcomes in these courses? (iii) How do these students describe what they must do to learn nutrition science (their approaches), (iii) What do students in these courses learn (their outcomes), and (iv) What are the relationships among motivations, approaches, and outcomes of students in these two upper level courses? We predicted that students with more *autonomous* motivations to study in these courses would adopt a *deep* approach to learning and students with a *deep* approach to learning would demonstrate better performance outcomes in the upper-level Nutrition Science courses.

Phenomenographic methods were used to explore individual nutrition science students' beliefs and behaviors as they progressed through two nutrition science courses. The study is grounded in the lived experiences, beliefs, and behaviors of the participants. Case studies were developed as a part of the analyses to illustrate major themes about nutrition science students' motivations for studying nutrition science and approaches to learning nutrition science.

METHODS

This was one of several studies comprising an exploratory, mixed-methods assessment for two upper-level nutrition science courses at Colorado State University (CSU), Course 1 (*Human Nutrition*) and Course 2 (*Integrative Nutrition & Metabolism*).

Participants

All students (approximately 500) who had completed Course 1 or 2 spring 2012–spring 2015 were invited to participate in an interview about teaching and learning in nutrition. A total of 39 students participated in a semi-structured interview for approximately one hour (range = 30-120min). Of these individuals, 12 had completed Course 1, while 27 had taken both Courses 1 and 2. The interviewees included 32 females and 7 males; 84% had been undergraduates (mainly juniors and seniors) while taking either of the courses and the remaining 16% were graduate students completing Course 1 as a nutrition science prerequisite for the program (Table 3.2). Race and ethnicity were not assessed.

Table 3.2. Characteristics of students interviewed. (Total n=39).

Characteristic		N (%)
Gender	Female	32 (82)
	Male	7 (18)
Class Level	Undergraduate	33 (84)
	Graduate	6 (16)
First Generation	Yes	4 (10)
	No	35 (90)

As a group, the individuals who volunteered to participate in this study were above average, good, or excellent students based on grades (Table 3.3). The lowest pre-course GPA for either course was a 2.83, which is the equivalent of just above a B-, and the average pre-course GPA was 3.42-3.45, the equivalent of a B+.

Table 3.3. Student Academic Variables (Total interviewees: n=39).

	Interviewees		All Students	
Academic Variable (Max Score)	N	Mean	N	Mean
Grade: Organic Chemistry (4)	32	2.83 (B-)	1555	2.74 (B-)
Grade: Physiology (4)	33	3.21 (B)	1523	2.95 (B-)
Grade: Biochemistry (4)	33	2.94 (B-)	1532	2.89 (B-)
Pre-Course GPA: Course 1 (4)	35	3.42 (B+)	1597	3.16 (B)
Pre-Course GPA: Course 2 (4)	27	3.45 (B+)	396	3.32 (B)
Course 1 (4)	39	3.62 (B+)	1236	3.29 (B)
Course 2 (4)	27	3.12 (B)	362	3.31 (B)

All study protocols were reviewed and approved by the Institutional Review Board (IRB) at Colorado State University. All participants were guaranteed confidentiality and consented to join the study. The university Institutional Research Office provided data for gender, computed index scores (calculated using a combination of high school GPA or high school rank percentage combined with ACT or SAT score), first-generation status, class level, major, instructor, cumulative GPA achieved prior to each course, grades in prerequisite courses, and final grades in each course. Instructors provided students' individual exam scores and final grades as percentages. Then, following IRB guidelines for data management to ensure students' privacy and confidentiality and minimum exposure to risk, a third party matched student data from these two sources, assigned each student a unique code, and removed all other identifying information. Data were maintained in an Excel (Microsoft, Inc., Redmond, WA) spreadsheet.

Positionality

In qualitative research, a researcher must position themselves in terms of their subjectivity—"social, locational, and ideological placement relative to the research project or to other participants in it" and recognize their biases analyzing and interpreting data.[37] The primary investigator (and interviewer) for this study was uniquely positioned, as someone with multiple roles, immersed in both Course 1 and Course 2 over several years—first as a student completing Course 1 and subsequently as a graduate student, teaching assistant, and instructional designer for Courses 1 and 2, and then as an instructor for Course 1. He was seen as an advocate and supporter recognizing the needs of students, instructors, and administrators in the department, with authority, credibility, with trust among all groups.

Courses Studied

Both Course 1 and Course 2 are lecture-based, generally taught in large classrooms or small auditoria, with fewer than 75 students/section. Instructors used slide presentations of new content (and some discussions), and during the year, taught three times a week for 50 minutes per session. The focus of lectures was to prepare students for material covered on in-class exams.

Course 1 is the first upper-level nutrition science course in the nutrition major. Two sections of the course are taught in both fall and spring semesters and one section is taught in the summer. It is a rigorous three-credit, 300-level science class with pre-requisites of general and organic chemistry, biology, and physiology and with an annual enrollment of approximately 300 students, mostly juniors and seniors. The course objectives are focused on providing students a foundation for understanding the metabolism of macro- and micronutrients, the physiological basis underlying dietary recommendations for human health, nutrients and dietary requirements for physical well-being, and evaluation of various diets and dietary intake patterns.[6] Students are expected to grasp the concepts covered to be successful in subsequent upper division nutrition courses.[6] They complete a variety of assessments, including 3-5 in-class exams and up to 20 short in-class or online quizzes and other small projects, with some variation, depending on the instructor. Exams comprised 75-85% of the final course grade. Exams had a variety of different types of questions including multiple-choice, fill in the blank, matching, and short answer, but typically did not include longer essay type questions.

Course 2 is the capstone nutrition science course for the major and builds on the foundation laid by Course 1. It is considered the most demanding nutrition science course in CSU's undergraduate program, with a strong focus on regulation of metabolism. Students must synthesize detailed complex information from nutrition biochemistry, endocrinology, molecular biology, and human physiology, and in many cases also apply these details to a diet or health scenario. Exam scores comprised 80–100% of the final course grade. The types of questions on exams vary among the different instructors teaching the course but include a smaller proportion of objective questions (generally some multiple-choice), short answer, and longer essay questions that required students to explain concepts in more detail and integrate material across sections. Students have also had additional "take-home" exams with several questions that require extended/detailed written answers and a comprehensive final exam with a focus on integration of material from the entire semester.

Instructors

Seven instructors taught the two courses—four taught Course 1 only, one taught Course 2 only, and two taught both courses (Table 3.4). Within each course, materials were consistent from one instructor/section to the next, but there was some variation in instruction, including aspects of classroom presentation and assessments. Course instructors, the department head, and the college dean were the primary gatekeepers related to this research, and all facilitated or were active participants in the project.

Table 3.4. Instructors by Course and Number of Students.

Instructor:	Course 1	Course 2
1	0	0
2	14	0
3	16	0
4	2	11
5	5	0
6	1	16
7	1	0

Data collection

Six types of data were collected as part of this study: 1) course artifacts; 2) student assessments; 3) field notes from participation observations; 4) informal student interviews outside or during class; 5) student formal, semi-structured interviews, and 6) informal instructor interviews. All data were used collectively to determine participants conceptions of nutrition science and approaches to learning it. However, the interviews were the primary sources of data, as is typical for phenomenological studies.

Course artifacts

Several instructional resources (textbooks, course notes, slides, and learning management websites) were used for each course. These were examined and used as the basis for development of questions for initial, informal interviews with students and instructors. Additional course artifacts used during and after interviews with students included an unofficial transcript for any student who requested to review it with the investigator to confirm their academic background in terms of courses taken, grades, and degrees completed (if applicable).

Student assessments

Course assessments, such as exams, quizzes, and other homework assignments for Courses 1 and 2, were gathered for analysis. These were not reviewed as a specific method of data analysis, but they were discussed with some students during interviews.

Field notes from participation observations

As part of pilot, ethnographic-style research, each course, study group, and recitation were regularly attended, and field notes were recorded and developed in a secure Evernote Premium electronic journal (Evernote Co, Redwood City CA). These included text and voice memos created during and after various instructional sessions and other interactions with students. Research memos were used throughout the project to guide data collection.

Informal student interviews

Students were also interviewed before, during, and after various instructional sessions and office hours. These were brief, informal discussions with students to about the research project, to check on their progress in the courses and the major and to get to know them better and to establish trust. These were recorded in research memos.

Formal student interviews (Appendix A)

The primary investigator performed all 39 interviews, which were informed by an interview protocol and conducted on campus outside of class. Interview questions were developed based on input from multiple sources, including course instructors and students, and were reviewed by several professionals with experience in qualitative research. Each semi-structured interview was audio recorded, transcribed verbatim, and reviewed multiple times while coding to ensure participants responses were accurately defined. Participants were invited to engage in a conversation with the interviewer. For example, they were asked to reflect on their motivations for studying nutrition, including what originally interested them in the area of study and if this changed since they began, and if so, how; what types of things motivated them to study for Course 1 and/or 2; what they intend to do with what they learn/have learned in Course 1 and/or 2; and regarding approaches to learning, what they think a student needs to do to learn nutrition, and to describe (in their own words) a typical study session for them in the course(s) they completed. If the student had completed both Courses 1 and 2, they were asked to answer the same questions for each course and to discuss how their motivations and approaches changed (or stayed the same) as they progressed from when they first entered the nutrition program and before and after taking each of the courses.

Informal instructor interviews

Instructors were interviewed prior to beginning the research studies and throughout the process. Initial interviews with instructors were used to establish the project need and to develop a grant application for redesigning Course 1. Current instructors participated in data collection and were informally interviewed throughout the study.

Data analysis

Analysis included open and focused coding of all transcripts. To begin, investigators 1-3 separately performed an inductive line-by-line review of six transcripts (selected at random), making notes as appropriate on themes that became apparent, then met to develop an initial set of a codes. Investigators 4 and 5 guided this process. The first set of codes included *intrinsic* and *extrinsic* motivations for studying nutrition, and *surface*, *strategic*, and *deep* approaches to learning nutrition. Next, investigators 1 and 2 independently coded each of the 39 interviews, using ATLAS.ti software (Berlin, Germany) for organization of transcripts, codes, and memos. This phase of coding was still open and inductive, guided by predetermined themes and those brought up by the students. To ensure students were accurately represented, investigator 1 also reviewed interview transcripts while listening to the interview audio files. Initially, whole transcripts were the unit of analysis. Later, transcripts were broken up into narrative units by thematic category, and excerpts were compared to find meaning and patterns among data and illuminate similarities and differences for component themes across student cases. Each investigator also performed memo writing, which helped to identify patterns, find confirming or disconfirming cases, summarize things that happened on one or more occasions, and relate patterns observed to larger themes. Initially, the memos were open, while later, they were more focused, and eventually became more integrative, collaborative summaries.

Regular meetings were held to discuss findings from coding, make connections among data points, whole interviews, and memos, and to ensure agreement. Experiences, beliefs, and behaviors of individual students were compared and contrasted in relation to the larger research questions. Final categories for each domain were developed based on interviewees motivations for studying nutrition and how they approached learning it and guided by academic literature related to motivations and approaches. As students' quotes were assigned to categories, the meaning of the categories evolved, and category definitions were revised accordingly. Ultimately, two mutually exclusive categories of motivations for studying nutrition (*controlled* and *autonomous*) and two mutually exclusive categories of approaches to learning (*surface* and *deep*) were selected as final categories of description. These categories were used as the final analyzable codes to guide remaining focused coding of data. The two categories of motivations for studying nutrition originally posited to be mutually exclusive, *intrinsic* and *extrinsic* motivations were not selected as the final categories of motivation. Rather, students were categorized as having either *controlled* or *autonomous* motivations because these categories incorporate other aspects of motivation, type of regulation, PLOC, and associated processes (Table 3.1). Similarly, the three categories of approaches to learning (*surface, strategic, deep*), originally posited to be mutually exclusive, were narrowed to two categories with further analysis, as it became clearer that strategic approaches were not used exclusively by the participants in this study. Rather, students were categorized as adopting a *surface* or *deep* approach to learning and also to some degree exhibited behaviors congruent with a strategic approach. Particular cases unique to each of the categories were selected to illustrate the category, general characteristics of it, and to explain how different cases were compared. As hierarchy of similarities and differences became apparent, student narratives were selected to illustrate categories. There was full agreement among researchers on the categories of responses for both domains.

SPSS version 25 (IBM, Inc., Chicago, IL) was used for all statistical analyses. Once all responses were categorized, relationships among students' motivations to study nutrition, approaches to learning, and course grades were assessed. Chi-square tests were run to determine significance of associations between motivations and approaches (Tables 3.8 and 3.9). Mann-Whitney U tests were run to determine significance of differences in mean grades between groups of individuals with *controlled* or *autonomous* motivations to study nutrition, and between individuals with *surface* versus *deep* approaches to learning nutrition (Table 3.10).

Trustworthiness of qualitative analyses

Throughout the four-year study, an important goal was to establish credibility and maintain trustworthiness and conceptual rigor. The investigator's unique position and experiences provided access to the research site and student-participants and the opportunity to develop a deep understanding of each course, its content, materials, students, instructors, and administrators, their culture, and the environment, as well as course needs. Immersion included 1) in-depth instructional design work on each course that required regular communication and interaction with multiple course instructors and instructional designers as part of a university-funded course redesign project, 2) persistent observation of patterns of behavior among students and reflection, and 3) daily interaction with students in a variety of scenarios, including one-on-one tutoring sessions, small group study, during a weekly recitation, in class during lectures, and in review sessions, and 4) informal interviews with students. Experiences were documented in a research journal as in-depth field notes and research memos, which informed the research design.

Regular debriefing with peers (other graduate teaching assistants involved in teaching these courses) and experts (course professors, a discipline-based education researcher, educational researchers not engaged in the study, and research advisors) provided opportunities to identify best research practices. In addition, member checking with participants allowed us to review the findings in an iterative manner to best describe the phenomena being studied. Subsequent to interviews, member checking by email and telephone was used for following up with several participants, to discuss points of ambiguity and ensure ideas were well represented.

RESULTS

The results will be described in three parts, corresponding to the first three research questions: (i) motivations for studying nutrition, (ii) approaches to study, and (iii) relationships between motivations, approaches, and performance.

Motivations for studying nutrition

Participants had diverse backgrounds and varying motivations for studying nutrition. They had either *controlled* or *autonomous* motivations for studying nutrition and were categorized accordingly. These two categories of motivations were based on SDT and our subjective interpretations of the participants' explanations of what motivated them to study for Course 1 and/or Course 2. There were differences among individuals within each group, but the distinction between groups was clear and the categories were considered mutually exclusive for participants (Table 3.5).

Based on this analysis, 21 (53.8%) of the 39 participants had *autonomous* motivations for studying nutrition in Course 1, and 17 (63%) had *autonomous* motivations in Course 2 (Table 3.6). Although, during the interview (Appendix A), participants were asked what originally interested them in the area of study, their response to this question was not the basis for how they were categorized. This is an important point since all interviewees suggested they were intrinsically motivated to learn nutrition when they first chose to study it and when entering Course 1. However, many were motivated to learn aspects of nutrition that were different than those taught in Courses 1 and 2. Specifically, these students indicated being intrinsically motivated to learn about food, cooking, and various diets, or health and wellness, or nutrition as a tool that can be used in a discrete area of health, or to influence athletic performance, but not the more scientific aspects of macro- and micro nutrient metabolism.

Table 3.5. Categories of student motivations for studying nutrition.

Motivation	Category	Motivating factors
Controlled	Extrinsic motivation External or Introjected Regulation External PLOC Compliance to extrinsic rewards or punishment or ego-focus on approval from self or others	*I wasn't on a clear path… I wasn't totally sure what I wanted to do.* *I needed to have it as a prerequisite, that was the only reason. If I got to pick otherwise, I probably would have picked the 100-level nutrition.*
Autonomous	Value Identification-Integration Internal Regulation Internal PLOC Endorse, accept value of activity Synthesis congruence of goals Inherent interest, enjoyment, satisfaction	*Interest in subject…relevant to my future.* *I want to learn science behind nutrition instead of alternative health perspective.* *What motivated me to do well is the interest in figuring it all out, seeing the bigger picture, connecting diet, the body, and physiology, connecting that biochemical side to physiological side to understand how to eat for optimal health.*

Related to the specific behavior of studying for the topics in Courses 1 and 2, *controlled* motivations included more proximal factors, such as completion of the courses as required for the program of study or performance (getting a good grade on assessments and in the course). Students categorized as having *controlled* motivations described being motivated by the course requirements set by the instructor and spending little time studying beyond what they believed was necessary to "get a good grade" on the tests. These students had extrinsic motivation, external or introjected regulation, an external PLOC, and were mainly focused on extrinsic rewards or ego-related factors (e.g., approval from themselves or others, including the instructor, classmates, or parents), and many of these students were surprised by the scientific nature of the courses. In contrast, *autonomous* motivations for studying included extrinsic motivations that were more congruent with long-term goals such as preparation for graduate school or a job or career in food, nutrition, dietetics, and related fields. Students with *autonomous* motivations were internally regulated and had either intrinsic motivation and an inherent interest in studying nutrition science and metabolism or *autonomous* extrinsic motivations with identified or integrated regulation, endorsing or accepting the activity and/or having other values congruent with it and wanting to learn it (e.g. for their future in graduate school or as a nutrition professional). Below is narrative evidence from a student with *controlled* motivations for studying nutrition, recalling their motivations (after finishing Courses 1 and 2):

> *I was scrambling to find some attachment or some program that somewhat suited me. I definitely didn't want to be in school. I wasn't ready to be in school, but my mom kept pushing me to keep going and going, get it done. I knew I wanted to move out to Colorado, and CSU was my excuse to do what I wanted. Finding something I was interested in. I was super into health and fitness. In terms of motivation for what I thought I might want to do and how I progressed as I went, I definitely do not feel I studied as much as I needed/wanted. I especially learned that in my final semester (in course 2…by the end, it was so cool to actually learn and to actually be interested and motivated. It was the coolest thing. I wished I would have waited to go to school. Now that I'm finished, I'm finally ready, and I get it, and I know how to study and how to progress and how to make things work and to retain and believe in myself and move forward. I definitely didn't feel any of that until the very end.*

Below is narrative evidence from a student with an *autonomous* motivation for studying nutrition (in Course 1):

> *I had experience with food science. I studied nutrition to gain knowledge in new and interesting topics. This was for my own personal understanding/enrichment, to become more able to interpret nutrition information in the media, to help myself… and help my family and friends understand how food affects the body and health and to take the information learned and make healthy food for myself and others. I also wanted good grades. I want to make enough money to open a tea shop in China or anywhere in the world and help others with healthy food/beverages.*

Below is narrative evidence from a student with an *autonomous* motivation for studying nutrition (in Course 2):

I study nutrition to learn. To learn about health. Staying healthy. Mind, body, and soul. To learn about obesity. To learn about how people can overeat so much. To learn about people who have poor nutrition. To learn about the poor effects on their body. To learn about nutrition as a whole. I study nutrition to help others. To find an occupation to help others. To fill my personal needs and to fulfill the needs of others. To take care of others. I do think it may have been a calling.

Table 3.6. Categories of student approaches to learning nutrition.

Approach	Category	Learning activities
Surface	Individual exhibits *surface* and some strategic approaches to learning	Obtain instructor's slides, attend classes, take notes in class, and complete all assessments. Study mainly for tests, typically only within the week before the test.
		Students manage time better, have more organized notes, and may participate in study groups, office hours, draw out pathways, but mainly only to memorize their details.
Deep	Individual exhibiting *surface*, strategic, and *deep* approaches to learning	Students reflect, use practiced approaches, read before class, formulate questions while studying, draw pathways, explain material, integrate knowledge through course.
		Students integrate knowledge from courses and apply to life beyond the class (e.g. health and chronic disease). May create integrative sketches, narratives, and/or summaries.

Approaches to learning

Some students changed their approach over time, as necessitated by course requirements; some students used a combination of approaches to learning (Table 3.6). A student's approach to learning was classified as either *surface* or *deep* based on how they described their beliefs and behaviors related to their overall approaches to learning in the course(s) for which they were interviewed. Some students adopted *surface* approaches and some strategic approaches, but not *deep* approaches. Other students exhibited behaviors like students with a *surface* approach, as well as activities congruent with a *deep* approach.

Most students (76.9%) adopted a *surface* approach to learning in Course 1 (Table 3.7). Students with a *surface* approach to learning were process and content driven, seeking to increase their knowledge by acquiring facts to meet class requirements and reproduce the information on assessments. They generally completed all required assessments and were attentive students (e.g., attending class, recopying notes, making study notecards, making drawings to supplement notes). Students at the upper limit of the *surface* category performed the same activities and used the same materials as the individuals at the bottom end, but they were more strategic and focused on performance. These individuals were more organized (e.g., exhibited better time management, organized notes, attended study groups organized by the instructor or university, found supplemental educational resources online), but were passive students (did not ask questions or become actively involved). Below is narrative evidence from a student using a *surface* approach to learning in Course 1:

> *I never really looked ahead. I just printed off PowerPoints and took notes in class. The professor would release a study guide. I would focus on the individual PowerPoint slides on the areas on the study guide… …on a Word document I would type out information underneath each bullet point of the study guide and make an extended study guide of what the professor expected. I would make that 3-4 days before the test, and then I'd go over it 3-4 times a day before the test…*

Nine students (23.1%) adopted a *deep* approach to learning in Course 1, while 81.5% adopted a *deep* approach to learning in Course 2 (Table 3.7). Students with a *deep* approach to learning may have performed some of the same activities performed by students with a *surface* approach to learning, plus had an intention of developing understanding. They had learning

Table 3.7. Distribution of Motivation for studying Nutrition and Approaches to Learning.

Category:	Course 1 (n=39)	%	Course 2 (n=27)	%
Motivation:				
1. *Controlled*	18	46.2	10	37
2. *Autonomous*	21	53.8	17	63
Approach:				
1. *Surface*	30	76.9	5	18.5
2. *Deep*	9	23.1	22	81.5

objectives for study sessions. They reviewed the slides or textbook and related ideas and topics discussed in more than one section or on multiple slides. They developed outlines and connected different sections to one another. They coordinated material, linking new and prior knowledge (e.g. from one section of the class to the next and from the current course to other coursework), were involved in study groups. They created pathway or summary drawings. They wrote narratives explaining figures. They became familiar with the literature. They asked questions to develop a larger understanding of why and how things happen in the body. Students with a *deep* approach to learning related their knowledge of nutrient structures and metabolic pathways and their regulation to whole body homeostasis, health and disease scenarios, larger issues in public health such as chronic metabolic diseases, and/or to promote optimal nutrition among patients. The following student narrative illustrates the use of a *deep* approach in Course 2.

> *I didn't really learn the value of creating a narrative until I got to Course 2… and that was because it was necessary for the, for the test. But now I find myself using that method more and more, for the study sessions or even if I don't understand something with our senior*

project. Okay, well what are you going to do? Explain this. You're going to write a narrative and kind of look over that… to make sure you can explain that information to someone else."

Relationships among Motivations, Approaches, and Performance

There was a statistically significant relationship between students' motivations and approaches in Course 1 (Table 3.8). Of students who had *controlled* motivations for studying nutrition in Course 1, 94.4% adopted a *surface* approach to learning (Table 3.8, Figure 3.1a). Of students who had *autonomous* motivations for studying nutrition in Course 1, a majority (61.9%) still adopted a *surface* approach to learning. Only nine of 39 (23.1%) students adopted a *deep* approach to learning. Of these students, 88.9% had *autonomous* motivations for studying nutrition in Course 1. A greater percentage had *autonomous* motivations (63%) for Course 2 (Table 3.9, Figure 3.1b). However, there were no statistically significant relationships between students' motivations and approaches in Course 2 (Table 3.8). Most students in Course 1 (76.9%) adopted a *surface* approach

Table 3.8. Relationship between Motivations and Approaches to Learning in Course 1.

Motivation	Approach		Total
	Surface	*Deep*	
1. *Controlled*	17 (94.4%)	1 (5.6%)	18 (46.2%)
2. *Autonomous*	13 (61.9%)	8 (42.9%)	21 (53.8%)
Total	30 (76.9%)	8/ (23.1%)	39 (100%)

% within participant approaches; Chi-square=5.781, $p = .016$, Phi = 0.385

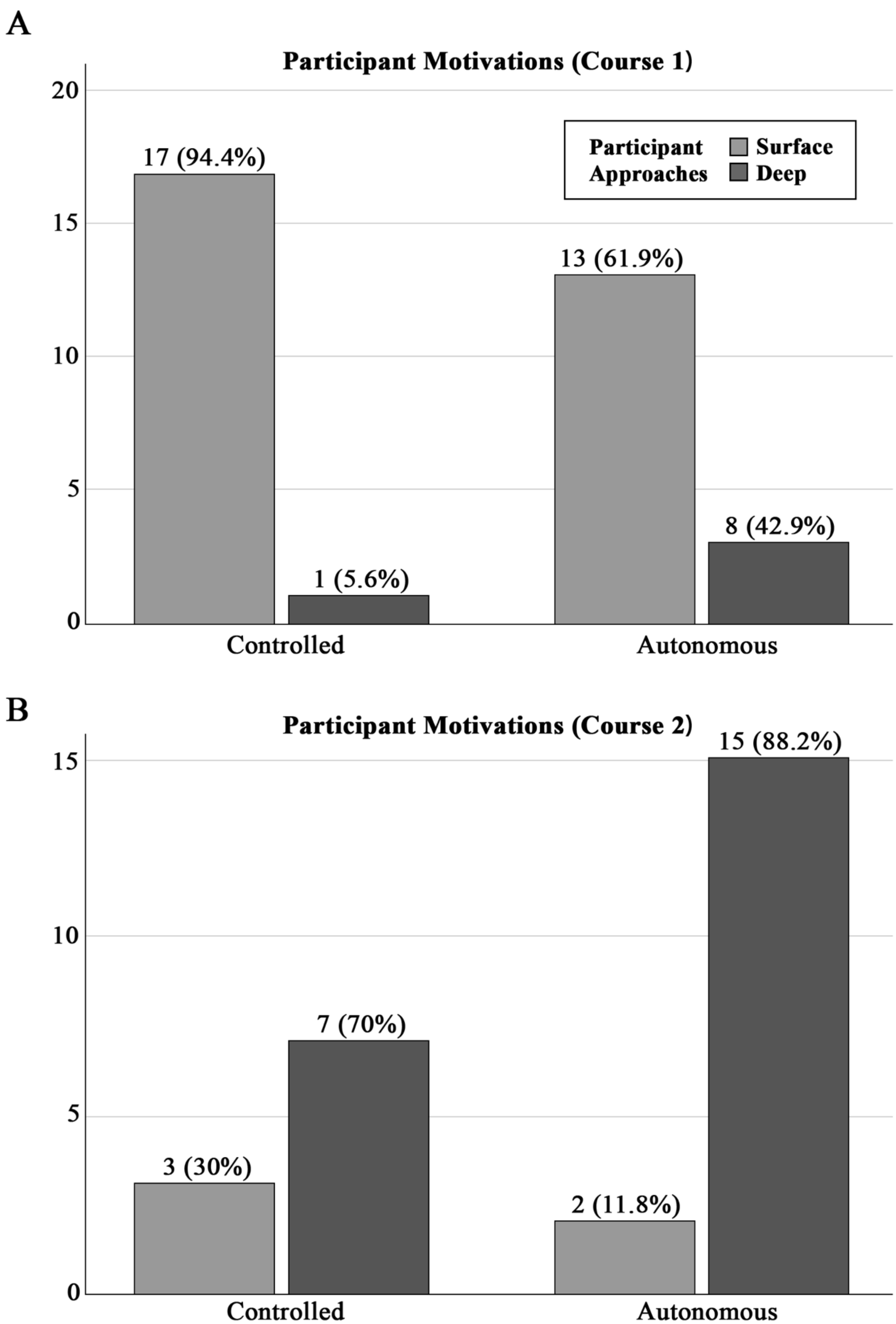

Figure 3.1. Participant motivations and approaches to learning in Course 1 (a) and Course 2 (b).

Table 3.9. Relationship between Motivation & Approaches to Learning in Course 2

Motivation	Approach		Total
	Surface	*Deep*	
1. *Controlled*	3 (30%)	7 (70%)	10 (37%)
2. *Autonomous*	2 (11.8%)	15 (88.2%)	17 (63%)
Total	5 (18.5%)	22 (81.5%)	27 (100%)

% within participant approaches; Chi-square=1.388, p = .239, Phi = .239

in both categories of motivation (Table 3.8, Figure 3.1a), and most students in Course 2 (81.5%) adopted a *deep* approach in both categories of motivation (Table 3.9, Figure 3.1b). For both Course 1 and 2, mean grades were higher for students with *autonomous* motivations for studying nutrition and/or a *deep* approach to learning. Based on the Mann-Whitney U test, grades for students with *autonomous* motivations were statistically significantly higher for Course 1 (U = 303; p =.001) and for Course 2 (U = 136.5; p = .008), and grades for students with *deep* approaches to learning were statistically significantly higher for both Course 1 (U = 197, p = .039) and Course 2 (U = 94.5; p = .010) (Table 3.10).

Table 3.10. Motivations, Approaches, and Grades in Courses 1 and 2.

Category	Grade (on 4-point scale)					
	Course 1 (n=39)			Course 2 (n=27)		
	Grade	N	Mean Rank	Grade	N	Mean Rank
Motivation						
1. *Controlled*	3.296	18	13.67	2.667	10	8.85
2. *Autonomous*	3.905**	21	25.43	3.392**	17	17.03
Approach						
1. *Surface*	3.522	30	26.89	2.400	5	6.10
2. *Deep*	3.963**	9	17.93	3.288**	22	15.80

*p ≤ .05; **p ≤ .01

DISCUSSION

The objectives of this study were to explore motivations for studying nutrition, approaches to learning nutrition, learning outcomes, and relationships among these variables among students in two upper-level nutrition science courses. Major findings were that most students were initially motivated to study different aspects of nutrition than covered in these courses but developed *autonomous* motivations for studying course topics as they progressed. Most students in Course 1 adopted *surface* approaches to learning, while most students in Course 2 adopted *deep* approaches to learning, and they selected the approach they perceived was required to "get a good grade" in the particular course. Students who completed both courses transitioned from a *surface* to *deep* approach from Course 1 to Course 2. For both courses, *controlled* motivations were associated with *surface* approaches to learning and *autonomous* motivations were associated with *deep* approaches to learning. Finally, learning outcomes and performance were positively associated with both *autonomous* motivations for studying nutrition and *deep* approaches to learning in either course.

The students interviewed were mainly nutrition majors who selected to study nutrition because they had a specific interest in the subject. They described in detail their academic and extracurricular background related to nutrition and their motivations for studying it, including what first interested them in nutrition, and how this changed over time or stayed the same. Findings were congruent with previous studies describing incoming students, in terms of their interests and motivations for studying and/or working in the field of nutrition. These studies have indicated that students begin their program with diverse backgrounds, experiences, interests, levels of prerequisite knowledge and skills, academic and professional goals, and views of what a career in nutrition might involve, a low level of awareness of the scientific nature of nutrition, and narrow views about the wide range of career pathways and other opportunities in nutrition.[38–42] Several students suggested wanting to learn more about nutrition from a desire to help others, because of a positive experience with a dietitian, or because they or a family member had health problems due to nutrition-related disease, or had an eating disorder, or weight management problem. Several specifically sought a career in clinical dietetics or other nutrition-related medical or applied science field, while most others were more generally interested in nutrition as it relates to food, diet, health, wellness, exercise, and fitness. Many also described an interest in alternative or holistic medicine.

Despite these students' intrinsic interests in nutrition, their belief it is an important area of health promotion and disease prevention, and their selection of it as a course of study, few indicated they initially had intrinsic interests in studying the scientific aspects of nutrition and metabolism nutrition taught in Courses 1 and 2. Some specifically indicated not being interested in these topics because they would not be relevant to their future plans. Rather they became more interested in these aspects of nutrition as they were covered in each course but had initially been surprised by the scientific rigor of the courses. In a parallel study found in chapter 4 of this dissertation, we learned this may be because most of these students did not have a *coherent* understanding of nutrition as a science. This has also been previously discussed, as a situation that may be problematic, e.g., if their prior knowledge was inadequate for mastery learning or if their misconceptions led them to adopt *surface* approaches to learning and poorer learning outcomes in their nutrition science courses.[43]

Students described how they studied for the nutrition science course(s) they had taken (their approaches), what types of things motivated them to study while they were taking the course(s), what they intended to do with what they learned, and what changed over time or stayed the same. As predicted, most students adopted *surface* approaches to learning in Course 1, like those described throughout the literature[15,16,18–26,44–51]—using minimal study approaches when preparing for more objective tests and when they believed their methods were adequate to meet their performance goals. Although this was a novel study in the field of nutrition, this particular finding was unsurprising based on the literature or our understanding of students in Course 1, who have suggested they do not always know how to study for mastery learning or how to tailor their approaches from one course or subject to the next.

Students suggested a variety of motivations for adopting their approaches in Courses 1 and 2. *Controlled* extrinsic motivations included more proximal factors, such as completion of the courses as required for their program of study, or performance alone. *Autonomous* extrinsic motivations were those that were more congruent with long-term goals such as preparation for graduate school or a job or career in food, nutrition, dietetics, and related fields. Based on preliminary discussions with students taking Courses 1 and 2, we originally expected participants to adopt *deep* approaches to learning in Course 1 if they began the course with an intrinsic motivation and/or more *autonomous* extrinsic motivations. To some extent this was the case, and an *autonomous* motivation was positively associated with a *deep* approach to learning and learning outcomes. However, not all students with an *autonomous* motivation for studying nutrition adopted *deep* approaches to learning it, and despite associations, motivation did not seem to be the primary driver of the approach students adopted in these courses.

Recently, Kyndt et al., studied the relationship between motivations and approaches to learning in the context of SDT and demonstrated that motivation has both direct and indirect influences on students' approaches to learning.[52] However, they demonstrated a positive relationship between an *autonomous* motivation and a *deep* approach to learning only when students were in a high workload situation.[52] They also suggested since a student's approach to learning is influenced by the course content, context, and their perceptions of the context,[20,53] and self-regulation is a mediator among personal and contextual characteristics and learning and performance,[54] then a student's motivation may influence their perception of the workload and task complexity, and could therefore have an indirect influence on their approach to learning and outcomes.[52] Essentially, in the high workload situation, a student with an *autonomous* motivation would be more likely to adopt a *deep* approach to learning if content is relevant to their interests, learning it is congruent with their goals, and because they have an IPLOC and perceive the work to be manageable.

The findings of Kyndt et al. corroborate our claim that there is a positive relationship between an *autonomous* motivation and a *deep* approach to learning and that students' approaches to learning were influenced by the course content, context, and their perceptions of the context. When reflecting on the course(s) they had completed, most said they had *autonomous* motivations for studying the more scientific aspects of nutrition taught in Courses 1 and 2. The proportion of students with *autonomous* motivations increased through Course 2, as many shifted from more *controlled* to more *autonomous* motivations for studying nutrition as they proceeded through these courses. They developed more intrinsic interest in the subject, more internal and integrated regulation, as well as what they described as "better study methods" and more time studying the material.

Whether or not they were intrinsically interested in the topics covered, students suggested their motivations to study were fueled by their performance motivations for the course. Although they valued long-term learning, they adopted approaches based on what they thought assessments would be like, their academic experiences, and what they perceived were preferences of instructors. Like other students previously described,[55] they viewed exam performance as a reflection of learning and an end in itself and adopted approaches they thought were necessary to get a “good grade” on exams and in the course. They could not spend the extra time to develop an integrative understanding of nutrition unless the course demanded it. Some described the situation as a conflict of interest for them. Long-term mastery learning was usually secondary to performance. For example, some students suggested they did not seek to learn molecular aspects of Course 1 at a mastery level because they did not initially value learning about nutrient structures or metabolic pathways, which seemed like isolated, unimportant details that would not be relevant to their planned career pathway. Rather, they crammed to memorize the discrete details they thought would be on an exam. They focused on the instructor’s slides, outlines, study guides, and their own class notes, but they did not use the textbook or other resources to develop a deeper understanding. They did not usually participate in study groups for the course to discuss the material outside of class or spend extra time writing narratives for themselves. Based on their perceptions of the content and context, they did not believe these methods were necessary to do well—including most with *autonomous* motivations (Table 3.7, Figure 3.1a).

Some students changed their study approach after they were able to identify what the instructor expected or gain an understanding of what exams would be like, typically after the first or second exam. Many modified their approaches through the semester from one exam to the next to find methods that worked. This was a common pattern of behavior. This adoption of a performance orientation and ability focus rather than a learning orientation and mastery focus is common and consistent with patterns previously described.[32]

Most students interviewed performed well in Course 1, despite adopting *surface* approaches to learning. The mean final grade for students in Course 1 was a B+, but there was a wide (>30 percentage point) range of scores. Students with *surface* approaches who achieved higher grades seemed take a more strategic approach or put more consistent effort into studying and stayed on top of their assignments, yet their study activities still did not specifically incorporate aspects of a *deep* approach, such as integration, reflection, or application. In many cases, this was sufficient to achieve the grades they desired on exams that were primarily comprised of multiple-choice, matching, and fill in the blank questions.

Of the nine students who adopted *deep* approaches to learning in Course 1, only two were traditional undergraduate students. Two were adult students who returned to academia to complete an undergraduate degree after deciding to change careers (to dietetics). Five were students who had previously completed a bachelor's degree and were taking the course in preparation for graduate training in nutrition. All nine of these students had a history of academic success. They had more *coherent* conceptions of learning and of nutrition as a science. They were high performers in Course 1 who also spent time reflecting and integrating the material outside of class and were individuals who were able to communicate their understanding of the material, e.g. in class, study groups, orally and/or in writing. These students were more prepared to learn when Course 1 began.

Several students reflected on their academic development through the program and suggested they had not developed *deep* approaches until nearly the end of Course 2, and they had not developed an appreciation for their major until the end of the course after studying for and taking the final comprehensive exam. Yet, many students transitioned from a *surface* to *deep* approach to learning from Course 1 to Course 2, and a large proportion of students (81.5%)

adopted a *deep* approach to learning in Course 2. Many of these students suggested they had developed intellectually and academically and/or their appreciation for the scientific aspects of nutrition increased during Course 1.

Most students said they began changing their approach after starting Course 2, having realized it was necessary keep up with the material and to get the grades they wanted on assessments, which required a deeper, more integrative understanding of the topics assessed and extended explanation of topics. For Course 2, students using a *surface* approach tended to have poorer scores on exams, and students who adopted a *deep* approach tended to have higher scores on exams. They still focused on the instructor's slides, outlines, study guides, and their own class notes, but they also used the textbook and other resources to develop a deeper understanding, worked with other students in small groups, and attended recitations to discuss the material with classmates. Many indicated developing detailed diagrams and spending extra time writing narratives for themselves. Based on their perceptions of the content and context in this higher workload situation, they believed these methods were necessary to do well—including most students with *controlled* motivations (Table 3.8, Figure 3.1b).

The fact that students developed more *autonomous* motivations and transitioned to *deep* approaches to learning from Course 1 to Course 2 is a positive outcome, reflecting their maturation as they proceeded in their courses. They began to develop better study skills and interest in the subjects in their major. However, this also reflects needs among students, that could be addressed earlier in the program—since many students did not have *autonomous* motivation to learn nutrition science before Course 1 and/or did not adopt a *deep* approach, which are both associated with higher quality learning outcomes.

Study limitations, strengths, and implications for future research and practice

As with any research, this study has limitations. Although the findings of this exploratory study may be applicable to situations involving different students in courses 1 and 2, other nutrition courses, or in other courses in related areas of study at this university or elsewhere, they were limited to data derived from interviews from a small sample of 39 volunteer participants who completed nutrition science courses at one university during a brief period of time. Additionally, these individuals reflected on past experiences, which were unique and influenced by a wide variety of other social and environmental factors. Thus, further research of a broader population of students in these and other courses at this university and elsewhere will be necessary to develop a more precise understanding of the influences on learning and performance. However, despite these limitations, robust relationships were identified. In particular, *autonomous* motivations for studying nutrition were associated with a *deep* approach to learning, and both were associated with higher mean grades. Furthermore, these relationships were congruent with previous data and well-established findings in the SDT literature on motivation, learning, and outcomes in other disciplines. As such, it seems likely these relationships would persist and may be amplified among a broader group of students in these and other similar courses.

Although it is beyond the scope of this study, the ways educators can influence students' motivations for studying nutrition and how they go about learning will be an important subject for future research and practice. One method to assess these issues will be to develop and deploy surveys to evaluate students' motivations and approaches to learning throughout their academic program, beginning with entry surveys during courses and seminars. These could be fine-tuned and validated for nutrition students in programs at other universities. Additionally, instructors could take steps to promote students' interest in nutrition science, support *autonomous* motivations, and encourage them to adopt *deep* approaches to learning throughout their program, which may ultimately facilitate their learning outcomes and better prepare them for graduate training, careers in nutrition, and to be experts in nutrition who can solve problems.

Based on data from pilot research and findings from this study, additional exploration will be necessary to explore students' conceptions of nutrition as a science and elucidate relationships among their conceptions, approaches to learning, and outcomes in these courses. These issues will be discussed in chapter 4 of this dissertation.

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CHAPTER 4: DIFFERENCES IN STUDENTS' CONCEPTIONS OF NUTRITION AS A SCIENCE AND THEIR APPROACHES TO LEARNING NUTRITION SCIENCE

CHAPTER OVERVIEW

Background

There is a global need for nutrition professionals with an integrationist approach to health sciences who are equipped to solve complex health issues. Many students in nutrition sciences courses, though, are not learning at a mastery level. They often have a *fragmented* conception of the subject of nutrition and adopt *surface* rather than *deep*, more meaningful approaches to learning that are necessary to integrate what they have learned and apply it to more advanced courses in nutrition sciences or careers as nutrition professionals.

Methods

We performed an exploratory analysis of interviews of 39 students (82% female, 85% undergraduate, 10% first generation) in upper-level nutrition science courses at Colorado State University (CSU) spring semester 2012–spring 2015 to explore their conceptions of nutrition as a discipline and their approaches to learning before and after taking Course 1 (*Human Nutrition*, n=12) or both Course 1 and Course 2 (*Integrative Nutrition & Metabolism*, n=27). We developed categories of conceptions and approaches using phenomenography, categorized participants for each variable, and assessed relationships among conceptions, approaches, and performance.

Results

Entering Course 1, 87% of students had a *fragmented* conception of nutrition as a science and unclear or inaccurate expectations for what would be covered, and 76.9% adopted a *surface* approach to learning. Most (82.4%) students with a *fragmented* conception of nutrition science adopted a *surface* approach to learning. For Course 2, 52% began with a *coherent* conception of nutrition as a science, and most (81.5%) adopted a *deep* approach to learning in the course. Statistically significant relationships were identified between students' conceptions and approaches to learning for Course 1. In both Course 1 and 2, the groups of students with *coherent* conceptions and/or *deep* approaches achieved significantly higher mean grades.

Conclusion

In general, students with a *fragmented* conception of nutrition as a science seemed to adopt a *surface* approach to learning. Students with a *coherent* conception of nutrition seemed to adopt a *deep* approach to learning and had higher grades. Yet the relationship differed between Courses 1 and 2, and students' adoption of an approach to learning seemed to be influenced by the course demands. How instructors and programs can intervene to address gaps in students' conceptions of nutrition and approaches to learning will require further investigation.

INTRODUCTION

Need for nutrition experts

Over recent decades there has been a global increase in the prevalence and incidence of diet- and lifestyle-related chronic, metabolic diseases that burden public health and the economy.[1,2] This has created an urgent need for experts in nutrition who understand science in a broad, integrative, and trans-disciplinary way. Nutrition has been described as a "uniquely integrative science field" that "offers great hope" for improving health.[3] It bridges core concepts in biology, chemistry, and physiology, pathology, genetics, and many other disciplines.[4] A student completing a degree in nutrition should be able to synthesize complex scientific concepts across their degree program,[3,5] communicate across disciplines and themes that span them,[3,6–8] translating science from the molecular level to whole body homeostasis, to behavioral and environmental issues,[3] and ultimately, to solve problems[6–11] related to the complex issues that burden public health and the economy.[1,2,12–15]

Learning gaps among students

There are learning gaps in undergraduate science education, and we are not currently graduating a sufficient number of experts with the skills to solve these problems.[10,16,9,17–19] Thalacker-Mercer and Vanderlan stated that students in a core nutrition science course at Cornell University "come to classes unprepared to learn or contribute in a way that would support development of important skills."[19] Instructors at Colorado State University (CSU) have made similar assertions—that many students in nutrition science courses do not adopt meaningful approaches to learning in their courses that are necessary to master the material, integrate what they have learned, and apply it to more advanced courses in nutrition sciences or careers as nutrition professionals.

Approaches to learning

The way a student goes about their academic tasks, thereby affecting the nature of their learning outcomes is termed their *approach to learning*.[20] In their classic studies, Marton and Säljö described qualitative differences in how students approached learning and processing the same material, which depended on their conception of the task and influenced their understanding and subsequent performance on assessments.[21,22] All students were told to read passages in preparation for questions about the material. There were no time constraints. Students who anticipated questions about specific details studied by going through the reading and seeking out facts. They skimmed the article, processing only at a "*surface*" level, to memorize details about it for the test. They did not attempt to understand the passage—rather, "their awareness skated along the *surface* of the text."[21,22] Many of these students suggested they felt feelings of heavy time pressure, anxiety, and hyperintention to perform (which impairs memory formation).[23] Other students sought to understand the message rather than memorize the text. They processed the material in a more meaningful way—at a "*deep*" level, and also remembered it very well.[23] The depth of processing was positively correlated with the quality of learning outcomes.[21,22] According to Marton, et al., this has been confirmed many times.[23]

In general, a *surface* approach to learning is process and content driven, and characterized by an extrinsic motivation, rote memorization, and learning as a quantitative increase in knowledge.[23] Students who adopt a *surface* approach take the most basic approach to studying, reviewing only the most readily available resources, seeking out details likely to appear on an assessment, and acquiring, recording, reciting, and memorizing discrete facts and procedures routinely.[23,24] They temporarily obtain knowledge of details without reflection on either purpose or strategy, with the intention of reproducing them on an assessment, often with minimal understanding or ability to relate the disparate pieces of information. There is little or no effort to integrate these details or connect them to new or previous ideas or to real life.[24] These students struggle to make sense of new ideas presented and often feel undue pressure and worry about work.[23] They simply attempt to cope with class requirements, which are externally imposed on them by instructors, and do not master material or develop lasting understanding.[23]

A *deep* or meaningful approach to learning is characterized by an intrinsic interest, appropriate engagement in the task, and the intention to understand.[24,25] Those who adopt a *deep* approach are active in learning, use a full range of learning activities to develop understanding, often including those adopted by *surface* learners (e.g. memorizing), as well as reflecting.[23] They seek and identify patterns, critically examining and incorporating evidence, and integrating concepts, relating new ideas to previous ones and to everyday experiences.[23,24] These students are actively interested in the course content and show an inherent motivation to learn.[23] They focus on making meaning and developing intellectually.[23]

Students may vary considerably in how they approach learning about the same phenomenon, concept, or principal. One student may use either or both approaches to learning, depending on a number of factors, including assessment characteristics.[23,26,27] Additionally, an instructor may influence students' approaches to learning by giving a certain type of exam because students will modify their study behavior to perform well on the type of test they expect to receive.[23,26–29] When students expect a more objective test, they are more likely to adopt a *surface* approach and study by looking for details and working within smaller units of information.[29] When students expect an essay exam, they are more likely to adopt a *deep* approach. They look for main points and try to strengthen their grasp of the subject matter in larger units taken as a whole.[29]

Approaches tend to be exclusive (e.g., *surface* or *deep*) for a task, but these are not stable traits and some students may switch between approaches, even within a single class. Students may also adopt strategic study approaches to balance time, learning, and performance.[26] These students are methodical and organized in their study, reflective on assessment performance, and motivated by achievement. A student's academic performance tends to correlate negatively with a *surface* approach and positively with a *deep* or strategic approach to learning.[30]

Surface and *deep* approaches to learning and the key factors that seem to encourage or discourage the adoption of one versus another have been described, compared, and contrasted.[28] In 2010, Baeten et al. reviewed the literature and summarized these factors, categorizing them into one of three groups: 1) contextual factors, (e.g. characteristics of instruction, instructors, the subject area, and the environment); 2) perceived contextual factors (e.g. the student's perceptions of teaching, supportiveness, their workload, clarity of course goals, and relevance of the course to the professional practice); and 3) student factors, such as experiences (with work, academics, and approaches to learning), intellectual ability and academic skills, as well as age, gender, motivations, emotions, and personality.[28] A common strategy that instructors use is to modify instruction to encourage the adoption of *deep* approaches to improve learning outcomes.[23,26–28,31]

Conceptions

A student's conception of learning may influence their approach to learning and outcomes.[18,32,33] For example, a less mature student may view learning as a matter of obtaining discrete information to reproduce it on a test. In contrast, a more mature learner may view learning as a way to reach personal understanding by transforming information (and themselves).[34] A student's conception of a discipline, or a specific topic (e.g., what they think the subject is about, whether they have an organized view of what it is, and what studying it involves) can also influence their approach to learning and outcomes.[18,32] A student with a more *coherent* view of a subject area is more likely to adopt a *deep* approach to learning the subject, while a student with a *fragmented* conception of a topic or discipline is more likely to adopt a *surface* approach to learning it and also have poorer learning outcomes and more negative perceptions of courses and instructors.[18,35] This has been demonstrated across disciplines, including physics,[32] mathematics,[36,37] and biochemistry.[18] Those with more experience in a discipline and greater prior knowledge of the subject are likely to have a more *coherent* view of the subject and would be more likely to adopt a *deep* approach to learning in a course.

Chapter 3 of this dissertation was an analysis of students' motivations and approaches to learning in courses 1 and 2. Yet, an interesting finding was related to their *conceptions* of nutrition as a science. Most students began these courses with intrinsic motivations for studying nutrition, but not the more scientific aspects of nutrition taught in these courses. They had little or no academic or professional experience in nutrition, inadequate prior knowledge from prerequisite courses, and although the focus in these courses is metabolism of nutrients, students' conceptions of nutrition were more congruent with coverage in the media. They had inaccurate or vague ideas of what nutrition is and what to expect in a nutrition science course and were surprised by the scientific rigor of the subject. This seemed to negatively influence their approaches to learning.

There have been no studies of these issues and there is a strong need for research regarding students' conceptions of nutrition as a science and their approaches to learning in university-level courses. Therefore, in this study, the same sample and methods (as those described in chapter 3) were used to answer the following research questions: (i) How do students in two upper-level Nutrition Science courses describe nutrition (their conceptions); (ii) How do these students describe what they must do to learn nutrition (their approaches), (iii) What do students in these courses learn (their outcomes) and (iv) What are the relationships among conceptions, approaches, and outcomes of students in these two upper-level courses? We predicted that students with a *coherent* conception of nutrition as a science would adopt a *deep* approach to learning and students with a *deep* approach to learning would demonstrate better outcomes in the upper-level Nutrition Science courses.

METHODS

Since most of the methods for this study were the same as those described in chapter 3, only methods specific to chapter 4 are included below. Please refer to chapter 3 for details about the researcher, participants, instructors, courses, and other sources of data.

Formal student interviews (Appendix B)

Participants were asked to reflect on their conception of the study of nutrition (what they believed nutrition was about), why that was their conception, what they thought a student must to do to learn nutrition, and to describe (in their own words) a typical study session for them in the course(s) they completed. If the student had completed both Courses 1 and 2, they were asked to answer the same questions for each course and to discuss how their conceptions and methods changed (or stayed the same) as they progressed through the nutrition program and before and after taking each of the courses.

Data analysis

Analysis included open and focused coding of all transcripts, as described in chapter 3. The mutually exclusive categories were *fragmented* and *coherent* conceptions of nutrition and *surface* and *deep* approaches to learning. As before, cases unique to each category were selected to illustrate the category, general characteristics of it, and to explain how different cases were compared. As hierarchy of similarities and differences became apparent, student narratives were selected to illustrate categories. There was full agreement among researchers on the categories of responses for both domains.

Statistical Analyses

SPSS version 25 (IBM, Inc., Chicago, IL) was used for all analyses. Once all responses were categorized, relationships among students' conceptions of nutrition, approaches to learning, and course grades were assessed. Chi-square tests were run to determine significance of associations between conceptions and approaches. Mann-Whitney U tests were run to determine significance of differences in mean grades between groups of individuals with *fragmented* versus *coherent* conceptions of nutrition as a subject and between individuals with *surface* versus *deep* approaches to learning nutrition.

RESULTS

The results will be described in three parts, corresponding to the first three research questions: (i) conceptions of the subject of nutrition, (ii) approaches to study, (iii) relationships among conceptions, approaches, and performance.

Conceptions of nutrition as a science

Students had diverse backgrounds and varying conceptions of nutrition as a science. The two categories originally selected based on the research literature (*fragmented* and *coherent*) were confirmed to be mutually exclusive for participants. (Table 4.1). Based on their interviews, students were categorized as having either a *fragmented* or *coherent* conception of nutrition as a science prior to taking Course 1 and/or Course 2, based on our subjective view of their explanation of what they thought nutrition was about and why, as well as their explanation of what they believed was necessary to learn nutrition and why. Although there were differences among individuals within each group, the distinction between groups was clear.

Table 4.1. Categories of student conceptions of nutrition.

Conception	Category	Example Narratives
Fragmented	Nutrition is the study of food, nutrients, and/or diet planning, or a tool that can be used in a discrete area of health.	*Tool for athlete to maximize athletic performance* *Food choices, meal planning, nourishing the body; prevent and manage disease/treatment.* *Food system may impact individual diet and health.* *Different foods, and what vitamins and minerals were in the foods, and what we should tell people to eat; relating food and nutrition, to diet and maybe practical advice.*
Coherent	Nutrition is the scientific study of nutrients and other food components as they relate to maintenance of cellular homeostasis, human health, and disease.	*How diet interacts with the body and physiology…* *Connecting that biochemical side to physiological side to understand how to eat for optimal health*

Of the 39 participants, 34 of them (87.2%) entered Course 1 with a *fragmented* conception of nutrition as a science (Table 4.6). They were mainly Food Science and Human Nutrition majors who had prerequisite courses in biology, chemistry, and physiology, and were interested in the subject of nutrition. Few started Course 1 with the conception that nutrition bridges core concepts in these areas. Most had little background in nutrition science prior to beginning the program and had a vague understanding of the types of content that would be covered in an upper-level nutrition science course. Nearly all students expressed surprise at the level of scientific rigor involved in Course 1. They did not think it would be so complex or as focused on the structures of nutrients and their metabolism in the body. Rather, they expected a relatively easy course that would not demand so much study time—less like a traditional science course and focused on different content. They had not selected nutrition to study the more scientific aspects of the subject, but to learn about food, nutrients, and/or diet planning, or a tool that can be used in a discrete area of health, or to influence athletic performance, and they viewed the more scientific aspects of their program and courses as compulsory (Table 4.4). The following narratives from two students illustrate *fragmented* conceptions of nutrition, as they recalled their conceptions of nutrition before Course 1:

> *I definitely didn't think of nutrition …I mean I totally went into [Course 1] thinking nutrition was something totally different. Like, I never really thought of it as a science… More like, choose better foods, and then you get to [Course 1] and it's like molecular things and like, I don't know, bonds, it's like a lot of chemistry and you didn't… I never really thought nutrition was like that.*

> *I must say I kind of signed up initially because I thought it would be an easy degree. I was like, "Oh, nutrition. I know food. I like food. This should be easy." I was wrong. I probably didn't have as much appreciation going into it as I did coming out of it.*

In contrast, students with a *coherent* conception of nutrition had a more advanced understanding of nutrition and expected to learn more about the science of how nutrients and other food components are related to physiology, health, and disease. Five (12.8%) of the 39 students interviewed entered Course 1 with a *coherent* understanding of nutrition as a discipline (Table 4.6). Of these individuals, four had already completed an undergraduate degree and were returning to take the course for personal interest or in preparation for a graduate program, and all five had previously completed a course in biochemistry. All of these students had more experience in health-related sciences. Most students (63%) with a *fragmented* conception of nutrition developed a more *coherent* conception by the time they completed Course 1. The following narrative is an example of a student with a *coherent* conception of nutrition described her ideas about nutrition in Course 1:

> *My original thing was cooking, and I really liked cooking back in high school and when I went to college I started to cook for myself and that's when I started experimenting with different food groups and so forth. It took an introductory nutrition course is a general elective and that's when I found out more about the nutrition aspects of cooking. When we did our diet projects I realized how badly I was eating and some of the health consequences and that made me reconsider what I was making. I became more interested in nutrition and recipe modification and making recipes a little bit healthier and using alternative ingredients. I worked with a dietitian at an elementary school and became more curious about nutrition and also had several friends in nutrition who were all becoming registered dietitians. I became more interested in nutrition and eventually decided to go back to school in dietetics. I'm interested in practicing clinical nutrition, and to get ready, I had taken classes in organic chemistry, biochemistry, physiology, and microbiology felt prepared [for Course 1] by learning the structures and how they interact with the body and the physiology as well. Now I'm connecting that biochemical side to the physiological side - I felt like Course 1 combined all of those prerequisites together.*

Table 4.2: Distribution of Conceptions of Nutrition & Approaches to Learning

Category:	Course 1 (n=39)	%	Course 2	%
Conception:				
1. *Fragmented*	34	87.2	13	48.1
2. *Coherent*	5	12.8	14	51.9
Approach:				
1. *Surface*	30	76.9	5	18.5
2. *Deep*	9	23.1	22	81.5

Of the 39 participants, 27 also completed Course 2. All completed Course 1 and biochemistry beforehand, and 52% had a *coherent* conception of nutrition as a science when they began Course 2 (Table 4.2). Many of these students suggested they began developing a more integrative understanding of nutrition as a science during Course 1 or biochemistry, through a combination of these and other courses in the curriculum, and/or via extracurricular activities. All students had *coherent* conceptions after finishing Couse 2.

Approaches to learning

See chapter 3.

Relationships among Conceptions, Approaches, and Performance

There was a statistically significant relationship between students' conceptions and approaches in Course 1, with 82.4% of students with a *fragmented* conception of nutrition adopting a *surface* approach (Table 4.3, Figure 4.1a). The relationship between conceptions and approaches was weak for Course 2.

Table 4.3. Relationship between Conceptions of Nutrition & Approaches to Learning in Course 1

Conception	Approach		Total
	Surface	*Deep*	
1. *Fragmented*	28 (82.4%)	6 (17.6%)	34 (87.2%)
2. *Coherent*	2 (40%)	3 (60%)	5 (12.8%)
Total	30 (76.9%)	9 (23.1%)	39 (100%)

% within participant approaches; Chi-square=4.405, p = .036, Phi = 0.336

Of the 27 students who completed Course 2, there were 22 (81.5%) who adopted a *deep* approach, and of these students, 13 (59.1%) had a *coherent* conception of nutrition (Table 4.4). For both Course 1 and 2, mean grades were higher for students with a *coherent* conception of nutrition and/or a *deep* approach to learning. For Course 1, only five students had a *coherent* conception, and all earned a grade of "A;" the remaining 34 students had a *fragmented* conception and grades ranged from "A" to "C." As such, the distribution of grades was not similar between groups, and based on the Mann-Whitney U test, the difference in grades between groups by conception for Course 1 was not a statistically significant (U = 127.5; p =.074), but it was for Course 2 (U = 156; p = .001).

Table 4.4. Relationship between Conceptions of Nutrition & Approaches to Learning in Course 2

Conception	**Approach**		**Total**
	Surface	*Deep*	
1. *Fragmented*	4 (30.8%)	9 (69.2%)	13 (48%)
2. *Coherent*	1 (7%)	13 (93%)	14 (52%)
Total	5 (18.5%)	22 (81.5%)	27 (100%)

% within participant approaches; Chi-square=2.494, p = .114, Phi = .304

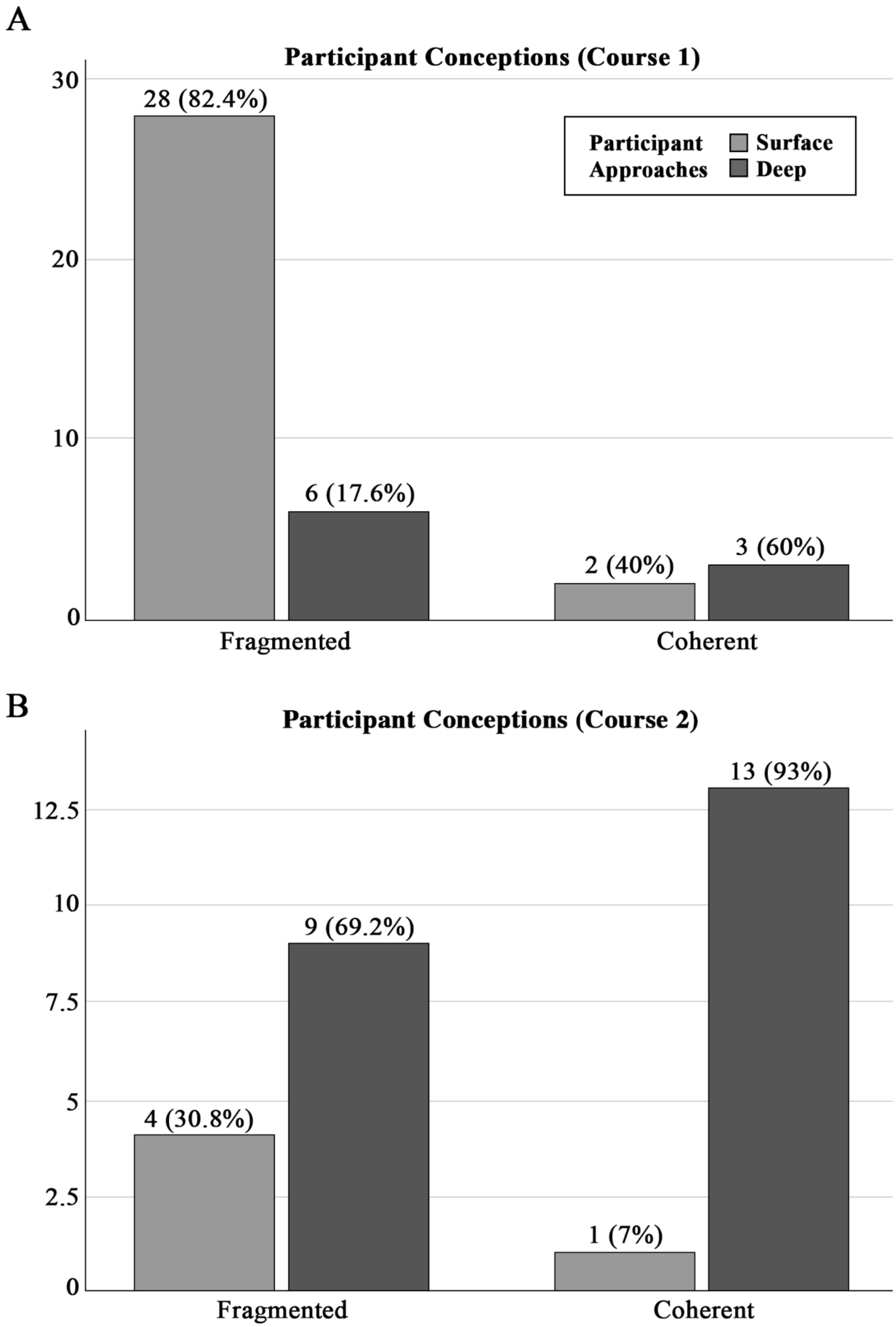

Figure 4.1. Participant conceptions and approaches to learning in Course 1 (a) and Course 2 (b).

Grades for students with *deep* approaches were also statistically significantly higher for both Course 1 (U = 242, p = .039) and Course 2 (U = 94.5; *p* = .010) (Table 4.5).

Table 4.5. Conceptions, Approaches, and Grades in Courses 1 & 2

Category	Grade (on 4-point scale)					
	Course 1 (n=39)			Course 2 (n=27)		
	Grade	N	Mean Rank	Grade	N	Mean Rank
Conception						
1. *Fragmented*	3.568	34	18.75	2.667	13	9.00
2. *Coherent*	4.000	5	28.50	3.54**	14	18.64
Approach						
1. *Surface*	3.522	30	26.89	2.400	5	6.10
2. *Deep*	3.963*	9	17.93	3.288*	22	15.80

*p ≤ .05; **p ≤ .01

DISCUSSION

The objectives of this study were to explore conceptions of nutrition as a science, approaches to learning nutrition, learning outcomes, and relationships among these variables among students in two upper-level nutrition science courses. Major findings were that most students began Course 1 with a *fragmented* conception of nutrition and began Course 2 with a *coherent* conception of nutrition. All students completed Course 2 with a *coherent* conception of nutrition and those who completed both courses transitioned from a *fragmented* conception of nutrition to a *coherent* conception of nutrition from Course 1 to Course 2. As discussed in chapter 3, most students in Course 1 adopted *surface* approaches to learning, while most students in Course 2 adopted *deep* approaches to learning, but they selected the approach they perceived was required to “get a good grade” in the particular course. Students who completed both courses transitioned from a *surface* to *deep* approach from Course 1 to Course 2. For both courses, *coherent* conceptions of nutrition as a science were associated with *deep* approaches to learning and learning outcomes.

This study examined students in two upper-level nutrition science courses, their conceptions of nutrition as a science, approaches to learning nutrition, learning outcomes in each course, and relationships among these variables. The students interviewed were mainly nutrition majors who selected to study nutrition because they had a specific interest in the subject. They described their academic and extracurricular background related to nutrition and described in detail their reasons for studying nutrition, what they thought nutrition was about, and what they thought was necessary to learn it (their conceptions) before and after taking Course 1 or 2, why they thought this, what changed over time or stayed the same, and how they studied for each course (their approaches). They began with varied backgrounds, experiences, interests, levels of prerequisite knowledge and skills, academic and professional goals, and views of what a career in nutrition might involve. Some sought careers in clinical dietetics or other biomedical or applied science fields, while others had an interest in nutrition as it relates to food, diet, health, wellness, exercise, fitness, and various other less scientific aspects of nutrition. Several suggested wanting to learn more about nutrition from a desire to help others, after a positive experience with dietitians, or if they or a family member had health problems due to nutrition-related disease, or had an eating disorder, or weight management problem. Other studies have described such diversity among dietetics students.[38–42]

Nutrition is a science field particularly prone to misconceptions. It has been described as a discipline without common understanding.[43] Nutrition is young compared to other sciences, and many academic departments in human nutrition and dietetics have developed from other programs, such as home economics and/or are joined with programs in food science. Nutrition is also a hot topic in the popular media, where coverage is often oversimplified and nonscientific, focusing on the newest fad diets, controversies, and debates. Consistent with our predictions (based on preliminary discussions with students taking Courses 1 and 2), most students had a *fragmented* conception of nutrition as a science when entering Course 1. Like the students Hughes and Desbrow described in their study of aspiring dietetics majors,[38] they had a low level of awareness of the scientific nature of nutrition and narrow views about the diversity of practice, types of career pathways, and other opportunities in nutrition. Much of what they knew about nutrition was from the media (rather than more credible sources), which is often a dualistic view of nutrition, e.g., differentiating foods, nutrients, or biomarkers based on whether they are "good" or "bad." Despite their interest in nutrition, their belief it is an important area of health and medicine, and their selection of it as a course of study, they did not have a *coherent* understanding of nutrition as a science field that bridges biology and chemistry. As previously discussed,[44] this may be problematic, e.g., if their prior knowledge was inadequate for mastery learning or if their misconceptions led them to adopt *surface* approaches to learning and poorer learning outcomes in their nutrition science courses.

As predicted, most students adopted *surface* approaches to learning in Course 1, like those described throughout the literature[17,18,21–29,32–34,36,45–48]—using minimal study approaches when preparing for more objective tests and when they believed their methods were adequate to meet their performance goals. Although this was a novel study in nutrition, this particular finding was unsurprising based on the literature or our understanding of students in Course 1, who have suggested they do not always know how to study for mastery learning or how to tailor their approaches from one course or subject to the next. Many participants reflected on their approaches to learning and their reasons for selecting their study methods in Courses 1 and 2 and suggested their initial conception of what the course was about influenced their initial approach.

Also, as predicted, students with a *fragmented* conception of nutrition as a science tended to adopt a *surface* approach to learning, while students with a *coherent* conception of nutrition as a science tended to adopt a *deep* approach to learning. These findings align closely with previous studies by Minasian-Batmanian and colleagues, who assessed allied health students' conceptions of the subject of biochemistry and approaches to learning it in a mandatory biochemistry course.[17,18] Most of those students had a *fragmented* conception of the topic of biochemistry and simplistic ideas about biology and chemistry (as discrete subjects unrelated to the human body) and were more likely to adopt a *surface* approach to learning it. A small group of students had a more *coherent*, integrated view of the subject as it relates to human physiology, and they were more likely to adopt a *deep* approach. These relationships were based on the students' beliefs that a *surface* approach to learning was suitable for learning biochemistry, and few felt a *deep* approach was necessary.[17,18] A major difference here is that the focus of this study was not on students taking a compulsory science course in another department. Rather, all students interviewed specifically chose to study nutrition (because they were interested in nutrition). In particular, Course 1 has been described as the pivotal nutrition course needed to be successful in virtually all of the upper-division nutrition courses in the department.[9] Yet, only nine students adopted a *deep*, mastery approach to learning in Course 1, and many suggested they were unable to recall material from Course 1 when they got to Course 2.

More generally, students adopted approaches to learning based on what they thought assessments would be like, their academic experiences, and what they perceived were preferences of instructors. They viewed exam performance as a reflection of learning and an end in itself and adopted approaches they thought were necessary to get a “good grade” in the course. Long-term mastery learning was secondary to performance. For example, some students suggested they did not seek to learn molecular aspects of Course 1 at a mastery level because they did not initially understand the value of learning about nutrient structures or metabolic pathways, which seemed like isolated, unimportant details that would not be relevant to their planned career pathway. Rather, they crammed to memorize the discrete details they thought would be on an exam. They focused on the instructor’s slides, outlines, study guides, and their own class notes, but they did not use the textbook or other resources to develop a *deep*er understanding. They did not usually participate in study groups for the course to discuss the material outside of class or spend extra time writing narratives for themselves, as they did not believe these methods were necessary to do well.

Some students changed their study approach after they were able to identify what the instructor expected or gain an understanding of what exams would be like, typically after the first or second exam. Many modified their approaches through the semester from one exam to the next to find methods that worked. This was a common pattern of behavior. This adoption of a performance orientation and ability focus rather than a learning orientation and mastery focus is common and consistent with patterns previously described.[49]

Most students interviewed did well in Course 1, despite adopting *surface* approaches to learning. The mean final grade for students in Course 1 was a B+, but there was a wide (>30 percentage point) range of scores. Students with *surface* approaches who achieved higher grades seemed take a more strategic approach or put more consistent effort into studying and stayed on top of their assignments, yet their study activities still did not specifically incorporate aspects of a *deep* approach, such as integration, reflection, or application. In many cases, this was sufficient to achieve the grades they desired on exams that were primarily comprised of multiple-choice, matching, and fill in the blank, and short answer essay questions.

Of the nine students who adopted *deep* approaches to learning in Course 1, only two were traditional undergraduate students. Two were adult students who returned to academia to complete an undergraduate degree after deciding to change careers (to dietetics). Five were students who had previously completed a bachelor's degree and were taking the course in preparation for graduate training in nutrition. All nine of these students had a history of academic success. They had more *coherent* conceptions of learning and of nutrition as a science. They were high performers in Course 1 who also spent time reflecting and integrating the material outside of class and were individuals who were able to communicate their understanding of the material, e.g. in class, study groups, orally and/or in writing. These students were more prepared to learn when Course 1 began.

Most students developed more *coherent* conceptions of learning and nutrition during Course 1. However, 48% of students entering Course 2 still had a *fragmented* conception of nutrition as a science. After completing Course 2, all 100% of students interviewed had a *coherent* conception of nutrition as a science. Several students reflected on their program and their academic development and suggested they did not develop *coherent* conceptions or *deep* approaches until nearly the end of Course 2, and they had not developed an appreciation for their major until the end of the course after studying for and taking the final comprehensive exam. Yet, many students transitioned from a *surface* to *deep* approach to learning from Course 1 to Course 2, and a large proportion of students (81.5%) adopted a *deep* approach to learning in Course 2. Many of these students suggested they had developed intellectually and academically and/or their appreciation for the scientific aspects of nutrition increased during Course 1.

However, most students said they began changing their approach *after* starting Course 2, having realized it was necessary keep up with the material and to get the grades they wanted on assessments, which required a *deep*er, more integrative understanding of the topics assessed and extended explanation of topics. For Course 2, students using a *surface* approach tended to have poorer scores on exams, and students who adopted a *deep* approach tended to have higher scores on exams. They still focused on the instructor's slides, outlines, study guides, and their own class notes, but they also used the textbook and other resources to develop a *deep*er understanding, worked with other students in small groups, and attended recitations for the course to discuss the material with classmates outside of class. They developed detailed diagrams and wrote narratives for themselves to study.

The fact that students developed more *coherent* conceptions and transitioned to *deep* approaches to learning from Course 1 to Course 2 is a positive outcome, reflecting their persistence as they proceeded in their courses. They began to develop better study skills and understanding of the material and concepts in their major. However, this also reflects needs among students, that could be addressed earlier in the program—since many students did not have a *coherent* understanding of what was required to learn in Course 1 and/or did not adopt a *deep* approach, which are both associated with higher quality learning outcomes.

Study limitations, strengths, and implications for future research and practice

The same limitations described in chapter 3 apply to this study, which was limited to data derived from interviews from the same participants. However, despite these limitations, robust relationships were identified. In this study, a *fragmented* conception of nutrition was associated with a *surface* approach to learning, and both were associated with poorer performance outcomes. A *coherent* conception of nutrition as a science was associated with a *deep* approach to learning, and both were associated with better performance outcomes. Also, like before, these relationships were consistent with data from previous studies in other fields, which indicated a student's conception of a discipline can influence the approach they adopt to learn it. These relationships would likely persist and be amplified among a broader group of students in these and other courses.

Again, although it is beyond the scope of this study, the ways we can affect/change how students conceive of nutrition and how they go about learning it will be an important subject for future research and practice. One method to assess these issues will be to develop and deploy surveys to evaluate a broader population of students' conceptions and approaches to learning throughout their academic program, beginning with entry surveys during courses and seminars. These could be fine-tuned and validated for nutrition students in programs at other universities. Additionally, steps could be taken to help students develop more *coherent* conceptions and to adopt *deep* approaches to learning throughout their program, which may ultimately facilitate their learning outcomes and better prepare them for graduate training, careers in nutrition, and to be experts in nutrition who can solve problems.

Future research is also necessary to explore students' perceptions of other course and program needs at different stages of the curriculum, changes that would improve learning, what would better prepare students for their nutrition science courses, as well as characteristics of an excellent instructor, appropriate expectations for instructors and students, and what an instructor could do to increase a students' expectations for themselves in a course. Ultimately, developing a better understanding of students' beliefs and behaviors related to learning will help educators to more effectively address their learning needs.

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CHAPTER 5. SYNTHESIS AND FUTURE WORK

Summary of major findings

The purpose of this dissertation was to explore determinants of learning among students in two in upper-level nutrition science courses at Colorado State University (CSU) with an overarching objective of generating knowledge that can ultimately be used to improve student learning. Several major findings were described; a summary is enumerated below:

1. Learning outcomes and performance were positively associated with:
   - General academic aptitude (computed index) (Chapter 2).
   - Specific academic aptitude (GPA and grades in prerequisite courses) (Chapter 2).
   - Prior knowledge in biology, chemistry, physiology, and nutrition (Chapter 2).
   - *Autonomous* motivations for studying nutrition (Chapter 3).
   - *Coherent* conceptions of nutrition as a science (Chapter 4).
   - *Deep* approaches to learning in either course (Chapters 3 and 4).

2. Most students adopted *surface* approaches to learning in Course 1 and *deep* approaches to learning in Course 2, and most students who completed both courses transitioned from *surface* to *deep* approaches from Course 1 to Course 2 (Chapters 3 and 4).

3. Most students in Courses 1 and 2 had intrinsic motivations for studying aspects of nutrition that were different from the nutrition science topics covered (Chapters 3).

4. *Controlled* motivations were associated with *surface* approaches to learning in both courses and *autonomous* motivations were associated with *deep* approaches to learning in both courses. Most students developed more *autonomous* motivations as they proceeded through Courses 1 and 2 (Chapter 3).

5. Most students began Course 1 with a *fragmented* conception of nutrition and began Course 2 with a *coherent* conception of nutrition. All students completed Course 2 with a *coherent* conception of nutrition (Chapter 4). Most students who completed both courses transitioned from a *fragmented* conception of nutrition to a *coherent* conception of nutrition from Course 1 to Course 2 (Chapter 4).

6. Motivations and conceptions were not the only influences on a student's approach to learning. Rather, they selected the approach they perceived was required to "get a good grade" in the particular course (Chapter 3).

Implications for Research and Practice

The first chapter of this document summarized the need for experts in nutrition who are equipped to solve complex issues like obesity and cardiometabolic disease. However, this dissertation has confirmed there are learning needs among students in upper-level nutrition science courses, as were originally described by instructors (at CSU and elsewhere) and observed in pilot research—too many students are entering these courses with inadequate cognitive prerequisites, have *fragmented* conceptions of the subject of nutrition as a science and *controlled* motivations for studying, and adopt a performance orientation and ability focus rather than a learning orientation and mastery focus. These characteristics are associated with the adoption of *surface* rather than *deep*, meaningful approaches to learning and poorer learning outcomes. Few students enter Course 1 prepared to learn at a mastery level or to develop expert skills in nutrition science.

Important aspects of students' progress through Courses 1 and 2 were described in Chapter 2 and 3. Most students matured academically as they were completing these courses in their junior and senior years, and they developed more *coherent* conceptions of nutrition, shifted from *controlled* to *autonomous* motivations for learning nutrition, and eventually began adopting *deep* approaches to learning by the end of Course 2. These were positive transformations. However, for many, by the time they made these shifts, they were nearly finished with their nutrition science coursework and the nutrition program as a whole, and there was little time left to benefit from these transitions in their academic program.

Chapter 2 and 3 were limited to 39 interviews of students who volunteered to participate. As a group, these students had above-average GPAs and scores on prior knowledge tests and in Courses 1 and 2. However, this was a sample that seemed representative of nutrition students who take these courses. Since few students from other majors participated, additional data may be necessary to better represent their views.

This group of interviewees included nine students who adopted *deep* approaches to learning in Course 1. It also included seven students who became study group leaders or teaching assistants for either Course 1 or Course 2—interestingly, not all seven students adopted *deep* approaches in Course 1. Several changed their approaches after Course 1. Eventually, all of them had *autonomous* motivations (including components of both intrinsic and extrinsic motivation), *coherent* conceptions, and adopted *deep* approaches and learned at a mastery level sufficient to apply their understanding to real-world problems. Many of these students became examples for their peers to emulate.

A goal of future research would be to develop instruments to assess a larger population of students' prior knowledge, conceptions of nutrition as a science, motivations for studying it, and approaches to learning. These instruments could be useful at other universities, as well. It would be important to assess and contrast different groups of nutrition majors and students from other majors who take nutrition courses, including introductory nutrition courses that provide foundational knowledge in nutrition science through upper-level courses in nutrition science, as well as community nutrition, lifecycle nutrition, and medical nutrition therapy.

Another research goal would be to develop and deploy a broad analysis of course and program needs. In 2012, the Associate Provost at the university suggested that courses should be designed using a learning ecologies approach that takes a broad view of a student path through their academic curriculum from the time they enter until they are "successful graduate and contributing members of society."[1] The program of study would need to include majors, minors, and concentrations that include required courses. The first step would be to assess objectives for students completing the program, which define what students should be able to do when they complete each course and when they get to the end of the program, and to ensure there is adequate overlap in objectives among courses. A practice goal would be to refine existing objectives and develop any needed objectives to create links across the courses and ensure the objectives build on one another from the beginning to the end of the program. It would also be important to develop objectives defining what nutrition students should be able to do when they complete their various courses in biology, chemistry, and physiology that provide foundational knowledge for nutrition courses. Individual students' proficiency in meeting the objectives could be evaluated through their academic curriculum to monitor their progress. Also, proficiency in meeting the objectives could be compared across various groups of students to identify unique needs or to evaluate the effectiveness of curricular modifications.

The next steps would be to assess content and instruction across the curriculum and other related opportunities for learning about nutrition as a subject, what the major entails, what will be covered in nutrition courses, and various career pathways for their specific program of study. Based on the learning ecologies approach,[1] this would require assessment of instruction and materials that are part of each course, learning programs such as tutoring, study groups, academic skills workshops, or other critical thinking activities and assignments that exist outside of courses, as well as undergraduate research, service learning, internships, mentoring programs, academic advising, and any other learning communities that would potentially influence students' nutrition knowledge, conceptions, motivations, and approaches. This would provide information about what students are learning and when they are learning it, which could help identify needs and guide changes to the curriculum and/or other learning environments. This information may also help with the development of clearer, more intentional links among courses and other high impact learning experiences that may help students develop a more *coherent* understanding of their area of study, as well as appropriate knowledge in the courses, motivations, and approaches.

Specific changes could be made to address each of these variables. An important goal would be for students to develop more *coherent* conceptions of nutrition as a science earlier in their academic program. This could be addressed through academic advising and introductory nutrition courses in the program to help students understand what to expect when they get to upper-level courses, or from advanced training or careers in nutrition. For example, students joining the program could be given information about previous graduates during introductory courses or in freshman seminars. Graduates could be interviewed and asked to provide more information about how they apply what they learned in their academic training in their day-to-day work, or to reflect on what they learned, what was useful, and what their suggestions would be for current students studying nutrition. It would be beneficial provide examples of recent students who are now working in dietetics (e.g., in clinical or community settings, in private healthcare in an office or outpatient care, who have specialties in counseling, sports nutrition, or pediatric nutrition, or who work in academia or government).

Many nutrition students may not be specifically interested in dietetics, but other health professions, or they may be interested in working in public health nutrition, education and research, or journalism. The purpose of listing all of these career options is to emphasize that in all of these scenarios, it is critical for students to have a strong understanding of nutrition science. Such information would be easily incorporated in marketing materials or within introductory courses to provide students a clearer understanding of the science of nutrition, as well as the overall learning objectives for their program, what it will be like, the types of content that will be covered, and how they might use the information they learn. Instructors for introductory courses could include previews of content that will be covered in more detail in upper-level courses or in research or a clinical setting, or in public health. This will necessitate conversation among instructors about the topics discussed in each course through the curriculum and what the various career pathways are in their areas of expertise.

An important goal is for students to shift from a performance orientation and ability focus to a learning orientation and mastery focus.[2,3] However, many students suggested that although they valued long-term learning, that it was often not possible because getting a good grade was more important when taking courses. Some described the situation as a conflict of interest for them because they felt they could not spend the extra time required to develop an integrative understanding of nutrition unless the course demanded it. To ensure they got a good grade, they would instead focus on the material the instructor covered in class, which they believed would be on the exam. Once they had completed the exam, they would shift their focus to other courses.

This is congruent with the situation Becker described fifty years ago in "Making the grade: The academic side of college life"—that grades are a universally defined academic currency—something a student can acquire that is of perceived value to them, to their parents, faculty, administration, and are a determinant of future success or failure.[4] On the other hand, students do not always value learning as much as grades or as much as learning is valued by their instructor. He suggests students are captives of a performance-based system and there can be a conflict between grades and learning because students believe that obtaining good grades on tests and in courses is a reflection on their maturity and ability to do their work and meet their obligations as students.[4] Some students have additionally suggested that spending time trying to learn the subject material beyond what is taught by the instructor can interfere with getting a good grade on an exam. One of suggested the following:

> *There are a lot of courses where you can learn what's necessary to get the grade and when you come out of the class you don't know anything at all. You haven't learned a damn thing really. In fact, if you try to really learn something, it would handicap you as far as getting a grade goes...(p59)."*[4]

The way a course is designed and how an instructor goes about teaching can influence how students perceive and approach learning, how much they learn, and the quality of their learning. Research has indicated it is possible for instructors to promote intrinsic interest, motivation, and engagement among students by supporting their autonomy.[5–8] For example, when students have an accurate understanding of course goals and the complexity of its tasks, they are able to self-monitor and control their approaches to learning. However, if students do not have sufficient prior knowledge and a *coherent* understanding of the subject matter covered in a course or its goals, they may initially make misjudgments about the course demands and what are appropriate approaches to learning. In this case, explicit instructions about the course goals and the complexity of its tasks may be necessary to promote *autonomous* learning, particularly in the initial stages of the learning process in a course, consonant with early course feedback (graded or otherwise).

Students feel more *autonomous* when they perceive low teacher control and high autonomy support, when they feel the work is purposeful and interesting and is at an appropriate level of complexity, and when they feel teachers are responsive and supportive and provide regularly/timely feedback on their progress through the course.[5–8] A simple example is developing different versions of content and assessments to provide students choices that are interesting to them. In these situations, students are more likely to engage in *deep*-level processing of information and be more persistent in their study efforts. Instructors should also consider beneficial aspects of both intrinsic and extrinsic motivations that are autonomy supportive, as students can combine these factors for an optimal balance of learning and performance.

To promote *deep*, mastery learning among students, instructors should develop and deploy active learning activities—instruction and assessments that require students to exert cognitive activity to construct meaning and develop mental models,[9] integrating new and prior knowledge.[10–22] Many of the students interviewed in this study suggested they found Courses 1 and 2 more interesting when instructors included more application, real world examples, problems, and case studies. Overwhelming evidence indicates replacing conventional, passive lectures with classroom activities that engage students in active learning[17] can promote mastery learning,[15] substantially improve performance, reduce failure rates, and reach a wider range of students.[1, 4, 6–14] In a recent meta-analysis of 225 papers, benefits of active learning (vs. lecture only) were seen across disciplines, course levels and experimental methodologies, with lower average failure rates (22% vs. 34%) and higher performance on exams (effect size = 0.47) and concept inventory (CI) tests (effect size = 0.88).[23] Yet, despite the importance of nutrition as a science discipline, active learning in nutrition science courses has not been studied. This may be an important area for future research.

Examples of active learning may include a variety of critical thinking assignments that replace or supplement traditional assessments, such as in-class collaborative activities like peer instruction, and team-based learning, and other individual or group activities that include more problem-solving and written and oral communication to provide students the opportunity to apply their understanding of what they are learning in their nutrition science courses to critically evaluate information various sources and communicate to different audiences.

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APPENDIX A: INTERVIEW: MOTIVATIONS AND APPROACHES

Before taking the course:

- What interested you in your area of study and how has this changed since you began?
- You have you taken Course 1 and/or 2 and other science courses (biology, chemistry, biochemistry, physiology). What related courses have you taken? Which have been helpful?
- What will you do with what you learn/have learned in Course 1 and/or 2?
- What types of things motivate you to study for Course 1 and/or 2?
  - Training for a job?
  - Learning?
  - To apply it to your health?
  - To help others?
  - Grades? To perform well on assessments?
  - What would you consider an ideal outcome in Course 1 and/or 2?
  - Based on your goals, do you think you study as much as you should for this course?
  - Has your performance in the courses reflected this?
  - How do you envision using what you learn/learned, e.g. in 5 years?

After taking the course:

Describe a typical study session in Course 1 or 2. Probes:

- **WHEN**: How often before/after lecture? Before test?
- **HOW LONG:** amount of time spent?
- **WHAT:** What does the studying include?
- Reading notes? Book?
- Writing notes summaries, essays?
- What other resources do you use? (Objectives, practice tests, notes from other classes, other books, student led study groups, private tutoring, teaching assistants' office hours, instructors' office hours, lecture recordings, online videos or other multimedia resources, other activities outside of class)?
- What helped or hindered learning?
- How did you learn these methods?
- **WHO:** Do you study by yourself, with one or more people, or both?

APPENDIX B: INTERVIEW: CONCEPTIONS AND APPROACHES

Before taking the course:

- **What is nutrition about?** Probe about why, based on previous experiences.
- **What did you think you needed to do to learn nutrition in this course?** Probe related to course student is about to begin — Course 1 and/or 2.

After taking the course:

Describe a typical study session in Course 1 or 2. Probes:

- **WHEN**: How often before/after lecture? Before test?
- **HOW LONG:** amount of time spent?
- **WHAT:** What does the studying include?
- Reading notes? Book?
- Writing notes summaries, essays?
- What other resources do you use? (Objectives, practice tests, notes from other classes, other books, student led study groups, private tutoring, teaching assistants' office hours, instructors' office hours, lecture recordings, online videos or other multimedia resources, other activities outside of class)?
- What helped or hindered learning?
- How did you learn these methods?
- **WHO:** Do you study by yourself, with one or more people, or both?

Now, what do you think you need to do to learn nutrition? Probes:
Details about specific study methods, resources, organizational skills, class attendance, interpersonal interactions, self-efficacy, motivations, values, and experiences

Now, what do you think nutrition is about? Probes:

- Why is this your perception?
- What changed?
- What is the same?
- What did you learn?
- Feedback?

APPENDIX C: NOTICE OF APPROVAL FOR HUMAN RESEARCH

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins, CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	December 21, 2014
TO:	Melby, Chris, 1571 Food Sci and Human Nutrition Peth, James, 1571 Food Sci and Human Nutrition, Pagliassotti, Michael, 1571 Food Sci and Human Nutrition
FROM:	Swiss, Evelyn, Coordinator, CSU IRB 2
PROTOCOL TITLE:	Peth Dissertation Phase 1: Needs Assessment for Courses in the Department of Food Science and Human Nutrition at CSU
FUNDING SOURCE:	NONE
PROTOCOL NUMBER:	14-5403H
APPROVAL PERIOD:	Approval Date: December 18, 2014 Expiration Date: October 25, 2015

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Peth Dissertation Phase 1: Needs Assessment for Courses in the Department of Food Science and Human Nutrition at CSU. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Swiss, Evelyn

Swiss, Evelyn

Approval is to recruit up to 100 participants with the approved recruitment and consent. The above-referenced project was approved by the Institutional Review Board with the condition that the approved consent form is signed electronically by the subjects and each subject is emailed a copy of the form. NO changes may be made to this document without first obtaining the approval of the IRB. NOTE: Please submit an amendment via eProtocol for additional phases of this research.

Approval Period:	December 18, 2014 through October 25, 2015
Review Type:	EXPEDITED
IRB Number:	00000202

APPENDIX D: INTERVIEW RECRUITMENT MATERIAL:

The co-PI is a teaching assistant for FSHN 350 and FSHN 470. With the permission of current instructors, a verbal announcement such as the following will be made in class:

Hello, my name is James Peth, and I am a TA for your class and a PhD student in Food Science and Human Nutrition at Colorado State University (CSU). For my research project, I'm planning to interview students, instructors, and administrators in FSHN to learn about what they think the main needs are related to our nutrition courses and program. By the end of today, you will receive an email from me asking you if you would like me to send you more information about the study. If you would, simply respond to the email, and I will email back with a consent form with more information and inviting you to participate if you are interested.

For participants I already know, such as faculty in our department, fellow teaching assistants, and former students I have known from working as a teaching assistant:

I will ask these individuals either in person or by email whether they would like for me to send them information about my project. If they say yes, I will send them an email with the same PDF (PethDissertationPhase1-ConsentForm.pdf)—with more information and inviting them to participate.

Dear FSHN XXX (350 or 470) Student,

As I mentioned during my announcement in class today, for my PhD research project, I'm planning to interview students, instructors, and administrators in FSHN to learn about what they think the main needs are related to our nutrition courses and program. If you would like me to send you more information about the study, simply respond to this email, and I will email back with a PDF named PethDissertationPhase1-ConsentForm.pdf with more information and inviting you to participate if you are interested.

Sincere thanks,

James

James A. Peth, M.S., M.P.H.
James.Peth@colostate.edu
PHONE: (970) 631-8690

The following footer was added to the email:

You are receiving this email because you are registered for FSHN XXX. Our mailing address is:

James Peth
101a Gifford Hall
Colorado State University
Fort Collins, CO 80523

APPENDIX E: CONSENT TO PARTICIPATE IN A RESEARCH STUDY AT COLORADO STATE UNIVERSITY

TITLE OF STUDY: Peth Dissertation Phase 1: Needs Assessment for Courses in Food Science and Human Nutrition at CSU

PRINCIPAL INVESTIGATOR: Chris Melby, D.Ph., Professor, FSHN, Chris.Melby@colostate.edu, (970) 491-6736

CO-PRINCIPAL INVESTIGATOR: James Peth, MS, MPH, PhD candidate, FSHN, jpeth@colostate.edu, (970) 631-8690

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You are invited to participate in a research study that is part of my PhD project in Food Science and Human Nutrition (FSHN) at Colorado State University (CSU). I am asking you to participate because you are a student, instructor, or administrator in FSHN and I believe your views will help me understand these issues.

WHO IS DOING THE STUDY? This study is being conducted by Dr. Chris Melby, a faculty member, and James Peth, a graduate student, in the Department of Food Science and Human Nutrition at Colorado State University.

WHAT IS THE PURPOSE OF THIS STUDY? The goal for this research is to learn about student, instructor, and administrator perceptions of needs related to FSHN courses and the FSHN program at CSU.

WHERE IS THE STUDY GOING TO TAKE PLACE? Interviews will take place in Gifford 101b or other mutually convenient location and at a convenient time or if you prefer, the interview may be conducted via phone or Skype.

WHAT WILL WE DO IN THE STUDY AND HOW LONG WILL IT TAKE? As part of your participation in this study, I will spend time with you and talk with you on 1-3 occasions of approximately 60-90 minutes over the course of a number of weeks. I will first talk with you by yourself about your experiences in FSHN courses and the program and ask you to discuss your thoughts about course needs, e.g. related to technology, course materials and resources (lecture slides, quizzes, exams, projects, and the textbook), instruction, and what you think about the subject matter in FSHN courses and their prerequisites, and your views and experiences on studying and learning. During or after this interview I may also ask you to participate with other students in a focus group that will be held on a later date. This may be the last part of the study, but my plan is to talk with each person I interview to see if it might be helpful for me to talk to some or all of you more. The most important thing for you to remember while you are participating in this study with me is that there are no right or wrong answers to the questions I ask you. All I am looking for is your opinions, ideas, and/or feelings, and if I ask you to tell me more, or explain your answer, it is because I want to be really sure I understand what you are telling me.

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY?
You should not participate if you are under 18 years of age.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? While there may be no direct benefit to you associated with participation in this research, some potential benefits are that (through activities of self-reflection and voicing answers to questions) you may learn new things about yourself and your learning, you might enjoy sharing your ideas and feelings about your courses and program with me and others like you, and you might even make friends with other participants, improve your study skills, and/or find out about additional resources. In addition, your participation in this study may help me and others better understand ways to improve the courses.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? There are no known risks. However, for some people, questions requiring self-reflection may be sensitive. To minimize risk, you are encouraged to skip any questions that cause you any distress. It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential risks.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled. This is your decision. I respect your time and wishes, and if you decide to stop doing this study, your decision will also not affect any future contact you have with me, the Department of Food Science and Human Nutrition, or Colorado State University.

Page **1** of **2** Participant's initials _______ Date _______

WHO WILL SEE THE INFORMATION THAT I GIVE? The PI and I will be the only people who know you are participating in this study. Any time I use the information you give me, I will identify you with a fake name (if you would like you can decide what name we use for you). When I interview you, I would like your permission to take notes and digitally record the audio to remind me what we discussed. I will be the only one allowed to listen to these recordings and view these notes, and when I am not using them they will be kept in a secure room on a password-protected device. Audio recordings will be transcribed soon after the interview and then the recording will be deleted. Once I have summarized my notes from the interview, I will ask you to review what I have written to ensure I have accurately represented you. When I write about the study to share with others, I will write about the combined information *I* have gathered, no identifiers will be linked to the data. I may be asked to share the research files for audit purposes with the CSU Institutional Review Board ethics committee, if necessary.

WHAT IF I HAVE QUESTIONS? Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, James Peth, M.S., M.P.H. at james.peth@colostate.edu; 970-631-8690. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970-491-1553. We will give you a copy of this consent form to take with you.

Sincerely,
Co-PI: James Peth, MS, MPH
PhD candidate, FSHN
James.Peth@colostate.edu
(970) 631-8690

PI: Chris Melby, D.Ph.
Professor, FSHN
Chris.Melby@colostate.edu
(970) 491-6736

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 2 pages.

[phone or online interview only] By typing your name and date on the consent form, and returning to the researcher via email, you will indicate that you have read the information stated and willingly agree to participate in this study.

____ _____________________
Signature of person agreeing to take part in the study Date

____
Printed name of person agreeing to take part in the study

____ _____________________
Name of person providing information to participant Date

____
Signature of Research Staff

Do you give permission for the researchers to contact you again in the future to follow-up on this study or to participate in new research projects? Please initial next to your choice below.

☐ Yes ______ (initials)
☐ No ______ (initials)