ASSESSING UNDERGRADUATE SUSTAINABILITY KNOWLEDGE AT CALIFORNIA
POLYTECHNIC STATE UNIVERSITY

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ABSTRACT

Assessing Undergraduate Sustainability Knowledge at California Polytechnic State University

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Sustainability education has become an important focus of many higher education institutions (HEIs), with the inclusion of many sustainability-related learning objectives for undergraduate students. As sustainability is a new, rising discipline, an increasing number of HEIs have made efforts to assess their teaching and learning effectiveness. However, most assessments fall short in determining the relationship between sustainability curriculum and the impacts on leaning outcomes. Therefore, this study aims to assess the impact of academic setting, specifically of a structured sustainability curriculum, on undergraduate sustainability knowledge, as well as analyze the implications of perceived barriers and opportunities to implementing sustainability into academics. Using California Polytechnic State University, San Luis Obispo (Cal Poly) as a case study, this research emphasizes the results from an online sustainability knowledge survey administered to honors students who take a structured sustainability knowledge curriculum and general students who are not required to take any sustainability courses, but can elect to do so. The study reveals that honors students have significantly higher sustainability knowledge scores (SKS) after taking a structured sustainability curriculum, but also reveals that those post-curriculum SKS of honors students are not significantly different from that of general students after taking 3 courses. The results further indicate that honors students that take a 3-course sustainability curriculum do not score significantly higher than those that take a 1-course sustainability curriculum. However, general students that take 3 sustainability-related courses score significantly higher than general students who take 0, or 1 to 2 sustainability-related courses. These results suggest that unlike honors students, general students need to take a minimum of 3 courses in sustainability to achieve significantly higher SKS. The findings also

show that the SKS of students do not significantly differ across colleges and that the SKS of students in the general population have the potential to improve, suggesting that additional sustainability education can benefit all students. Additionally, the analysis of student perceptions reveals that students support the integration of sustainability into existing courses, which can help address the main perceived barriers of time constraints, lack of course promotion, and lack of relevance to major. Ultimately, the results suggest that university-level decision-makers should focus efforts on integrating sustainability into existing courses, increasing the opportunity for all students to take at least 3 sustainability-related courses during their undergraduate experience. Such efforts would be a first step in developing sustainability education at an HEI and would help achieve significant improvement in undergraduate student SKS.

Keywords: Sustainability Education, Knowledge Assessment, Higher Education Institutions, Sustainability Curriculum

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INTRODUCTION

Within the past few decades, there has been an increased focus on the environmental, social, and economic states of the world. These are all interconnected areas of concern, known today as the three main pillars of sustainability, or sustainable development. This increased global focus on sustainability can be seen through the work of the United Nations (UN) over the years, which has developed a comprehensive action plan to address sustainable development (United Nations, 1992) and has outlined specific Sustainable Development Goals to ensure that all people enjoy peace and prosperity by 2030 (United Nations, 2015). While the notions included in sustainability are not new, especially the emphasis on the environment and natural resources which were the focus of the environmental movement in the 1960s and 70s (*The Modern Environmental Movement*), the official concept of sustainability has a relatively short history within western science. It was not until 1987 that the official concept of "sustainability" was coined, in which the UN specifically defined the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). This widely used definition encompasses a well-supported emphasis on the environment, but uniquely, through the social and economic context of development. Over the years, sustainability has developed into a complex concept that focuses on the overall wellbeing of future generations by emphasizing efforts to foster and sustain social equity, global environmentalism, and economic vitality. While global sustainability is a complex goal to achieve, it is crucial in order to ensure the future survival and long-term success of human society and the planet as a whole.

In 1992, the UN recognized that global education, training, and public awareness were all critical tools in the transition towards sustainable development and a more sustainable future (United Nations, 1992). Connecting multiple concepts, sustainability is applicable to and can be

argued as important in every discipline. As every student at a university or Higher Education Institution (HEI), regardless of academic discipline or career focus, has the capacity to be an agent of social change, all students should learn to contribute to a more sustainable world (Buckler & Creech, 2014). Further, as universities and HEIs have an immense reach on many students (Buckler & Creech, 2014), they have an innate responsibility to develop sustainability literate graduates who will become a new generation of sustainability literate adults and global citizens (Koehn & Uitto, 2014). Increasing the amount of sustainability literate, global citizens in all societal realms can help foster creative, sustainable solutions to the world's interconnected problems. Sustainability literacy refers to "the knowledge, skills, and mindsets that allow individuals to become deeply committed to building a sustainable future and assisting in making informed and effective decisions to this end" (United Nations, 2018). Knowing that they are major agents of social change (Horvath et al., 2013), with the unique ability to shape the minds of the students through university efforts (Stephens et al., 2008), many HEIs have already proclaimed a dedication to sustainability and education for sustainable development, signing declarations and encouraging faculty, staff, and students to attend sustainability-focused conferences. However, it is commonly argued that such symbolic notions need to be met with tangible efforts toward implementing academic and institutional change (del Mar Alonso-Almeida et al., 2015; Everett, 2008; Moody & Hartel, 2007). A growing number of efforts to expand sustainability principles and to implement sustainability within academics have taken various forms within education and research, with a common emphasis on implementing sustainability education within academic curriculum (Lidgren et al., 2006; Lozano et al., 2013). In order to assess if such curricular efforts are meeting sustainability learning objectives, such as developing sustainability literacy, HEIs need to report their progress and assess the impact of the curricular changes. As the first component to developing full sustainability competency (Sterling, 2013) and as necessary to generate sustainability related action (O'Brien, 2007), sustainability knowledge is often the aspect of sustainability literacy that HEIs begin to assess.

Prior research and assessment have shown that a variety of curricular efforts can generally help improve various aspects of undergraduate student sustainability literacy, such as sustainability knowledge. For example, the inclusion of a sustainability module in an engineering curriculum increased general awareness of sustainability (Bielefeldt, 2011). Also, other findings indicate that at least one course in sustainability education can help students develop greater sustainability knowledge (Levy & Marans, 2012), and that students who take 3 or more sustainability courses have significantly higher levels of sustainability knowledge than those who take fewer courses (Horvath et al., 2013). However, even if many sustainability-related courses are offered, students who elect to take sustainability courses are most likely already interested in the subject, meaning that sustainability education is not reaching students who do not have prior interest in the subject. A structured sustainability curriculum is a curricular effort that, to a certain extent, controls for student interest in sustainability by requiring all students to take sustainability courses despite prior interest level. Despite the previous research regarding the impact of separate courses and certain curricular efforts, the specific impact of a structured set of courses in a sustainability curriculum, on sustainability knowledge is relatively unexplored. As a results, current literature lacks specification of ideal curricular design to meet sustainability learning objectives at HEIs.

Additionally, studies have found variation in student sustainability or environmental knowledge across disciplines or colleges. For example, multiple studies have found that students enrolled in colleges with a traditionally strong academic focus on sustainability concepts have higher sustainability or environmental knowledge levels than those in other colleges. Students enrolled in the College of Agriculture and Natural Resources at the University of Maryland (Horvath et al., 2013), and the College of Agriculture at Iowa State University (O'Brien, 2007), obtained the highest or second highest mean knowledge score compared to students enrolled in other colleges at each HEI. However, variations in significant results of these studies lack clarity regarding the true impact of students' college enrollment on sustainability knowledge.

Understanding how student sustainability knowledge levels vary across disciplines and colleges can help HEIs determine where to target sustainability education initiatives. Also, while understanding institutional barriers can help HEIs determine ways to overcome sustainability challenges (Blanco-Portela et al., 2017), research regarding barriers to and opportunities for implementing sustainability in academics, as it relates to academic setting, is minimal. Academic setting refers to student learning environments and academic characteristics, such as program, college of enrollment, or year in school.

This research aims to address these knowledge gaps, using California Polytechnic State University in San Luis Obispo (herein referred to Cal Poly), as a case study for analyzing the impacts of a set of courses in a structured sustainability curriculum and other aspects of academic setting on student sustainability knowledge at an HEI. Again, while sustainability knowledge level does not encompass all aspects of sustainability literacy (Hartman et al., 2017), it provides a foundation to begin to assess the potential and ability of students to become sustainability literate graduates. Also, while Cal Poly does not currently require sustainability courses to fulfill graduation requirements as part of the core general education curriculum, a small subset of students who accept the offer to be in the Honors Program are required to take a structured sustainability curriculum as part of their graduation requirement. As Honors programs typically have innovative academic programs, they represent an opportunity to compare results of differing curricula (Reihman et al., 1990), such as in the unique case of sustainability curricula and sustainability knowledge scores (SKS) at Cal Poly. Additionally, as an HEI with six different colleges, separating different disciplines, Cal Poly allows for further analysis regarding the impact of college enrollment on sustainability knowledge. This case study also provides the opportunity to expand upon previously published research, which is the foundation of the current study (See Figure 1), regarding student perceived barriers to and solutions for implementing sustainability into academics (Pompeii et al., 2019).

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Previous Literature
- Sustainability education at HEIs

Prior Study at Cal Poly

- General sustainability knowledge levels
- Perceived barriers to and solutions for implementing sustainability into academics
- Semi-structured interviews
- Small sample size

(Pompeii at al., 2019)

Current Study at Cal Poly

- Quantified sustainability knowledge
- Barriers to and opportunities for implementing sustainability into academics
- Impact of structured sustainability curriculum on sustainability knowledge

Administration of online survey to a large sample of general and honors students

Organization, sorting, and coding of data

Analysis of data and interpretation of results

Figure 1.Conceptual diagram of the general approach used in this research. Previous literature and a prior study at Cal Poly were used to inform the current study. The focus of the current study and steps taken to conduct the research are also provided.

To analyze the impacts of academic setting on undergraduate sustainability knowledge and perceived barriers to and opportunities for implementing sustainability into academics, this study focuses on a large-scale survey administered to those in a structured sustainability curriculum and those not, honors and general students respectively. Specific research questions and hypotheses are provided to address specific knowledge gaps and assumptions (See Table 1). Survey data from both honors students and the general student population were collected and analyzed in an effort to address the knowledge gaps (See Figure 1). Ultimately, the aim of this research is to understand the overall implications of the findings on university-level decision-making regarding sustainability education, and in the materialization of the university's theoretical dedication to sustainability in academics for all students. The results of this study can

help decision makers plan and implement an action plan for tangible change in the curriculum to

help increase undergraduate student sustainability knowledge.

Table 1. List of research questions and associated hypotheses tested and addressed in this research.

Research Question	Hypothesis
RQ1: Which factors of academic setting impact undergraduate student sustainability knowledge and what is the impact?	H_1: Students who take a structured sustainability curriculum as part of the Honors Program have higher sustainability knowledge than those who do not.
	H_2: Students who take 3 or more sustainability courses have higher sustainability knowledge than those who take 1 to 2, or 0 sustainability courses.
	H_3: Students who are in the College of Agriculture, Food, and Environmental Sciences have higher sustainability knowledge than those in other colleges.
RQ2: How does academic setting impact student perceived barriers to and opportunities for implementing sustainability into academics?	H_4: Students who take a structured sustainability curriculum as part of the Honors Program do not perceive time and accessibility as main barriers to implementing sustainability into academics.
	H_5: Students who take a structured sustainability curriculum perceive implementing a sustainability GE as the best opportunity for implementing sustainability into academics.

Chapter 2

LITERATURE REVIEW

A Review of the Literature Regarding Sustainability Initiatives at Higher Education

Institutions

2.1 Context

In the past few decades, there has been an increased focus on the state of the environment, with many environmental problems, such as increased depletion of natural resources and climate change, coming to the forefront of public concern. In the United States, the modern environmental movement began in the 1960s and 1970s, with the publishing of Rachel Carson's *Silent Spring* in 1962 and the first Earth Day in 1970 (*The Modern Environmental Movement*). Along with environmental issues, however, the world has also increasingly faced issues with social and political unrest, cases of economic downturn, and continuous injustice and inequity. By the late 1980s, these global issues, from those emphasized through the environmental movement to the seemingly separate social and economic issues, became commonly addressed as interconnected problems. For example, in 1987, the concept used to show the connection of these problems, now known as "sustainability," was coined in the *Brundtland Report*, also known as "Our Common Future." In this report, the United Nations specifically defines the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). This definition encompasses a well-supported emphasis on the environment, but uniquely, through the social and economic context of development. Over the years, sustainability has developed into a complex concept that focuses on the overall wellbeing of future generations by emphasizing efforts to foster and sustain social equity, global environmentalism, and economic vitality. These three interconnected areas of concern, the

environment, society, and economy, have become known as the three main pillars of sustainability.

Connecting multiple concepts and pillars, sustainability is applicable to and can be argued as important in every field of work or discipline. The United States Environmental Protection Agency has acknowledged that sustainability is a priority interest for many organizations and recognized the importance of sustainability as a guiding influence in all realms of work (EPA, 2020). Additionally, in 1992, the United Nations recognized that global education, training, and public awareness were all critical tools in the transition towards sustainable development and a more sustainable future (United Nations, 1992). It is also acknowledged that each student, regardless of academic discipline or career focus, has the capacity to be an agent of social change. As a result, all students should be learning to contribute to a more sustainable world (Buckler & Creech, 2014). However, even though sustainability is theoretically applicable in every discipline and career, not many people are equipped with the tools to actually apply sustainability related practices in their fields of work. For example, studies between 1997 and 2001 found that only one-third of American adults in a variety of disciplines can pass a simple test of environmental knowledge, with a grade equivalent to a C or higher (Coyle, 2005), let alone specifically sustainability knowledge or having the ability to apply that knowledge. With sustainability stakeholders including climate scientists, non-governmental organizations, activists, and most importantly future generations (de Lange, 2013), it is important to target literacy and education efforts towards those that have time to change the future, this being the younger generation of students. As HEIs have an immense reach on millions of students (Buckler & Creech, 2014), they have an innate responsibility to develop sustainability literate graduates who will become a new generation of sustainability literate adults and global citizens (Koehn & Uitto, 2014).

Increasing the amount of sustainability literate, global citizens in all societal realms can help foster creative, sustainable solutions to the world's interconnected problems. Sustainability

literacy refers to "the knowledge, skills, and mindsets that allow individuals to become deeply committed to building a sustainable future and assisting in making informed and effective decisions to this end" (United Nations, 2018). However, to generate sustainability-related action, efforts must first aim to increase knowledge (O'Brien, 2007), as knowledge is the first component in developing full sustainability competency (Sterling, 2013).

2.2 Teaching Sustainability at Higher Education Institutions

Many HEIs have proclaimed a dedication to sustainability and to develop sustainability literate graduates. The described, unprecedented scale of linked social, environmental, and economic problems, have ultimately become at the center of the push for sustainability at HEIs (Horvath et al., 2013). While some universities have signed declarations and have attended sustainability-focused conferences, many simply do so to show symbolic and vague dedication to sustainability (Moody & Hartel, 2007). However, these vague, symbolic notions need to be met with actual, tangible efforts toward implementing academic and institutional change (del Mar Alonso-Almeida et al., 2015; Everett, 2008).

Sustainability initiatives and efforts are crucial at HEIs as it is commonly argued that HEIs and their students are major agents of social change and play a key role in the development of society as a whole (del Mar Alonso-Almeida et al., 2015; Lozano, 2010). Being significant stakeholders in the dissemination of knowledge throughout society (Stephens et al., 2008), HEIs have the ability to not only shape the education of the students, but also have the potential to influence the information being brought into society. With this being said, HEIs, as agents of social change with the ability to help shape the minds of young adults, possess the opportunity to advance global sustainability through university efforts and also have the opportunity to increase overall societal response to global change (Stephens et al., 2008). One way in which HEIs can foster sustainability literate graduates is by addressing sustainability at the operational and

curriculum level. At these levels HEIs can fill the need to provide students with the information necessary to help recreate the world to achieve a just and sustainable future (Cortese, 2003; Everett, 2008). Because of this unique capacity, HEIs have an inherent responsibility to take action and make tangible change (Koehn & Uitto, 2014), beyond the initial dedication and symbolic notions.

Because of the interdisciplinary and holistic nature of sustainability, providing sustainability education at HEIs can help show students that many disciplines overlap, and are not inherently siloed. By implementing environmental and sustainability initiatives for all students, HEIs can also reach further than those already in environmentally-specific disciplines (O'Brien, 2007). With the ability to see the interconnection of multiple disciplines, students can begin to use a systems thinking approach, or a holistic approach inherently fostered by the concept of sustainability, to solve more complex issues. With a foundation in sustainability, including interdisciplinary knowledge and skills, students ultimately have a better opportunity at becoming more well-rounded graduates.

Additionally, sustainability education is now considered essential for all graduates, as sustainability literacy aligns with many preferred graduate attributes (Winter & Cotton, 2012). This is despite a common misconception that sustainable development is separate from other HEI agendas, such as employability, enterprise, quality, recruitment, or internationalism (Sterling, 2013). For example, graduates that are well-rounded global citizens, with a foundation of sustainability literacy, correlate with graduates with high employability (Shiel et al., 2005). For HEIs, that historically have ongoing concerns about employability and the challenge of graduates not being work-ready (Leal Filho et al., 2016), this realization is crucial. Research shows that employers are actually looking for this type of well-rounded graduate, especially as sustainability issues become more pressing. Business firms, corporations, and various companies have started to take sustainable development more seriously, looking for ways to address the opportunities, challenges, and responsibility to address sustainability problems (Artz et al., 2012; Shiel et al.,

2005). This means that graduates in the job market need to demonstrate awareness of such issues. Society, including governments, industries, and other organizations, are looking to HEIs to come up with sustainable solutions, but also to foster sustainability literate graduates (Stewart, 2010).

2.3 Sustainability Learning Objectives and Curriculum

Including environmental and sustainability education within the HEI student curriculums (Emanuel & Adams, 2011) requires focused learning objectives and curriculum development. University-level learning objectives not only show a dedication to sustainability education, but also articulate specific desired outcomes that allow for measurement of performance, or assessment. Currently, learning outcomes for sustainability literacy in HEI graduates range from understanding and knowledge, to attitudes, behavior and application of skills. While knowledge and awareness are the first necessary components of achieving sustainability literacy, it is recognized that knowledge-based learning outcomes have limitations in establishing student sustainability literacy (Hartman et al., 2017), as it is only the first step in sustainability education for initiating change in student attitudes and towards intentional sustainability-related behavior (Emanuel & Adams, 2011; Lundquist et al., 2018).

To meet their sustainability learning outcomes and expanded sustainability principles, many HEIs have included efforts to teach sustainability across the curriculum and throughout the institution, with sustainability literacy as the common goal (Lozano et al., 2013; Zwickle et al., 2013). In the past couple decades, many HEIs have actually incorporated and institutionalized these principles of sustainable development, and such efforts are still growing (Blanco-Portela et al., 2017; Lozano & Young, 2013). These sustainability efforts take various forms within education, research, facilities, and more. Some researchers even call for a combination of these efforts and best practices to truly tackle sustainable development and foster sustainability literate university graduates. For example, one researcher indicates that graduation course requirements,

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1st year education, and interdisciplinary education, are all necessary components to the comprehensive HEI integration of sustainable development, but notes that these initiatives are typically used separately (Stewart, 2010). While there are many recommended methods, one of the most common themes for sustainability initiatives is for HEIs to consider curricula as an important part of sustainable development in the university system (Lidgren et al., 2006; Lozano et al., 2013). However, a 2001 study found that only 11.6% of HEIs required environmental literacy courses, such as the University of Minnesota and Humboldt State University, with 55% of HEIs offering relevant options or courses that count toward graduation requirements (Rowe, 2002). This statistic does not include sustainability literacy courses, which is a newer concept, and most likely in lesser numbers than that of environmental courses today. These research findings suggest that HEIs need to increase efforts to make curricular changes to incorporate sustainability education, learning from those HEIs who are on the forefront of this movement. For example, only seven universities in the United States have achieved the top, platinum STARS rating, a global sustainability standard within HEIs. These HEIs, at the forefront of integrating sustainability into curriculum in the United States include University of Connecticut, Arizona State University, Cornell University, Colorado State University, Stanford University, University of California, Irvine, and University of New Hampshire (*STARS Participants and Reports*).

2.4 Sustainability Reporting and Assessment

Sustainability reporting is typically used by universities to understand the impact of various sustainable development efforts and curricular changes, and to measure if learning outcomes are being met. Practical findings from sustainability reporting can be used to assess learning outcomes, improve program effectiveness, communicate progress, develop a common tool for analysis, and shed light on aspects of organizational behavior (del Mar Alonso-Almeida et al., 2015; Shushok Jr, 2006). However, sustainability reporting has shown to remain in the

early stages of development and implementation. Reporting has been inconsistent among HEIs, many of which fail to report annually, if at all (Ceulemans et al., 2015; del Mar Alonso-Almeida et al., 2015). Annual reporting can help determine the long-term impact of university sustainability initiatives and can assess if such initiatives are meeting the original goals. More specifically, there is a scarcity in reporting of environmental and sustainability literacy (Fisher & McAdams, 2015). If having sustainability literacy, starting with sustainability knowledge, is a desired learning outcome within HEIs, then adequate reporting, measurement, and assessment is necessary (Lidgren et al., 2006). "Assessment" strictly measures what students learn or how they change, while "outcomes" examines student achievements after completing a program, specifically (Reihman et al., 1990). When focusing on sustainability initiatives within curriculum, assessment of student knowledge levels can help inform university stakeholders of the impact of the curriculum. Ultimately, implementing sustainability reporting and discussing the findings from assessments can lead to incremental changes in both sustainability awareness throughout HEIs and improvements from internal stakeholders, to actually plan and implement change to the sustainability initiative in question (Ceulemans et al., 2015).

2.5 Previous Sustainability Knowledge Assessments and Knowledge Gaps

Previous sustainability assessments have assessed the sustainability knowledge of undergraduates at HEIs and have supported the idea that curricular efforts, from adding sustainability-focused lesson plans to full sustainability courses, can generally improve students' level of sustainability knowledge. For example, the inclusion of a sustainability module in an engineering curriculum increased general awareness of sustainability (Bielefeldt, 2011). Research findings indicate that sustainability education should include at least one course in sustainability to help students and faculty develop greater sustainability knowledge. One course is argued to increase awareness and knowledge of issues just enough to support environmentally responsible

behaviors (Levy & Marans, 2012). However, due to a lack of support from other studies, it has yet to be determined whether taking only one course is enough to meet actual university learning objectives (Rowe, 2002), but is a step in the right direction (Stewart, 2010). Looking deeper into the effects of curricular development efforts, exploratory analysis of an environmental stewardship and knowledge assessment at a public university, showed that more than one sustainability course correlated with higher scores on the assessment (Hartman et al., 2017). Similar findings in other studies show an increase in environmental literacy with more sustainability courses taken, but with relatively few students taking 3 or more courses (Fisher & McAdams, 2015). With this being said, few students taking 3 or more courses means that an additional assessment with a larger sample size is needed to support this finding regarding environmental literacy. It is also important to acknowledge that these past examples regarding more than one course, assess environmental knowledge specifically, rather than sustainability knowledge. With that being said, while more courses in these studies correlate with a higher level of knowledge, this knowledge may not be fulfilling sustainability-specific learning objectives.

In regard to sustainability knowledge specifically, a sustainability knowledge assessment at Cal State University, Northridge showed that the general student population improved knowledge scores with each successive year of coursework (Lundquist et al., 2018). Similarly, in an assessment of sustainability knowledge at the University of Maryland, students taking 3 or more courses had significantly higher sustainability knowledge levels than those that took less (Horvath et al., 2013). These examples from previous assessments show that research has been done to evaluate the impact of various curricular efforts on sustainability knowledge specifically. In the cases of both environmental and sustainability knowledge, more sustainability related courses seem to correlate with higher knowledge levels.

An aspect that many of the previous assessments have in common is that they analyze the impact of separate courses and curricular efforts, rather than assessing a planned sustainability curriculum. Sustainability curriculum can be considered a single or series of sustainability-

focused courses, offered to students at HEIs, which aim to develop fundamental and foundational student sustainability knowledge, awareness, and interest. More specifically, a structured sustainability curriculum is one that is required to meet graduation requirements. While previous research has shown that certain curricular efforts can generally help increase various aspects of undergraduate sustainability literacy, the impact of other aspects of academic setting, such as having a structured sustainability curriculum, on student sustainability knowledge seems to be relatively unexplored. As a result, the current literature lacks clarity, failing to specify an ideal curricular design to meet sustainability learning objectives at HEIs.

Additionally, studies have found a variation in student sustainability knowledge levels across disciplines. Specifically, a study at the University of Maryland assessed if significant differences in SKS were found for students in colleges with traditionally strong academic focus on sustainability as compared to those with less. The study found that, as expected, the College of Agriculture and Natural Resources and the School of Architecture and Planning scored the highest on the sustainability knowledge test, compared to other colleges. However, the study was unable to assess if such differences were truly significant (Horvath et al., 2013). In another study at Iowa State University, researchers found an actual significant difference between students' environmental knowledge and their respective college of enrollment. More specifically, the students in the College of Agriculture had the second highest mean knowledge score, only second to the students enrolled in the College of Veterinary Medicine (O'Brien, 2007). However, this significant difference was only found regarding environmental knowledge, rather than sustainability knowledge. As a result, there is still a lack of clarity regarding the true impact of students' college of enrollment on sustainability knowledge. Understanding how student sustainability knowledge levels vary across disciplines and colleges can help HEIs determine where to target sustainability education initiatives. It is also known that understanding institutional barriers can help HEIs determine ways to overcome sustainability challenges (Blanco-Portela et al., 2017), but such research regarding barriers to and opportunities for

implementing sustainability in academics, as it relates to academic setting, is minimal. These gaps in the literature provide an opportunity for further research regarding the impact of academic setting on student sustainability knowledge and perceived barriers and opportunities to implementing sustainability in academics. Such additional research has the potential to inform university-level decision-making regarding sustainability education, and to influence the materialization of the theoretical dedication to sustainability in academics for all students.

Chapter 3

METHODOLOGY

3.1 Institutional Context

   Cal Poly is a nationally ranked, four-year public university located on the Central Coast of California, in San Luis Obispo. The university is a predominantly undergraduate university and a predominantly white institution. In Fall 2018, Cal Poly enrolled 21,037 undergraduate students in six colleges (See Figure 2) (*Cal Poly Quick Facts*).
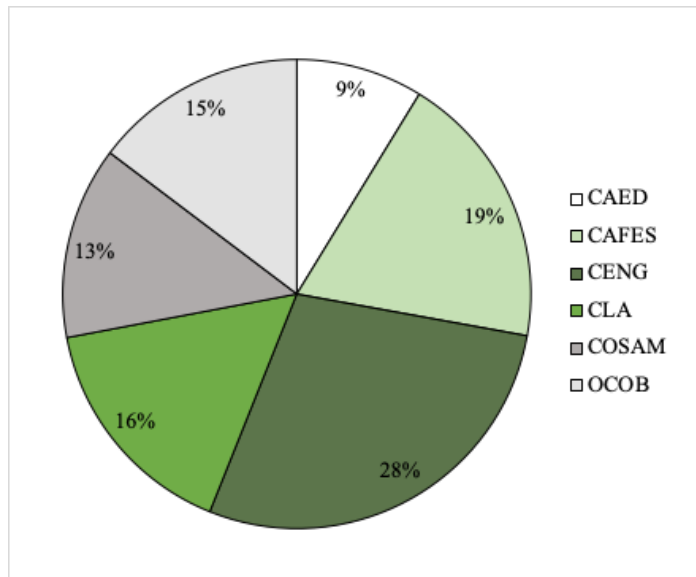
Figure 2. Percentages of Cal Poly Undergraduate Enrollment by College Fall 2018, from a total of 21,037 undergraduate students (Cal Poly Quick Facts).

   This includes the College of Agriculture, Food, and Environmental Sciences (CAFES), the College of Architecture and Environmental Design (CAED), the College of Engineering (CENG), the College of Liberal Arts (CLA), Orfalea College of Business (OCOB), and the College of Science and Math (COSAM). The departments within CAFES range from Agribusiness and BioResource and Agricultural Engineering to Natural Resources Management and Environmental Sciences, while those in COSAM range from Kinesiology and Public Health to Statistics and Physics. The departments within CAED range from Architectural Engineering

and Landscape Architecture to City and Regional Planning, while those in CLA range from Art and Design to Journalism and Social Sciences. The departments included in CENG include all other engineering departments and OCOB includes all other business-related degree programs.

Cal Poly also has expressed a commitment to sustainability, signing the Talloires Declaration in 2004 (Academic Senate California Polytechnic State University, 2003), which is a ten-point action plan to advance environmental and sustainability education, curriculum, and literacy. Cal Poly took steps toward this action plan by including the aspect of basic sustainability awareness in the overall university learning objectives in 2007:

> "All students who complete an undergraduate or graduate program at Cal Poly should be able to … Make reasoned decisions based on an understanding of ethics, a respect for diversity, and an awareness of issues relating to sustainability"(Academic Senate California Polytechnic State University, 2007).

Further, the university promoted the idea that all graduating students should have foundational sustainability knowledge by adding specific sustainability learning objectives in 2009:

> "Cal Poly defines sustainability as the ability of the natural and social systems to survive and thrive together to meet current and future needs. In order to consider sustainability when making reasoned decisions, all graduating students should be able to:
>
> 1. Define and apply sustainability principles within their academic programs,
>
> 2. Explain how natural, economic, and social systems interact to foster or prevent sustainability,
>
> 3. Analyze and explain local, national, and global sustainability using a multidisciplinary approach, and
>
> 4. Consider sustainability principles while developing personal and professional values" (Academic Senate California Polytechnic State University, 2009)

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Additionally, in 2014, the California State University system, which includes Cal Poly, adopted a system-wide sustainability policy which establishes a goal of further integrating sustainability into the academic curriculum (California State Universities, 2014). This system-wide policy, along with the university-level learning objectives, show that Cal Poly has had at least a theoretical dedication to sustainability over the past two decades, which aims to provide sustainability education to all students.

3.1.1 Sustainability Curriculum at Cal Poly

Like many other HEIs, Cal Poly uses a variety of approaches to promote sustainability education and to foster sustainability literacy among students. However, despite the expressed commitment to producing sustainability literate graduates, the institution currently does not require sustainability curriculum for the general undergraduate student population. Cal Poly offers a few sustainability focused or related degrees and programs, such as the Environmental Management and Protection Major or Sustainable Environments Minor. While these programs are available, the majority of students do not choose to specialize in sustainability and do not enroll in such programs.

Cal Poly students also have access to the Cal Poly Sustainability Course Catalog (SusCat). The SusCat lists general education (GE) and elective options for sustainability focused courses offered at Cal Poly. Courses listed in the SusCat merely represent potential course options for students, and not a structured curriculum needed for graduation. There is a total of 35 sustainability focused or related GE courses, that are non-honors courses and open to all students, with 11 of those being lower-division courses (*Sustainability Catalog*). This means that there are only 11 sustainability course options, out of hundreds of GE courses, for undergraduate students to take early on in their undergraduate experience. As such, unless an individual student elects to enroll in a specific major, minor, or class, students may never take a sustainability course in their

entire undergraduate experience, which has been a reality for the majority of students at other universities (Wilke, 1995).

While a university-level sustainability curriculum has not yet been implemented at Cal Poly, students that opt to enroll in the Cal Poly Honors Program take a structured set of sustainability focused courses. The Cal Poly Honors Program is a well-recognized university program that provides students with an academically enriched, experiential and interdisciplinary learning experience (University Honors Program, 2020b). Rather than being automatically placed in the Honors program, students choose to submit an application, upon which they are accepted into the program by the honors coordinators. To be considered for admission to the Honors Program, freshmen applicants must have a cumulative high school non-weighted grade point average (GPA) equal to at least 3.75 (University Honors Program). All students in the program are expected to engage in learning activities in academics, sustainability, global perspectives, and justice issues. As for the structured sustainability curriculum, the Honors program provides a unique example at Cal Poly, in which students of all disciplines, rather than just those in environmental disciplines, take a set of sustainability courses. The honors sustainability curriculum courses, while listed in the SusCat as fulfilling a GE requirement for students in the Honors Program, are not open to the general undergraduate student population.

In 2018, the Cal Poly Honors program provided two different tracks, 1) a year-long or 2) a quarter-long sustainability focused track. The year-long honors sustainability curriculum is for first year students who join the honors program in the Fall quarter of their first year. The year-long curriculum consists of a core set of three, two-unit courses focused on "Creating Sustainable Communities." The core curriculum also provides students who complete the three courses with GE credit, which emphasizes courses on society and the individual. In this series, students delve into and engage in the environmental, social, economic, and political facets of sustainability, in both local and global contexts. This year-long curriculum is an award-winning program, winning

the Best Practice Award in the Sustainability in Academics category at the California Higher Education Conference in 2018.

The quarter-long honors sustainability curriculum is for first year students who join the honors program in the Spring quarter of their first year, and consists of a single, two-unit course titled "Introduction to the Honors Community." In only a single course, students focus on sustainability, ethics, and the general transition to college. While this course does not fulfill any GE requirement, it is a sustainability-related course that covers similar topics to the year-long curriculum. Either of these Honors Program sustainability curriculum tracks are required for graduation from the Honors program and typically cover in more depth the concept of sustainability as compared to a general environmental science course would, such as including the interconnectedness of the three pillars of sustainability. All students in the Honors program are taught these aspects of sustainability that not every student at Cal Poly learns or knows about without taking a variety of specific classes. While not all students are receiving the education necessary to meet the sustainability learning objectives, honors students seem to meet them through both the year-long and quarter-long sustainability curriculum.

Because of the different sustainability curriculum tracks, the Cal Poly Honors Program can serve as a valuable model for the rest of the university (Clauss, 2011). Other factors that have the potential to academically separate Cal Poly honors students from general students, such as learning styles and personal interests, will be included and further examined in the discussion section of this research report. As an HEI with defined sustainability learning objectives and with multiple sustainability curriculums, each with varying requirements or lack thereof, Cal Poly makes an appropriate case study for understanding the impacts of academic setting and sustainability curriculum on student learning and level of sustainability knowledge.

3.1.2 Prior Study at Cal Poly

In 2016, Cal Poly registered with the Association for the Advancement of Sustainability in Higher Education (AASHE), joining a network of 993 other HEIs dedicated to sustainability. Cal Poly adopted the AASHE Sustainability Tracking, Assessment, and Rating System (STARS) as its method of sustainability reporting and assessment of sustainability development within the institution. STARS is a transparent, self-reporting framework for HEIs to measure their sustainability performance indicators and criteria within six categories, including institutional characteristics, academics, engagement, operations, innovation and leadership, and planning and administration. An institution's overall STARS ranking, based on the described categories, is scored as a bronze, silver, gold, or platinum rating. Also, to achieve a higher STARS rating, HEIs must improve ratings in the individual categories.

Upon completing the self-reported sustainability assessment in 2017, Cal Poly was awarded a Silver STARS rating, which was the average level of certification among STARS reporting colleges in 2017 (Singh, 2017). While achieving only a portion of possible points in each major category, Cal Poly received only 28.13 points out of 40 possible points in the academic category, notably losing points for lacking a comprehensive list of sustainability related and focused academic courses and lacking an assessment of student sustainability literacy. These findings emphasize that, while Cal Poly has a theoretical dedication to sustainability education (University, 2007, 2009), this commitment was not actually materializing within actual academics. Effective sustainability education requires more than statements and documents of proclaimed dedication, but also tangible action (del Mar Alonso-Almeida et al., 2015). Following these results, Cal Poly took preliminary action by creating a comprehensive list of sustainability related and focused courses offered, which has been previously described as the SusCat. However, this was just one example of the steps taken to increase the STARS rating.

Aligning with typical uses of sustainability reports (del Mar Alonso-Almeida et al., 2015), Cal Poly also used the 2017 ratings to begin to assess learning outcomes and to try to understand institutional behavior, in an effort to make actual change. An interdisciplinary faculty learning community, with representation from four of six colleges, focused on *Teaching Sustainability Across the Curriculum*, came together to develop a study that would help explain the implications of Cal Poly's first STARS rating for curriculum development. The study was aimed at understanding how the perception of barriers to and solutions for the integration of sustainability correlates with sustainability knowledge, in order to identify opportunities for improving sustainability education (Pompeii et al., 2019). Understanding barriers to integrating sustainability at HEIs is known to help institutions properly plan and use resources in working to become more sustainable (Blanco-Portela et al., 2017). Using a qualitative research method, through 56 in-person interviews with students and faculty across all 6 colleges, the study found that students, across all knowledge levels, identified accessibility, time constraints, and personal neglect or disinterest in sustainability as main barriers to integrating sustainability into academics. Additionally, students across all knowledge levels identified promotion, integration into existing curriculum, and having a sustainability GE as the main solutions for overcoming the perceived barriers. With these initial findings, researchers developed a baseline understanding of sustainability knowledge, as well as barriers to and solutions for integrating sustainability into academics.

However, with results from only 39 students and 17 faculty members, this first study was only exploratory in nature, and left Cal Poly in a unique position to take the research further. The *Teaching Sustainability Across the Curriculum* faculty group, came together again to propose an additional study, one which expands upon the first and which fulfills the need for an assessment of student sustainability literacy. This second study, based on a large-scale survey regarding sustainability knowledge and perceived barriers, is the focus of this particular paper. The findings

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of this study are used to address the described overall knowledge gaps and to help the institution construct a path to develop well-rounded, sustainability-literate graduates.

3.1.3 Focus and Hypotheses of Current Study

This research aims to fill the knowledge gaps and expand upon the findings in the current literature, regarding the impact of academic setting, specifically structured sustainability curriculum, such as the Cal Poly Honors Program, on undergraduate sustainability knowledge. Additionally, this study aims to assess the underlying differences between honors student and general student sustainability knowledge, using Cal Poly as a case study. This study also aims to identify specific barriers and potential opportunities to implementing sustainability into curriculum at HEIs. Specific hypotheses were developed to address these knowledge gaps (See Table 1).

3.2 Development of a Sustainability Assessment

In 2018, an online, campus-wide survey was developed to assess student sustainability knowledge and perceived barriers and opportunities to implementing sustainability in the Cal Poly curriculum. The overall goal of the survey was to fulfill the STARS assessment component and obtain additional data to inform faculty research as well as future decision-making regarding sustainability initiatives (Singh, 2019). As STARS is a self-reporting framework, AASHE does not provide a specific framework of assessment to measure sustainability literacy, rather HEIs are required to come up with their own method of assessment. To develop a framework of assessment, between January and May 2018 the *Teaching Sustainability Across the Curriculum* faculty group drafted a survey to evaluate student level of sustainability knowledge. In April 2018, the *Climate Change Action Research Group* (CCARG), an interdisciplinary team of students with a common interest in climate change action, social research, and sustainability

education at Cal Poly helped to edit and pre-test the survey. Having both the student and faculty group develop the survey and assessment, the need for key members of the university's sustainability community to be involved in the assessment process was met (Horvath et al., 2013).

Together, the faculty and students created a structured and semi-structured survey composed of 16 multiple-choice and free-response questions (See Appendix A. Survey). Demographic questions were chosen to aid later data analysis, such as asking for a participant's year in school or for their specific major. One question asked students to provide a self-assessed number of sustainability-related courses, or "courses that address the topics presented in this survey," taken thus far in their undergraduate experience. While this type of "self-assessed" demographic question is subjective and answered based off students' personal definitions of what they believe sustainability-related courses are, it allowed students to provide a basic metric of the number of sustainability related courses they had taken while at Cal Poly. Additionally, other sustainability assessments have used self-reporting and similar subjective wording when asking about the number of sustainability-related courses students have taken (Horvath et al., 2013).

A few questions regarding student attitudes and perceptions were included in the survey. For example, using a Likert scale question, students were asked to rate how important they think sustainability is on a scale of 0 to 5, not important to very important respectively. Students were also asked about their perception of barriers and opportunities to implementing sustainability education. Assessing barriers and opportunities were specifically chosen to supplement the findings of the previous 2016 study regarding sustainability teaching and curriculum at Cal Poly (Pompeii et al., 2019). Students were asked to choose from a given list of 11 barriers and 9 opportunities, up to 3 perceived barriers and up to 3 perceived opportunities to integrating sustainability into the curriculum. The given lists include the major barrier and opportunity themes identified by Cal Poly students and faculty in the previous study (Pompeii et al., 2019). Students were also given the opportunity to provide comments for any additional information they wanted to provide.

The official sustainability knowledge assessment portion of the survey includes 10 knowledge-based questions, which cede complexity for simplicity. While having comprehensive sustainability literacy requires answering more than 10 knowledge-based questions correctly, it is common for assessments of large bodies of students to assess learning outcomes at a lower cognitive level (Hartman et al., 2017). Additionally, a crude assessment tool is commonly preferred over a sophisticated one, if it properly assesses the questions being asked (Reihman et al., 1990). In this case, the chosen questions aim to provide a baseline assessment of basic sustainability knowledge, which is a starting point for addressing student sustainability literacy and the impacts of sustainability curriculum. Also, while learning outcomes are more properly assessed by knowledge put into practice, data from sustainability assessments can be useful to systematically analyze knowledge among different populations (Zwickle et al., 2013) and to evaluate if the general learning objective of obtaining sustainability knowledge is being adequately met. For this survey, the knowledge questions and respective answers were chosen from previous sustainability assessments completed at other HEIs, including Ohio State University (Zwickle et al., 2013) and California State University, Northridge (Lundquist et al., 2018). Specific questions were chosen to capture the multiple, intersectional aspects of sustainability, including social, economic, and environmental components.

The final survey was officially verified by the University's Institutional Review Board (IRB) as of minimal risk to the target population and was allowed to be administered to the test subjects. Following IRB'S human subject research approval, the survey was transcribed onto Survey Gizmo, a survey software that allows for anonymous responses. The survey was first pre-tested in June 2018 and administered to only first year and graduating honors students of the 2017-2018 academic year. This initial pre-test served as the trial run of the online survey and ensured that the survey could be administered smoothly. The results from the pre-test of the survey are not included in the survey results of this study.

3.3 Sampling and Implementation

The survey was officially administered to three different student samples at Cal Poly, including a sample of the general student population and samples of honors students from two different cohorts, in either of the two sustainability curriculums (See Table 2). The honors students represent a subset of the general student population, who opt to take a specific course of study that includes required courses focused on sustainability, to meet the Honors program's graduation requirement. The general student population represents undergraduate students who are not required to take sustainability focused courses to meet graduation requirements. The honors students in the three-course curriculum (also referred to as the Fall 2018 cohort), honors students in the one-course curriculum (also referred to as the Spring 2019 cohort), and the general student population are three different samples that allow for the comparison of results between students in two different structured sustainability curriculums and with students without a structured sustainability curriculum.

A total of 1,033 student surveys were collected, including all pre and post data for honors and general students. From these surveys, 18 were removed from the data analysis as the students either did not give consent for the data to be used, were not undergraduate students, or failed to fully complete the survey. This resulted in a total of 1,014 viable student surveys used in the data analysis of student SKS. As for the barriers and opportunities questions, where students were asked to choose up to three of each, there are 2,203 student responses for perceived barriers and 2,683 student responses for perceived opportunities.

Table 2. Characteristics of each of sample used in this study.

Sample	Characteristics
1. 2018 General student population	• No required sustainability curriculum to graduate • Can choose to take 0, 1 to 2, or 3 or more sustainability courses • 1st to 5th year undergraduate students • n = 861
2. Fall 2018 honors cohort	• Structured sustainability curriculum to graduate from the Honors program • Required to take 3 sustainability courses • 1st year undergraduate students • Pre sustainability curriculum (n = 55) and post sustainability curriculum (n = 52)
3. Spring 2019 honors cohort	• Structured sustainability curriculum to graduate from the Honors program • Required to take 1 sustainability course • 1st year undergraduate students • Pre sustainability curriculum (n = 22) and post sustainability curriculum (n = 24)

3.3.1 Honors Students

In September 2018, the survey was administered to first year honors students of the 2018-2019 academic year, during Fall Quarter, at the beginning of the structured year-long, three course sustainability curriculum (herein referred to as the Fall 2018 honors cohort). The survey was also administered in April 2019 to the first-year honors students, who enrolled in in the honors program during Spring Quarter, at the beginning of the one course sustainability curriculum (herein referred to as the Spring 2019 honors cohort). The September 2018 and April 2019 surveys were administered to the honors students prior to each cohorts' respective curriculum to assess their pre-curriculum sustainability knowledge. For both cohorts of honors students, the link to the survey on Survey Gizmo was provided to students by the instructor and

respondents completed the survey as part of an initial class assignment. The three course and one course honors cohorts were then resurveyed in June 2019 after the completion of their respective sustainability curriculums, as part of a final class assignment (See Table 3). In both cases, the survey was administered to the entire cohort before each respective curriculum and after the completion of the respective curriculum, providing adequate pre and post curriculum data for honors students who completed both assignments.

For honors students, a total of 55 pre-curriculum responses and 52 post-curriculum survey responses were gathered from the Fall 2018 honors cohort, and a total of 22 pre-curriculum and 24 post-curriculum survey responses were gathered from the Spring 2019 honors cohort. While the response rate dropped in the Fall 2018 honors cohort between the two tests, the response rate increased in the Spring 2019 Honors cohort. It is important to acknowledge that the honors cohort samples are relatively small compared to the sample of the general student population, but still provide adequate insight into the average sustainability knowledge of students who have taken structured sustainability curriculum.

3.3.2 General Student Population

In October 2018, the survey was fully administered by members of CCARG, to a sample of the general Cal Poly student population. Students in the general population were selected using 25Live, a campus scheduling software. In an effort to increase the sample size, relatively large classrooms were identified that would typically be used for General Education (GE) courses with a large number of students from a variety of majors. From this search, CCARG members contacted the instructors of 40 different GE courses via email, regarding administering the survey in the instructors' courses. Of the 40 instructors contacted, a total of 11 instructors gave CCARG members permissions to administer the survey during class time. The 11 GE courses ranged in GE area fulfillment and in course level, ranging between upper and lower division GE courses.

The enrollment for the surveyed courses ranged from 35 to 275 students, and the courses included a variety of GE courses, ranging in topics from astronomy to cultural anthropology. At a time agreed upon by the instructor, a CCARG member surveyed the students in each course that showed up to class on the day that the survey was administered. The CCARG member recited a short, scripted introduction to the survey and provided a link to the survey on survey gizmo. To mitigate for interviewer bias, the scripted introduction provided no context regarding CCARG, the group's mission, or sustainability in general. Additionally, students who had already taken the survey, potentially in another course or through the honors program, were asked to not take the survey again to help eliminate the potential for duplicate responses from the same participant. Students were given 5 to 10 minutes to complete the survey in class, using their own personal electronic devices (i.e. laptop, cellphone, etc.). If students did not have their own electronic devices, they were encouraged to borrow one from a peer, or were not able to participate in the survey. This particular sampling method was chosen to obtain a large, representative, sample of general undergraduate students enrolled at Cal Poly. The sample of general students represents undergraduate students, of various years, in various colleges, and having taken a various number of sustainability-related courses. Unlike the honors student samples, the general student sample includes students who are not required to take a structured sustainability curriculum to meet their described graduation requirements. Also, the sample of the general student population represents only one reference point of data, as students were surveyed only once, after taking 0, 1 to 2, or 3 or more sustainability courses thus far in their undergraduate experience. As only one reference point of data, the sample of the general student population will be considered post-data, to compare to the post-data of the honors student sample (See Table 3).

To represent the general undergraduate student population, which consisted of 21,037 students in Fall 2018 (*Cal Poly Quick Facts*), a total of 861 viable general student survey responses were collected. This is an 82.1% response rate from the 1,049 total students enrolled in the courses in which the survey was administered.

Table 3. Timeline of administering the sustainability knowledge assessment at Cal Poly. The cell shaded black represents the trial run of the survey. Cells shaded green represent pre-tests, before starting a specified curriculum, and cells shaded yellow represent post-tests, after completing sustainability courses or curriculum.

	2018							2019					
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Trial survey	■												
Fall 2018 honors cohort				🟩									🟨
Spring 2019 honors cohort											🟩		🟨
General students					🟨								

3.4 Analysis

Following the administration of the survey, all undergraduate student responses were extracted from Survey Gizmo, which easily compiles the responses into an Excel spreadsheet. The data was sorted and coded in Excel Version 16.38, creating additional columns for grouping purposes and transcribing some responses into binary, and easy-to-analyze categories. For example, grouping columns were created to identify responses for honors students versus the general student population (referred to as "group") and to identify responses for pre versus post data (referred to as "test"). For the sustainability knowledge questions, responses were coded using a binary metric where 1 represents a correct answer and 0 represents an incorrect answer. Similarly, for the perceived barriers and solutions questions, a binary metric was used where 1 indicated the student identified barrier or opportunity as important and 0 indicates the student did not identify the particular barrier or opportunity as important. Students who did not give consent to the survey, failed to complete the survey, and one graduate student who participated, were

removed from the sample of undergraduate students and their responses were not included in the data analysis.

For the 10 sustainability knowledge questions, each respondents' answers were marked as correct or incorrect, a total SKS was then calculated for each student. Thus, for the data analysis in this study, all reported SKS were calculated out of 10 points. To analyze the data and SKS, summary statistics and statistical models were completed in R (R Core Team, 2019) and R studio Version 1.1.383, a statistical coding software. Statistical analysis and graphs were completed using the packages ggplot2, gplots, phia, plyr, rockchalk, and Rmisc. Analysis of Variance (ANOVA) tables were computed from linear model fits to understand the predictors of SKS, using the variables obtained through the survey's demographic questions. The variables tested include student sample group, pre-test/post-test, number of courses taken, college, year in school, and personal importance. Tukey Pairwise Comparisons were used to further analyze the models and Chi-squared tests were used to analyze responses regarding barriers and opportunities (See Table 4). Throughout the data analysis, a p-value of less than 0.01 was considered to be a statistically significant difference and a p-value of less than 0.05 was considered to be a marginally significant difference. Versions of these methods of statistical analysis are used in and adapted from other previous studies, such as in a comparison of honors and non-honors students in general (Gerrity et al., 1993), and in assessments regarding environmental knowledge (Kaplowitz & Levine, 2005; Tikka et al., 2000). The information from these chosen tests aim to produce relevant results that can subsequently be used to better meet the University's goal of having undergraduates with a high level of sustainability knowledge.

Table 4. Data sets, variables, and statistical tests used to analyze the data and obtain research results, organized by research question.

Research Question	Sample Data	Linear Equation in R $(Y = \alpha + \beta_1 X)$	Tests
RQ1	General student population and honors cohorts post data	Eq 1: $Score = \alpha + \beta_1\,Group + \beta_2\,Courses$ Eq 1.5: $Score = \alpha + \beta_1\,Group + \beta_2\,Courses + \beta_3\,Group{*}Courses$	- ANOVA - Post hoc Tukey test
	Honors cohort pre and post data	Eq 2: $Score = \alpha + \beta_1\,Test + \beta_2\,Courses + \beta_3\,Test{*}Courses$	
	General student population post data	Eq 3: $Score = \alpha + \beta_1\,Courses + \beta_2\,Year + \beta_3\,College + \beta_4\,Importance$	
RQ2	General student population and honors cohorts post data	Eq 4: $Barriers = \alpha + \beta_1\,Group$ Eq 5: $Opportunities = \alpha + \beta_1\,Group$	- Pearson's Chi-squared test

For this study, multiple models of SKS and perceived barriers and opportunities were made between various sample sub-categories. Comparisons were also made within the individual honors cohorts and general student population samples, as well as between the honors cohorts and general student population samples. When comparing honors versus general students, only the post data is used, as there is no pre-course data for general students.

Overall, the analysis and results provide a look at undergraduate sustainability knowledge and perceived barriers and opportunities to implementing sustainability into academics at Cal Poly, through a wide lens. Such analysis provides a better understanding of how differences in academic setting and sustainability curriculum can impact student level of sustainability knowledge and student perceptions of barriers to and opportunities for implementing

sustainability into academics. This specific case study allows for further discussion of the

differences between honors and general student sustainability knowledge.

Chapter 4

RESULTS

The following section outlines the main results of this study, which aimed to address two central research questions: RQ1 asks "Which factors of academic setting and characteristics impact undergraduate student sustainability knowledge and what is the impact?" RQ2 asks "How does academic setting impact student perceived barriers to and opportunities for implementing sustainability into academics?" For the purpose of this study, high sustainability knowledge is based off of statistically significant differences and defined as the positive progress of student sustainability knowledge by the time that they leave their undergraduate university, rather than focusing on a threshold.

4.1 Sample Demographics

Demographic information is provided for the Cal Poly student population during Fall 2018, the general student sample at the time they were surveyed, and the honors student samples at the time of the post-curriculum survey (See Table 5). In regard to college demographics specifically, all three samples provide representation from each official college at Cal Poly (See Table 5). On the other hand, the three samples do not provide representation of the "Other" category included in the report of official enrollment by college in Fall 2018 (*Cal Poly Quick Facts*). The "Other" category for college represents students who are in interdisciplinary degree programs that fall under multiple colleges, such as Liberal Arts and Engineering Studies. As for gender, the Cal Poly Common Data Set 2018-2019 fails to take into account that students may identify as gender non-binary, gender fluid, or maintain another gender identity that is not included here. As a result, such gender identities are represented in the "Other" category for gender in the survey and are not accounted for in the Common Data Set information. Looking at just female and male gender identities, both honors cohorts, post-curriculum have a higher percentage of female-identifying students and a lower percentage of male-identifying students,

compared to that of the entire Fall 2018 undergraduate student population. In regard to year in

school, the Common Data Set also fails to provide a clear breakdown of undergraduate student

year in school, rather using academic level as a parallel indicator of student demographics.

However, in this case, student year in school and academic level cannot easily be converted. For

example, students in their 1st year in school can be of sophomore standing due to number of

academic credits. As a result, demographic information regarding year in school is not provided

for the Fall 2018 undergraduate student population.

The demographic information from the samples, except for gender, is analyzed in more

detail, as it relates to sustainability knowledge and barriers and opportunities to implementing

sustainability in academics. The demographic information chosen to be analyzed, such as college

and year in school, represent other aspects of academic setting.

Table 5. Demographic characteristics of California Polytechnic State University, San Luis Obispo (Cal Poly) sustainability knowledge survey's post-curriculum respondents and the Cal Poly student population for the 2018 fall quarter (Cal Poly Quick Facts; Common Data Set 2018-2019). Values are given first in number of respondents, then in percent of group total.

Characteristic	Level	General student population respondents # (%)	Fall 2018 honors cohort # (%)	Spring 2019 honors cohort # (%)	Fall 2018 Cal Poly All Students # (%)
Respondents	All	861 (100)	52 (100)	24 (100)	21,037 (100)
College	CAFES	305 (35.4)	12 (23.1)	4 (16.7)	4,005 (19)
	CAED	45 (5.2)	5 (9.6)	1 (4.2)	1,840 (8.8)
	CENG	148 (17.2)	10 (19.2)	7 (29.2)	5,921 (28.2)
	CLA	110 (12.8)	15 (28.8)	6 (25)	3,348 (15.9)
	OCOB	164 (19)	3 (5.8)	3 (12.5)	3,088 (14.7)
	COSAM	89 (10.3)	7 (13.5)	3 (12.5)	2,784 (13.2)
	Other	0	0	0	51 (0.2)
Gender	Female	444 (51.6)	41 (78.8)	17 (70.8)	10,158 (48.3)
	Male	411 (47.7)	11 (21.2)	7 (29.2)	10,879 (51.7)
	Other	6 (0.7)	0	0	*
Year in School	1st	427 (49.6)	52 (100)	24 (100)	*
	2nd	115 (13.4)	0	0	*
	3rd	163 (18.9)	0	0	*
	4th	119 (13.8)	0	0	*
	5th +	37 (4.3)	0	0	*

*Numbers not available from Cal Poly's Institutional Research Office

4.2 Impact of Various Predictor Variables on Sustainability Knowledge

Under RQ1, H_1 hypothesizes that students who take the Honors Program sustainability curriculum will have higher sustainability knowledge than those who do not. H_2 hypothesizes that students in the general student sample who take 3 or more sustainability courses will have higher sustainability knowledge than those who take 0, 1 or 2. Finally, H_3 hypothesizes that students in CAFES have higher sustainability knowledge than those in other colleges. These hypotheses for RQ1 are addressed below, followed by additional findings regarding other variables.

A summary of the average SKS of each group by predictor variable is provided (See Table 6). The data illustrates that the average score of the cumulative honors student sample, combining all post-curriculum honors scores ($\bar{x} = 8.20$, SD $= 1.21$) is higher than the cumulative score of all general students. ($\bar{x} = 6.24$, SD $= 2.00$). With the honors sample separated by cohort, the highest average score of the three samples belongs to the Spring 2019 honors cohort, post one-course curriculum ($\bar{x} = 8.25$, SD $= 1.29$), with the Fall 2018 honors cohort, post three-course curriculum with a similar average score ($\bar{x} = 8.17$, SD $= 1.18$). General students who have taken three or more courses having the highest average SKS ($\bar{x} = 7.35$, SD $= 1.95$) compared to general students who have taken less. For the general undergraduate student sample, CLA students have the highest average SKS of all six colleges ($\bar{x} = 6.36$, SD $= 2.07$), with CAFES students having the second highest average ($\bar{x} = 6.33$, SD $= 2.15$), and CAED students have the lowest average score of all six colleges ($\bar{x} = 5.93$, SD $= 1.81$). Students in their 1st year in school have the lowest average score of all years ($\bar{x} = 5.97$, SD $= 2.02$), while students in their 5th year in school have the highest average score of all years ($\bar{x} = 6.81$, SD $= 1.82$). Also, students who rate the importance of sustainability as a 0 have the lowest average score of all ratings ($\bar{x} = 3.75$, SD $= 1.98$), while those that rate the importance of sustainability a 5 have the highest average score of all ratings ($\bar{x} = 6.72$, SD $= 1.85$).

Overall, the group variable, that being whether a student was an honors student or general student, was a significant predictor of undergraduate student SKS (See Table 6). Within the honors student cohorts, the pre- vs. post-test variable was the most significant predictor of SKS while number of courses was not a significant predictor of score. Within the general student sample, number of courses and personal importance of sustainability were the most significant predictors of sustainability knowledge. On the other hand, college and year in school were not statistically significant predictor variables for SKS. The detailed results of the statistical analysis regarding each hypothesis and additional findings for RQ1 are provided in the following subsections.

Table 6. Summary of the average sustainability knowledge scores by predictor variable for each group including test, courses, college, year in school, and personal importance. The Fall 2018 and Spring 2019 honors cohorts are referenced by the number of courses in each sustainability curriculum, 3 courses and 1 course respectively.

Group*	Sample Size (n)	Average Sustainability Knowledge Score ($\bar{x}$)	Standard Deviation (SD)
Honors			
Test*			
Pre	77	7.06	1.71
Post	76	8.20	1.21
Courses			
Pre-3 courses	55	6.91	1.77
Pre-1 course	22	7.45	1.53
Post-3 courses	52	8.17	1.18
Post-1 course	24	8.25	1.29
General			
Test			
Post	862	6.24	2.00
Courses*			
0 courses	461	6.00	1.94
1 to 2 courses	306	6.28	2.00
3+ courses	94	7.35	1.95
College			
CAFES	305	6.33	2.14
CAED	45	5.93	1.81
CENG	148	6.27	1.83
CLA	110	6.36	2.07
OCOB	164	6.04	1.79
COSAM	89	6.31	2.15
Year in School			
1_{st}	427	5.97	2.02
2_{nd}	115	6.05	1.95
3_{rd}	163	6.72	1.97
4_{th}	119	6.61	1.89
5_{th}	37	6.81	1.82
Personal Importance*			
0	8	3.75	1.98
1	10	3.90	2.28
2	17	4.17	2.32
3	55	4.85	1.89
4	212	5.74	1.85
5	559	6.72	1.85

*Significant Predictor of Sustainability Knowledge ***

**4.2.1 Impact of Structured Sustainability Curriculum**

When considering student sample group and number of courses, an ANOVA shows that there is a significant difference between the SKS of students who take a structured sustainability curriculum and those who do not ($F_{(2,932)} = 14.82$, $p < 0.001$). More specifically, a post hoc Tukey test shows that there is a significant ($p < 0.001$) difference between the Spring 2019 honors cohort, post one-course structured sustainability curriculum and general students. However, there is not a significant difference ($p = 0.065$) between the Fall 2018 honors cohort, post three-course structured sustainability curriculum and general students (See Table 7).

Table 7. ANOVA output, including P-value and 95% Confidence Interval, from the various comparisons of interest. Results from a post hoc Tukey test, comparing average sustainability knowledge scores of general undergraduate students, by group and courses, using Eq1 and Eq2.

Comparison	95% Confidence Interval (Lower, Upper Limit)	P-value
Honors post 1 course vs. Honors pre 1 course	(-0.34, 1.93)	Greater than 0.05
Honors post 3 courses vs. Honors pre 3 courses	(0.52, 2.01)	Less than 0.01
Honors post 1 course vs. General all	(0.98, 2.84)	Less than 0.01
Honors post 3 courses vs. General all	(-0.03, 1.25)	Greater than 0.05

The pre and post data from both honors cohorts is used to further analyze the impact of a structured sustainability curriculum on student sustainability knowledge. Honors students in both cohorts start the honors program with a lower cumulative average SKS ($\bar{x} = 7.06$, $SD = 1.71$) than when they finish their sustainability curriculum ($\bar{x} = 8.20$, $SD = 1.21$) (See Table 6). When considering pre- and post-test scores, number of courses, and an interaction between the two, an ANOVA reveals that there is a significant difference between the SKS of students before and after they take either of the honor's structured sustainability curriculum ($F_{(1,149)} = 22.29$, $p < 0.001$). More specifically, a post hoc Tukey test shows that there is a significant difference ($p < 0.001$) between the SKS of the Fall 2018 honors cohort post 3-course curriculum and pre 3-course curriculum. The 95% confidence intervals of the pre and post 3-course curriculum scores do not

overlap (See Figure 3). However, there is not a statistically significant difference ($p = 0.27$)

between the SKS of the Spring 2019 honors cohort post 1-course curriculum and pre 1-course

curriculum, in which the 95% confidence intervals overlap (See Figure 3; Table 7).
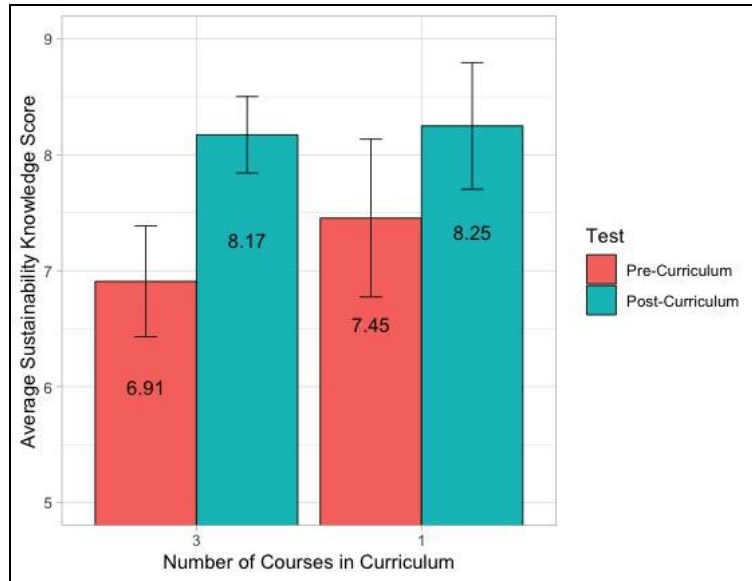
Figure 3. Bar chart of average sustainability knowledge scores of honors students, by number of sustainability related courses taken in the sustainability curriculum and test, either pre-curriculum or post-curriculum. The number on each bar represents the average sustainability knowledge score of the group and the error bar represents the 95% confidence interval for the group.

The distributions of student SKS are more right skewed after taking a structured

sustainability curriculum (See Figure 4). For the Fall 2018 cohort, none of the students scored

less than 6 on the post-curriculum test, with more students scoring 8 and higher. For the Spring

2019 cohort, less students scored a 6 or below on the post-curriculum test, with more students

scoring a 9 or 10.

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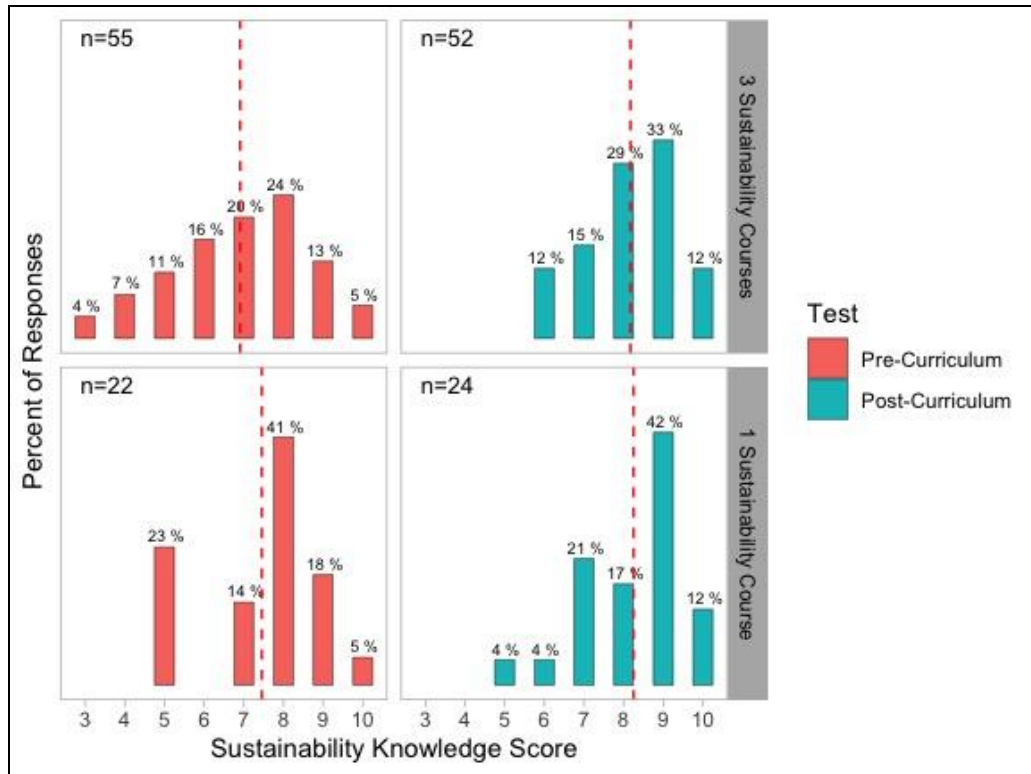
Figure 4. Matrix of honors student sustainability knowledge scores, by number of sustainability related courses taken in the sustainability curriculum and test, either pre-curriculum or post-curriculum. The red dashed line represents the average sustainability knowledge score of the group.

4.2.2 Impact of the Number of Courses Taken

The Spring 2019 honors cohort, post one-course curriculum, has a higher average SKS ($\bar{x}$ = 8.25, SD = 1.29) than the Fall 2018 honors cohort, post three-course curriculum ($\bar{x}$ = 8.17, SD = 1.18). However, when considering pre- and post-test, number of courses, and an interaction between the two, an ANOVA shows that there is not a significant difference (p = 1.00) between the scores of the Fall 2018 Honors cohort and Spring 2019 Honors cohort, post curriculum. Also, only the Fall 2018 cohort scored significantly higher on their post-curriculum score than on their pre-curriculum score, after taking the 3-course structured sustainability curriculum.

Within the general student population, the average SKS generally increase with more sustainability related courses, with general students who have taken three or more courses having the highest average SKS ($\bar{x} = 7.35$, SD = 1.95) (See Figure 5).
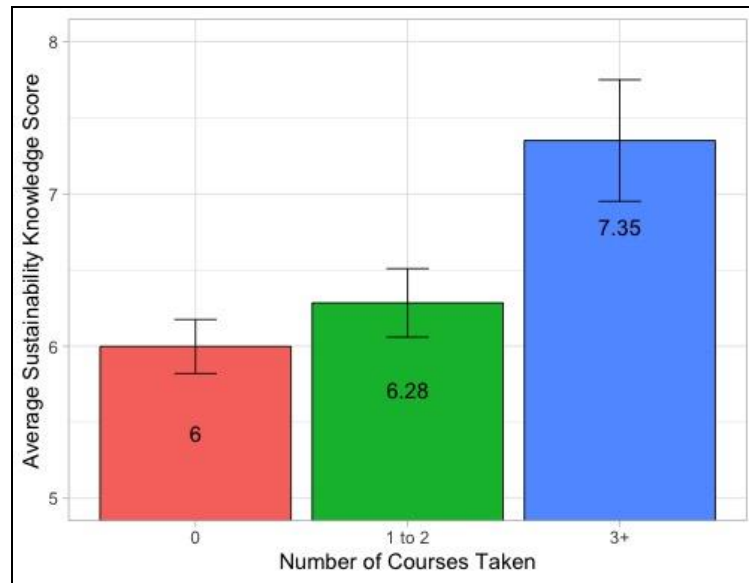
Figure 5. Bar chart of average sustainability knowledge scores of general students by number of sustainability related courses taken. The number on each bar represents the average sustainability knowledge score of the group and the error bar represents the 95% confidence interval for the group.

The distribution of scores of general students who have taken 0 or 1 to 2 courses are similar, while the distribution of scores of general students who have taken 3 or more courses is more right-skewed. There are few general students who have taken 3 or more courses that scored less than a 5 (See Figure 6).
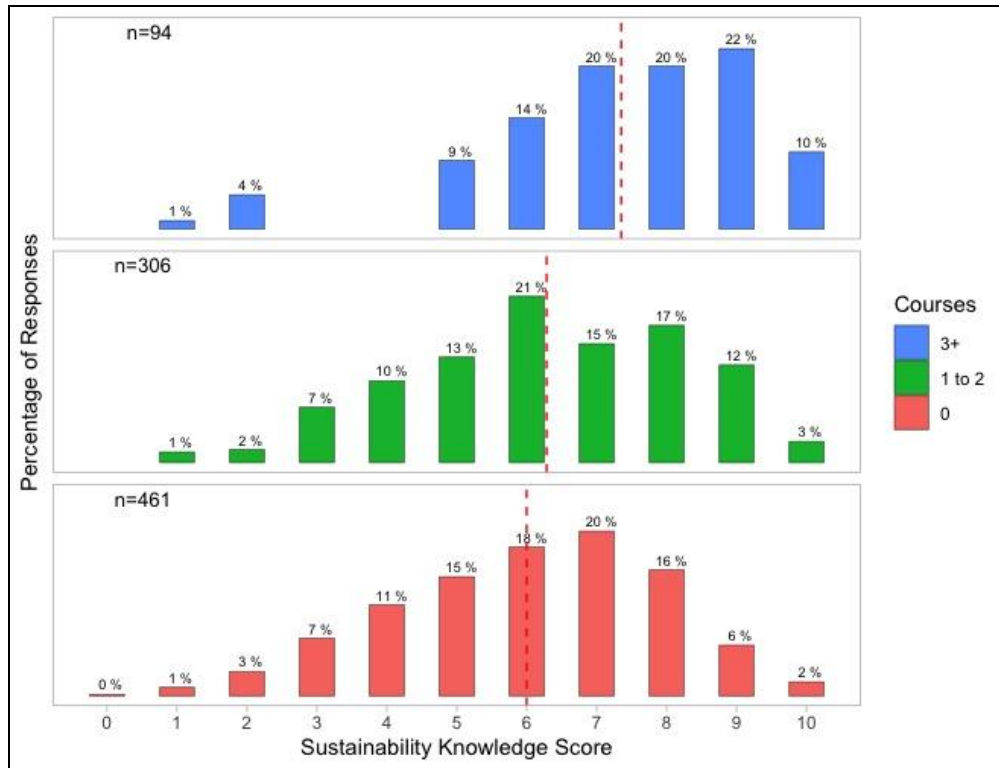
Figure 6. Matrix of the general student sustainability knowledge scores, by number of sustainability-related courses taken. The red dashed line represents the average sustainability knowledge score of the group.

Considering number of courses, year in school, college of enrollment, and importance rating of sustainability, an ANOVA reveals that there is a significant difference between SKS of general students who take different numbers of sustainability-related courses ($F_{(2,844)} = 21.43$, $p < 0.001$). More specifically, a post hoc Tukey test shows that there is a significant difference ($p < 0.001$) between general students who have taken three or more courses and zero courses. There is also a significant difference ($p < 0.001$) between students who have taken three or more courses and one to two courses. On the other hand, there is not a significant difference ($p = 0.09$) between general students who have taken one to two courses and zero courses (See Table 8).

When considering student sample group, number of courses, and an interaction between the two, an ANOVA shows that there is a marginally significant interaction between the number of courses taken and group ($F_{(1,932)} = 4.77$, $p = 0.03$). A post hoc Tukey test shows that there is

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a significant difference (p < 0.001) between the scores of the Spring 2019 honors cohort, post one-course curriculum and general students post one to two courses. However, there is not a significant difference (p = 0.13) between the scores of the Fall 2018 honors cohort, post three-course curriculum and general students post three or more courses (See Table 8).

Table 8. Results from a post hoc Tukey test, comparing average sustainability knowledge scores of general undergraduate students, by group and courses, using Eq 3 and Eq 1.5.

Comparison	95% Confidence Interval (Lower, Upper Limit)	P-value
General 3+ courses vs. General 0 courses	(0.83,1.88)	Less than 0.01
General 3+ courses vs. General 1 to 2 courses	(0.52, 1.61)	Less than 0.01
General 1 to 2 courses vs. General 0 courses	(0.05, 0.63)	Greater than 0.05
Honors post 1 course vs. General 1 to 2 courses	(0.81, 3.12)	Less than 0.01
Honors post 3 courses vs. General 3+ courses	(-0.12,1.77)	Greater than 0.05

4.2.3 Impact of College

Analysis by college was not conducted for the honors student cohorts, as the sample sizes are small and creating further sub groupings would further reduce sample size and statistical power. With that being said, analysis by college is provided for the general student sample.

For the general undergraduate student population, CLA students have the highest average SKS of all six colleges ($\bar{x}$ = 6.36, SD = 2.07) and CAED students have the lowest average score of all six colleges ($\bar{x}$ = 5.93, SD =1.81) (See Table 6). The small gap between the highest and lowest average scores leaves a narrow range for average SKS of the other colleges. Additionally, all of the 95% confidence intervals of each college overlap (See Figure 7).
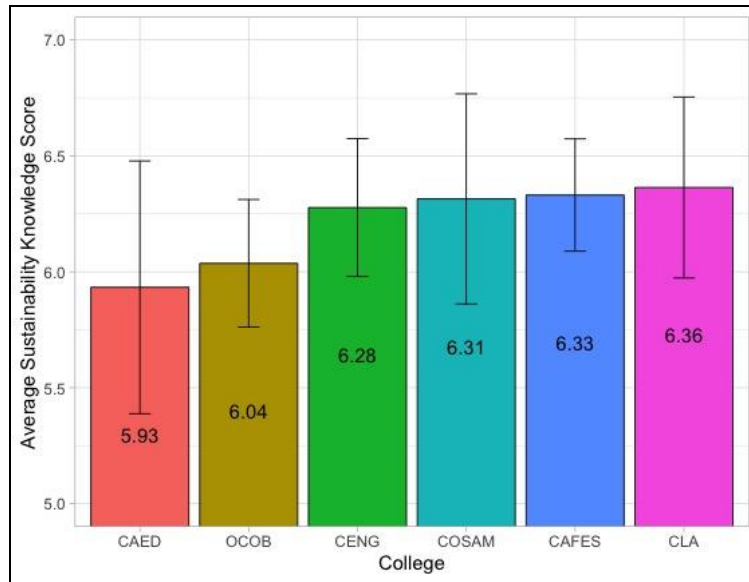
Figure 7. Bar chart of average sustainability knowledge scores of general students by college. The number on each bar represents the average sustainability knowledge score of the group and the error bar represents the 95% confidence interval for the group.

Also, all six colleges have similarly shaped distributions of general student scores. However, even though students in CLA have the highest average SKS, students in CAFES have the highest percentage of students that score an 8 or higher, compared to all other colleges (See Figure 8).

Considering number of courses, year in school, college of enrollment, and importance rating of sustainability, an ANOVA shows that there is not a statistically significant difference between scores of students in different colleges ($F_{(5,844)} = 1.24$, $p = 0.29$). For example, there is not a significant difference ($p = 0.28$) between the average SKS of CLA students and CAED students. When added to Eq3, there is not a significant interaction between college and number of courses taken ($F_{(10, 834)} = 1.76$, $p = 0.06$).
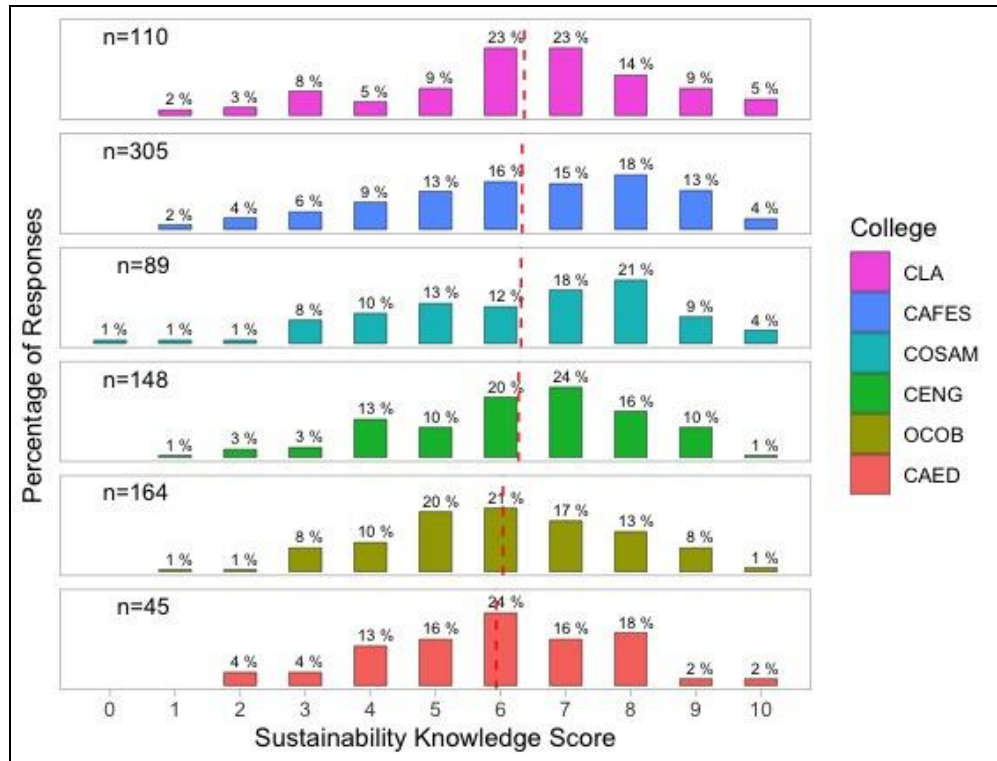
Figure 8. Matrix of the general student population sustainability knowledge scores, by college. The red dashed line represents the average sustainability knowledge score of the group.

4.2.4 Additional Findings

The data from the survey allows for some additional analysis under RQ1, outside the scope of the original hypotheses. Given the demographic questions used in the survey, analysis based on student year in school and self-assessed personal importance of sustainability is provided.

4.2.4.1 Impact of Year in School

As the honors student samples consist of only first year students, there is no statistical analysis of year within the honors cohorts. With that being said, analysis by year in school is provided for the general student sample. Within the general undergraduate student sample, there is a general trend of average SKS increasing as year in school increases (See Table 6). First year

students have the lowest average sustainability knowledge ($\bar{x} = 5.97$, SD = 2.02), while fifth year

students have the highest average SKS ($\bar{x} = 6.81$, SD =1.82). The only disruption to this general

trend is that third year students ($\bar{x} = 6.72$, SD =1.97) have a higher average SKS than fourth year

students ($\bar{x} = 6.61$, SD =1.89) (See Figure 9).
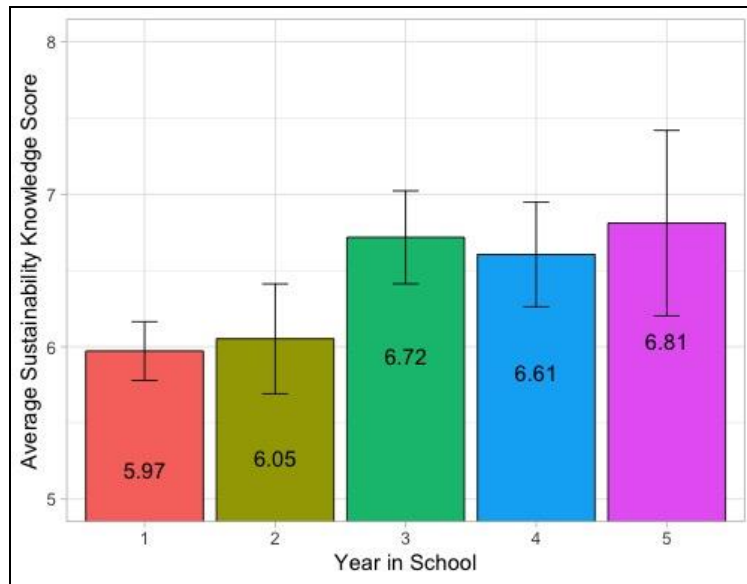
Figure 9. Bar chart of average sustainability knowledge scores of general students by student year in school. The number on each bar represents the average sustainability knowledge score of the group and the error bar represents the 95% confidence interval for the group.

Third year and up students score higher than the overall general student average ($\bar{x} =$

6.24, SD = 2.00), while first and second years score lower than the total general student average.

Looking at the distributions of general student scores by year in school, the scores of students in

year three and up are slightly more right-skewed than those in year one or two (See Figure 10).

Again, considering number of courses, year in school, college of enrollment, and

importance rating of sustainability within the general undergraduate student sample, an ANOVA

reveals that there is not a significant difference between scores of students in different years (F

$(4,844) = 2.25$, $p = 0.06$). When added to the model, there is no significant interaction between

year and courses taken (F (8,836) = 0.88 = 0.53). Also, when added to the model, there is no

significant interaction between year and college (F (19,825) = 0.96, p = 0.50).
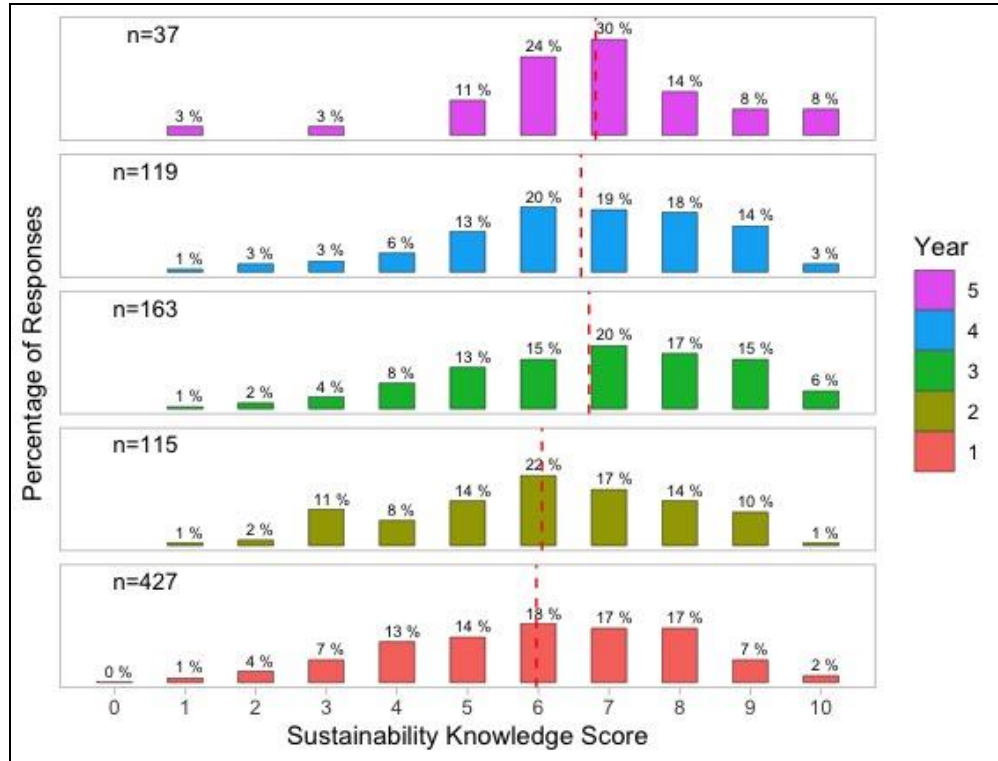
Figure 10. Matrix of the general undergraduate student population sustainability knowledge scores, by student year in school. The red dashed line represents the average sustainability knowledge score of the group.

4.2.4.2 Impact of Personal Importance of Sustainability

A complete analysis of personal level of importance is not included for the honors

samples as, again, further categorization of the small honors samples would reduce statistical

power. However, it's important to note that all honors students, post-curriculum, rated the

importance of sustainability as a 3 or higher. Analysis by rating of personal importance of

sustainability is provided for the general student sample. It is important to keep in mind that the

sample sizes for those that rate the importance of sustainability as a three or below, are relatively

small compared to the entire sample of general students.

Within the general undergraduate student sample, there is a general trend between personal rating of importance of sustainability and SKS. As personal rating increases, the average SKS increases (See Table 6; Figure 11).
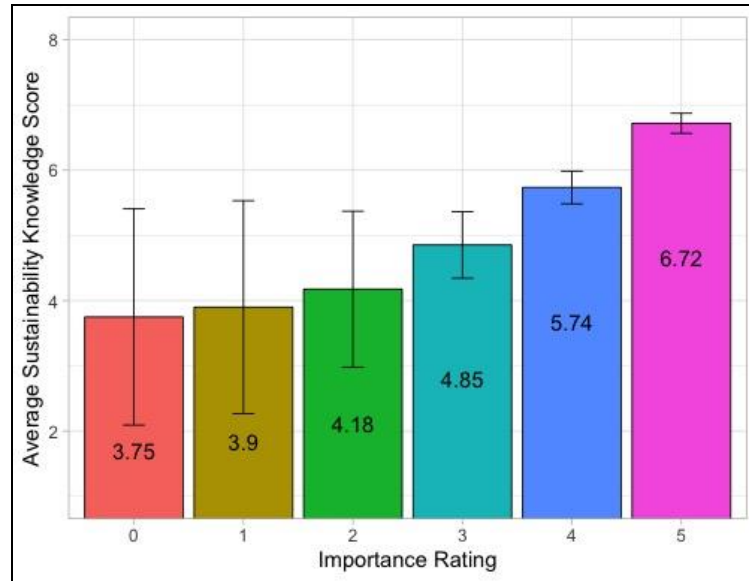
Figure 11. Bar chart of average sustainability knowledge scores of general students by rating of personal importance of sustainability. The number on each bar represents the average sustainability knowledge score of the group and the error bar represents the 95% confidence interval for the group.

The distribution of general student scores is distinctly right skewed for those that rate the importance of sustainability as a five. On the other hand, the distribution of general student scores is distinctly left skewed for those that rate the importance of sustainability as zero or one (See Figure 12).
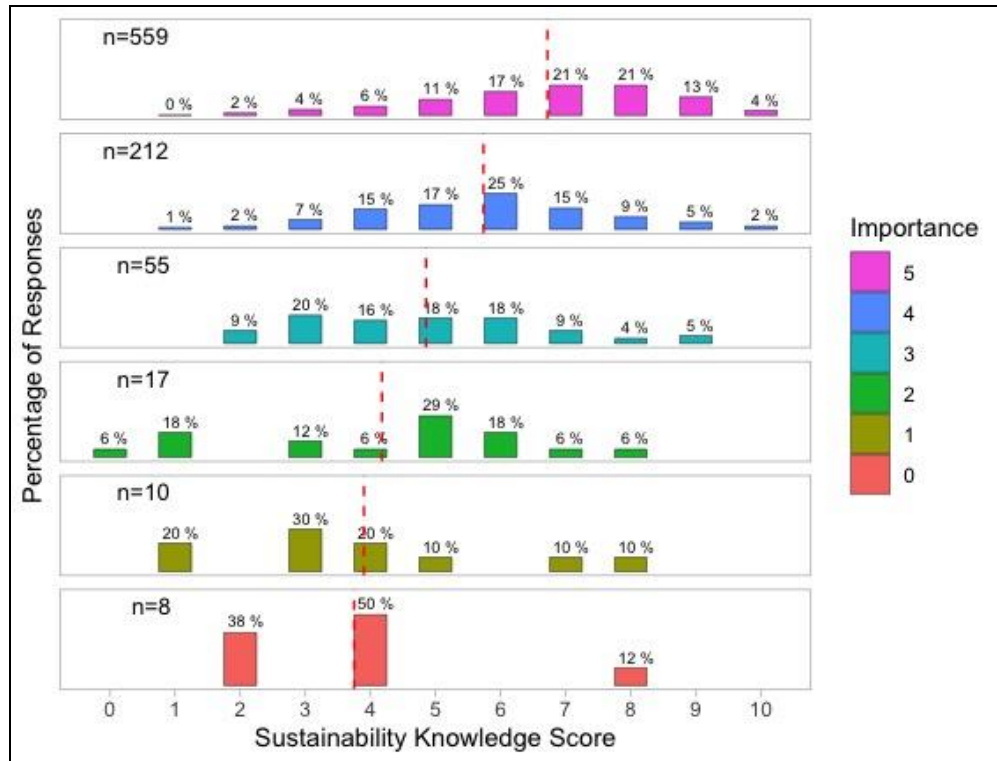
Figure 12. Matrix of the general student population sustainability knowledge scores, by rating of personal importance of sustainability. The red dashed line represents the average sustainability knowledge score of the group.

Considering number of courses, year in school, college of enrollment, and importance rating of sustainability, an ANOVA shows that there is a significant difference between scores of general students with differing personal levels of importance ($F_{(5,844)} = 24.94$, $p < 0.001$). A post hoc Tukey test shows that there is a significant difference between the SKS of those that rate the importance of sustainability as a 4 or 5, and those that rate sustainability as less important (See Table 9). When added to the model, there is no significant interaction between personal importance and college ($F_{(22, 822)} = 1.37$, $p = 0.12$), or between personal importance and year ($F_{(17,827)} = 1.63$, $p = 0.051$). However, when added to the model, there is a significant interaction between personal importance and courses taken ($F_{(9,835)} = 3.16$, $p < 0.01$). When importance rating is high, then the effect of courses on SKS is also high, but when the importance rating is low, then the effect of courses is low.

Table 9. Results from a post hoc Tukey test, comparing sustainability knowledge scores of general undergraduate students, by personal rating of importance, using Eq 3.

Rating Comparison	95% Confidence Interval (Lower, Upper Limit)	P-value
5 vs. 4	(0.46, 1.31)	Less than 0.01
4 vs. 3	(0.00, 1.58)	Less than 0.01
4 vs. 2	(0.29, 2.93)	Between 0.01 and 0.05
4 vs. 1	(0.07, 3.45)	Less than 0.01
4 vs. 0	(0.21, 3.98)	Less than 0.01

4.3 Impact of Academic Setting on Perceived Barriers and Opportunities

From RQ2, H_4 hypothesizes that students who take the structured Honors Program sustainability curriculum do not perceive time and accessibility as barriers to implementing sustainability into academics. H_5 hypothesizes that students who take a structured sustainability curriculum perceive implementing a sustainability GE as the best opportunity for implementing sustainability into academics.

4.3.1 Impact on Perceived Barriers

In the case of analysis, the list of barriers to implementing sustainability into academics is referred to by the full description or the label (See Table 10). The distributions of general student and honors student perceived barriers to implementing sustainability into academics are similar (See Figure 13). General students most commonly perceive time constraints (B1), lack of promotion (B8), and lack of relevance to major (B2) as the major barriers to implementing sustainability into academics. Honors students most commonly perceive the same three barriers, with the addition of elective constraints, or not having enough units allocated to elective courses in their degree requirements (B6), as a barrier. While not considered a top barrier, general students more commonly perceive not knowing how to find sustainability courses (B4) as barrier, compared to honors students. A Pearson's chi-squared test with a simulated p-value, using group as the dependent variable and perceived barriers to implementing sustainability into academics as

the independent variable, shows that there is a significant relationship between the two variables, group and perceived barriers (X_2 (10, N = 2203) = 23.60, p = 0.01). More specifically, the observed counts of honors students who perceive not caring about sustainability (B3) or not knowing how to find the courses (B4) as a barrier are significantly lower than what would be expected for honors students in this sample. Also, the observed counts of honors students who perceive elective constraints (B6) as a barrier is significantly higher than what would be expected.

Table 10. Full description of the choices of perceived barriers to implementing sustainability into academics, used in the survey.

Label	Full Description
B1	I do not have enough time
B2	It does not fit with my major or academic goals
B3	I do not care about sustainability
B4	I do not know how to find the courses
B5	Cost
B6	I do not have enough electives
B7	Cal Poly does not offer enough sustainability courses
B8	Courses are not well promoted
B9	Professors lack motivation
B10	Professors lack competency in the subject
B11	The university does not prioritize funding
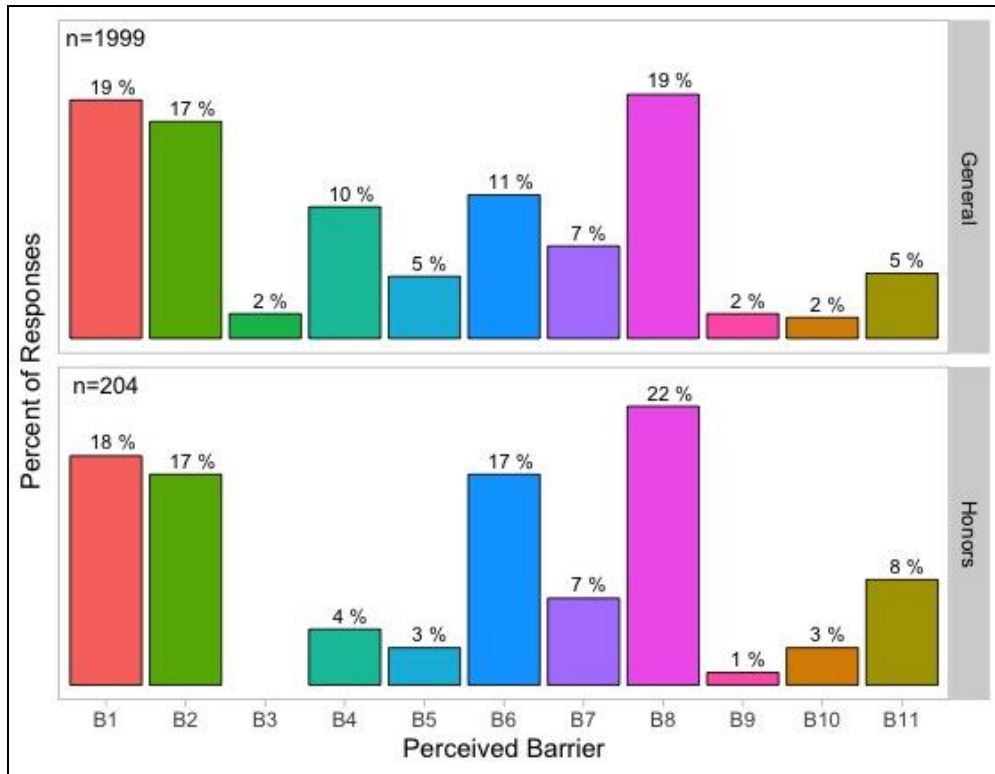
Figure 13. Bar plot of the perceived barriers to implementing sustainability into academics, by group. The sample size in the top left corner represents the total number of perceived barriers selected by respondents, as each respondent could choose up to three. For a full description of the choices of perceived barriers see Table 10.

4.3.2 Impact on Perceived Opportunities

Just like the perceived barriers, the list of opportunities to implementing sustainability into academics is referred to by the full description or just the label as defined in the table below (See Table 11). The distributions of general student and honors student perceived opportunities to implementing sustainability into academics are also similar (See Figure 14). Integrating sustainability into existing courses (S2) is the most selected perceived opportunity to implement sustainability into academics by both honors (24% of all responses) and general students (23% of all responses). The second most selected perceived opportunity, by both honors (15% of all responses) and general students (18% of all responses), is creating a sustainability GE requirement (S4). Both the honors and general students also perceive explaining the application

of sustainability to career relatability (S5) as the next top opportunity to implementing

sustainability into academics. A Pearson's chi-squared test with a simulated p-value, using group

to predict perceived opportunities to implementing sustainability into academics, shows that there

is no significant relationship between student sample group and perceived opportunities (X_2 (8, N

= 2683) = 6.10, p = 0.63). This means that the observed counts of perceived opportunities, by

student sample group, is not significantly different from the expected counts under a normal

distribution.

Table 11. Full description of the choices of perceived opportunities for implementing sustainability into academics, used in the survey.

| Label	Full Description
S1	Better marketing of sustainability classes
S2	Integrate sustainability topics into already existing classes
S3	Offer more sustainability in major
S4	Make sustainability a GE requirement (would not increase number of required units)
S5	Advise how sustainability education relates to career opportunities
S6	The university should make it a priority by allocating more funds to sustainability education
S7	Professors should allocate more time to sustainability education
S8	Add first year sustainability education opportunities
S9	I do not think we should make sustainability education more accessible
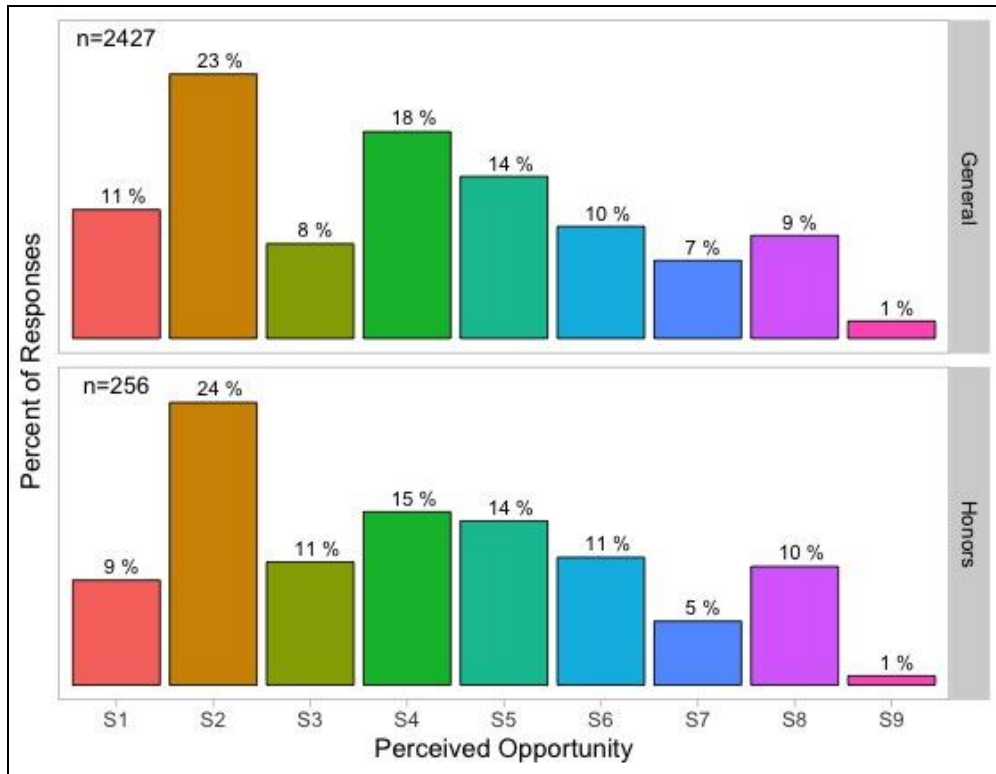
Figure 14. Bar plot of the perceived opportunities for implementing sustainability into academics, by group. The sample size in the top left corner represents the total number of perceived opportunities selected by respondents, as each respondent could choose up to three. For a full description of the choices of perceived opportunities see Table 11.

Chapter 5

DISCUSSION

5.1 Overview of Findings

The results of this study contribute the existing body of research pertaining to

sustainability education at HEIs: by 1) addressing which factors of academic setting impact

undergraduate sustainability knowledge and 2) identifying how academic setting impacts student

perceptions of barriers to and opportunities for implementing sustainability into academics (See

Table 1). The specific hypotheses addressed for each research question, along with the conclusion

regarding each hypothesis, are included in the table below (See Table 12).

Table 12. Overview of the final conclusions made about each hypothesis in this study.

Hypothesis	Full Description	Conclusion
RQ1-H_1	Students who take a structured sustainability curriculum as part of the Honors Program have higher sustainability knowledge than those who do not.	Accepted
RQ1-H_2	Students who take 3 or more sustainability courses have higher sustainability knowledge than those who take 1 to 2, or 0 sustainability courses.	Partially Accepted
RQ1-H_3	Students who are in the College of Agriculture, Food, and Environmental Sciences have higher sustainability knowledge than those in other colleges.	Rejected
RQ2-H_4	Students who take a structured sustainability curriculum as part of the Honors Program do not perceive time and accessibility as main barriers to implementing sustainability into academics.	Rejected
RQ-H_5	Students who take a structured sustainability curriculum perceive implementing a sustainability GE as the best opportunity for implementing sustainability into academics.	Partially Accepted

The study reveals that honors students have significantly higher SKS after taking a

structured sustainability curriculum. The results further indicate that honors students that take a 3-

course sustainability curriculum do not score significantly higher than those that take a 1-course

sustainability curriculum, but general students that take 3 sustainability-related courses score significantly higher than general students who take 0, or 1 to 2 sustainability-related courses. The findings also show that student SKS do not significantly differ across colleges or years in school. Additionally, the analysis of student perceptions reveals that students perceive time constraints, lack of promotion, and lack of relevance as major barriers, as well as support the integration of sustainability concepts into existing courses as a major opportunity. Ultimately, the findings in this study (See Table 13) lead to a recommendation for HEIs to integrate sustainability into existing courses, which will help increases the opportunities for students in the general population to take at least 3 sustainability-related courses during their undergraduate experience. Doing so can significantly increase undergraduate student sustainability knowledge and help HEIs develop sustainability literate graduates.

Table 13. Summary of the main findings of this study, organized by research question and hypothesis.

Hypothesis	Finding
RQ1-H$_1$	*1:* There is a significant difference between average score of honors students after taking a sustainability curriculum and students in the general population. *2:* There is a significant difference between average score of honors students before and after they take a structured sustainability curriculum.
RQ1-H$_2$	*3:* There is not a significant difference between the scores of the Fall 2018 honors cohort, post 3-course curriculum and the Spring 2019 honors cohort, post 1-course curriculum. *4:* General students who take 3 sustainability courses score significantly higher than those who take 0, 1 or 2 courses. *5:* There is not a significant difference between the scores of honors and general students, after both taking 3 sustainability courses.
RQ1-H$_3$	*6:* There is not a significant difference between the knowledge scores of students in different colleges.
RQ1-Additional	*Additional 1:* There is not a significant difference between the knowledge scores of students in different years in school. *Additional 2:* There is a significant interaction between importance rating and number of sustainability courses taken in regard to sustainability knowledge score.
RQ2-H$_4$	*7:* General students and honors students both perceive lack of promotion, lack of time, and lack of relevance to major as major barriers.
RQ-H$_5$	*8:* General students and honors students both perceive integration into existing classes and creating a sustainability GE as major opportunities.

5.2 Academic Setting and Sustainability Knowledge

This study aims to fill the knowledge gaps and expand upon previous research regarding academic setting and student sustainability knowledge. The implications of the chosen sample populations are first discussed in order to address the potential confounding factors that come with sampling honors students and to help contextualize the discussion of the results.

5.2.1 Implications of Being an Honors Student

This research uses survey responses from students who take a structured sustainability curriculum, as part of the Cal Poly Honors program. While honors students do not have fixed-

characteristics and have much in common with non-honors students (Achterberg, 2005), there are

a few differences in academic characteristics of honors and general students that are worth

exploring to help in the explanation of findings. A few notable academic characteristics of honors

students that were not controlled for in this study include high-academic achievement, a proactive

approach to education, and potential personal interest in related topics.

One of the most important differences in academic characteristics, is that honors students

are typically academically high achieving students. In a study of a university-wide honors

program, open to students across all disciplines and focused on general education, honors

students who completed the honors program requirements had the highest academic performance,

highest graduation rates, and shortest time to degree completion compared to non-honors students

(Cosgrove, 2004). To be accepted in the Cal Poly Honors Program students must have at least a

cumulative high school non-weighted GPA of 3.75 (University Honors Program), which is not

necessarily the prerequisite that general students have to meet to get into Cal Poly. The middle

50% of first-year students admitted for Fall 2019, across all colleges at Cal Poly, had average

GPAs ranging from 3.96 to 4.25 (*First-Year Student Profile*). Like at Cal Poly, many HEIs might

accept students that are generally high-achieving, but Honors programs typically attract students

who are the top of their class and favor more academic rigor (Achterberg, 2005). This is typically

true of students in the Cal Poly Honors program. The fact that Honors Program students are

proactive in seeking out a structured set of curriculum to promote higher learning may be the

most defining characteristic of these students. It can also be argued that such academic

achievement is a product of the privileged learning environment that comes with electing a

rigorous program. For this discussion, a privileged learning environment refers to special honors

program attributes, such as smaller student to teacher ratios that lead to greater experience with

faculty (Achterberg, 2005), or having designated study rooms specifically for honors students

(University Honors Program). If all students had access to the same academic resources as honors

students, then perhaps there would be a smaller gap between the academic achievement of honors and general students.

Students who choose to apply for honors programs might already be interested in the specific topics and focus of their HEI's Honors Program, such as social justice or global issues. In one study, honors students were 2.5 times more likely to meet with a faculty member to discuss political, social, or world issued outside of class, compared to non-honors students (Shushok Jr, 2006). In the case of the Cal Poly Honors Program, students who are interested in sustainability, equity, social justice, and global perspectives might be encouraged to apply to the Honors program because of the year-long curriculum that focuses on these specific topics or because of the inclusion of sustainability in the program's learning objectives (University Honors Program). Being high-achieving students and having a personal interest in sustainability, with all of the honors students rating the importance of sustainability as a 3 or higher, can help explain why honors students have higher pre-curriculum scores compared to the scores of general students in most categories (See Table 6). Also, these characteristics might influence the post-curriculum score of honors students and play a role in how high they score on average. While some students may choose to enroll in the Cal Poly honors program for other reasons, it is still possible that students who enroll are predisposed to a higher interest in sustainability. Further analysis of potential confounding variables and of the differences between honors and general students is outside the scope of this research, however, the described characteristics are important to keep in mind for the following discussion.

5.2.2 Implications of Group, Test, Courses, and College

Previous research has focused on the impact of various curricular efforts on sustainability knowledge but has yet to identify the specific impacts of a structured sustainability curriculum on sustainability knowledge. H_1, H_2, and H_3 hypothesized that taking the Honors Program

sustainability curriculum, taking 3 or more courses, and being enrolled in CAFES, respectively, would all lead to significantly higher SKS.

The results of this analysis indicate that H_1 is accepted by showing that there is a significant difference between the average SKS of general students and honors students after taking a structured sustainability curriculum, specifically after the 1-course curriculum (See Table 12). Additionally, H_1 is supported by results showing a significant difference between honors student scores before and after they take the structured sustainability curriculum, specifically after the 3-course curriculum. While honors students in the 1-course curriculum have a higher average post-curriculum score, there is not a significant difference between the pre and post scores of these students, but this lack of significance between pre and post scores can be attributed to the Spring 2019 cohort having high pre-curriculum SKS. Interestingly, the average pre-curriculum scores of the Spring 2019 cohort is numerically higher than the average score of general students that take 3 or more sustainability related courses. This indicates that it would be difficult to duplicate the Honors Program experience for the general population, as Honors students have pre-existing sustainability knowledge that cannot easily be matched by general students, even after taking 3 or more courses. As discussed, there are multiple academic characteristics of honors students that can help explain high pre-curriculum SKS, such as being academically high-achieving students. However, additional research regarding student background and former academic experience is necessary in order to understand how honors students obtain high SKS prior to any structured sustainability curriculum.

Additionally, the Spring 2019 honors cohort has a higher average pre-curriculum score than Fall 2018 honors cohort, with the only known academic difference between these two honors cohorts being the timing of enrollment into the Honors program. While the actual explanation for this difference in pre-curriculum scores is unknown and requires further research, a possible reason is that students in the Spring 2019 cohort had two quarters of college before being tested,

which allowed time for personal research or involvement in sustainability-related organizations where they could gain related knowledge.

It is important to note the differences between the results of these two honors cohorts, and to also emphasize finding 3, which highlights that there is not a significant difference between the post-curriculum scores of the Spring 2019 and Fall 2018 honors cohorts. The findings reveal that honors students in the one-course curriculum, both score the highest on average and have similar scores to those in the three-course curriculum, without having to take two additional courses. These results suggest that for honors students specifically, one sustainability-related course is enough to improve SKS and achieve a high sustainability knowledge level. As honors students in the one-course curriculum came in with average higher SKS to begin with, leading to a lack of significance between pre and post scores, further research and increased sample sizes are necessary to confirm these results.

While the results from the honors cohorts begin to address H_2, by rejecting that students who take 3 or more courses have higher SKS than those who take less, these findings seem to be unique to honors students. However, the results from the general student sample indicate that H_2 is partially accepted. The results support H_2 by showing that students in the general population who take 3 or more sustainability courses score significantly higher than those that take 0 or 1 to 2 courses. Previous studies also show support for a higher number of courses to significantly increase sustainability knowledge (Lundquist et al., 2018). Specifically, a study at the University of Maryland came to the same conclusion that students who take 3 or more sustainability themed courses seemingly have more sustainability knowledge than those who take 2 or less (Horvath et al., 2013). These findings support the idea that for students not enrolled in the Honors Program, 3 or more courses represent the minimum number necessary to significantly increase student sustainability knowledge.

Further, there is a marginally significant interaction between number of courses and student sample group, meaning that the effect of number of courses on SKS depends on which

sample group a student belongs to, honors or general, and vice versa. For example, students that take 3 or more courses score significantly higher on average than those that take 1 to 2 courses, specifically when they are general students and not honors students. Similar to what has been discussed regarding honors students, however, general students who have elected to take 3 or more sustainability courses may also obtain higher SKS as a result of personal interest in the subject. In contrast, students in the Honors Program who take the one-course curriculum score higher, although not significantly higher, than students who take the three-course curriculum. While the results for the Honors Program are not significant, this is an unexpected finding. A potential explanation for this difference in findings between groups is the unique characteristics of honors students. Again, honors students are typically high achieving students that may only need one class to fully understand and retain sustainability concepts. On the other hand, general students might not immediately understand the concepts of sustainability, or the relation of sustainability to their field of study and may take longer to completely retain and learn sustainability concepts. To further explain these differences, additional research on potential confounding variables, such as the attributes of both honors and general students, and further testing with increased sample sizes of honors cohorts is necessary.

Further analysis of the interaction reveals that there is not a significant difference between the average scores of the honors students after taking the 3-course curriculum and general students after taking 3 or more sustainability courses. This means that after taking 3 or more courses in sustainability, general students have similar scores to that of honors students who take 3 structured sustainability courses. The major difference between these two groups, again, is that the general students have elected to take these courses, whether they count towards their degree or not, while honors students are required to take these courses as part of the structured Honors Program curriculum, which actually count towards their degree. As discussed, it is improbable that general students in a structured sustainability curriculum, similar to that of the Honors Program experience, would achieve as high of SKS as honors students. These results

suggest that a sustainability curriculum for students in the general population should include a minimum of 3 sustainability-related courses, but also can have a different design than that of the Honors Program and still be effective. While this result shows that 3 courses in sustainability do not have to be structured for high sustainability knowledge, there is currently a low percentage of general students taking 3 or more courses. As only about 11% of general students take 3 or more sustainability courses, there are still many students in the general population who are not reaching their potential for high sustainability knowledge.

Given that global education in sustainable development is a goal of the United Nations and that high sustainability knowledge is a learning objective of many HEIs, including Cal Poly, it would be in the university's best interest to help increase the number of students who take 3 or more sustainability courses in their undergraduate experience. In the case of sustainability knowledge at Cal Poly, honors students are provided with the opportunity to learn about a sustainability in a 3-course structured curriculum, while general students that are interested in sustainability choose to take a random set of classes in this field of study. By finding more creative ways to implement a sustainability curriculum and provide students with exposure to a minimum of 3 sustainability related courses throughout their academic career, the learning objective of having high sustainability knowledge can be met by larger majority of students, not just honors students and select general students.

As for the impact of college, previous studies have found a variation in student sustainability knowledge levels across disciplines. For example, a previous a study at the University of Maryland found that students in the College of Agriculture and Natural Resources scored the highest on a sustainability knowledge assessment compared to students in other colleges (Horvath et al., 2013), and a study at Iowa State University found that students in the College of Agriculture had significantly higher environmental knowledge than students in other colleges (O'Brien, 2007). It was expected that similar results would extend to SKS in the case of Cal Poly, as CAFES, in addition to several disciplines rooted in traditional agriculture, is home to

several disciplines rooted in environmental science and natural resources. As such, approximately 26% of all SusCat courses (*Sustainability Catalog*) are taught by faculty in CAFES. As courses within a student's own college are typically easier to enroll in and have the potential to be approved electives that count towards the student's degree, it would be expected that students with greater access to sustainability-related courses would potentially have higher SKS. However, the results of this analysis indicate H_3 is rejected and shows that students in CAFES do not have significantly higher SKS than those in other colleges. While the average scores of students in CLA, CAFES, COSAM, and CENG are numerically higher than that of OCOB and CAED (See Figure 7), these differences are not statistically significant. Also, interesting to note, CAFES has a relatively small 95% confidence interval that indicates relatively stable scores throughout the college, as compared to other colleges. CAFES is also the college with the highest percentage of students scoring an 8 or higher and the highest percentage of students scoring a 3 or below, which may signify that the scores within the college are not as stable as the confidence interval shows (See Figure 8). Perhaps these high and low scores can be explained by CAFES including both environmental disciplines that focus on sustainability and traditional agricultural disciplines that may lack acceptance of sustainability concepts. Overall, these findings fail to provide evidence that students in certain environmentally related, or agriculture related colleges have higher sustainability knowledge than those in other colleges.

While there is not a significant interaction between college and number of courses taken, about 24% of CAED student respondents and 18% of CAFES student respondents had taken 3 or more sustainability courses, compared to about 7% or less of student respondents from the other colleges. This shows that CAED and CAFES students may be more likely to take 3 or more sustainability courses. However, students in CAED had the lowest average SKS of all colleges. As a college in which 24% of the student respondents had reported taking 3 or more sustainability related courses, and in which 29% of the SusCat courses are held (*Sustainability Catalog*), CAED would be expected to have one of the highest average scores, if not the highest. However, it is

important to note that students in CAED were relatively underrepresented in the general student sample, accounting for only about 5% of the general student sample, but representing almost 9% of the undergraduate student population in Fall 2018 (*Common Data Set 2018-2019*). In order to understand if these results are truly a product of specific college-related opportunities, institutional limitations, or an unidentified factor, additional research is necessary.

Overall, in the case of Cal Poly, finding 6 provides support that university-level decision makers need to emphasize efforts that will facilitate the increase of student sustainability knowledge across all colleges. While a significant difference in sustainability knowledge was not found between students on a college level, there may be a significant difference at a discipline or major level, which could explain the instability of student scores within colleges. With a larger sample size of students within each discipline or major, further analysis can be done on this aspect of academic setting.

5.2.3 Implications of Additional Findings

Compared to this study, previous research has made contradictory findings regarding student year in school and environmental knowledge. For example, in an environmental knowledge survey at Michigan State University (MSU), findings suggest a positive correlation between academic level and environmental knowledge (Kaplowitz & Levine, 2005). In the case of MSU, academic level refers to freshman, sophomore, junior, or senior level, which generally matches the year categories in this study, 1st, 2nd, 3rd, 4th and 5th respectively. Similarly, a study at Iowa State University found a significant difference between environmental knowledge scores of students in different academic levels. Additionally, freshman students scored significantly lower than all other levels and senior students scored significantly higher than sophomore students (O'Brien, 2007). While these studies focus on environmental knowledge, similar results would be expected in regard to sustainability knowledge and year in school, or academic level. However,

the findings of this research show that, in the case of Cal Poly, there is not a significant difference between the SKS of students in different years in school. Additionally, an expected positive linear correlation between year in school and SKS is disrupted by third year students, who have higher average score than fourth year students. When looking at the demographics of students by year, third year students consist of a slightly higher percentage of students who had taken three or more sustainability related courses, while fourth year students consisted of a slightly lower percentage of such students. Again, general students who take 3 or more courses have a significantly higher SKS than those who take less courses (See Table 8), which could account for the variance from the expected scores of 3_{rd} and 4_{th} year students in the general student sample. However, there is not specific evidence in the data to completely explain this observation. Additionally, while there is not a significant interaction between year in school and number of courses taken, it is interesting to note that only 2% of the 1_{st} year respondents had taken 3 or more sustainability courses at the time of the survey, while 40% of 5_{th} year respondents had taken 3 or more courses. This shows that students in later years in school seem to be more likely to take 3 or more courses in sustainability, which makes sense as they have had more opportunities to enroll in courses and have had more time on enrolled at Cal Poly. Overall, there is still a lack of statistical support for the idea that students in later years in school have higher sustainability knowledge, but rather additional support for the idea that students in all years can benefit from additional university efforts towards increasing sustainability education.

The research findings highlight that there is a significant difference between SKS of general students with different ratings for the importance of sustainability (See Table 9). Students that rate sustainability as very important, a 4 or 5, score significantly higher than those that rate sustainability as less important. Also, those that rate the importance of sustainability as a 5 score significantly higher than those that rate the importance as a 4. Students that rate a 5 account for about 65% of the entire general student sample with relatively small sample sizes for those who rate the importance as less than a 5. These findings are not surprising as people who find

sustainability to be important would be expected to know more about sustainability, from either personal interest or just caring about the topic more. Those who rate sustainability as more important also may be able to recognize the importance of learning opportunities as related to sustainability and therefore have a higher likelihood of improving their SKS. These findings also concurs with previous research at Cal Poly, that a higher importance rating aligns with higher sustainability knowledge (Pompeii et al., 2019). It is also not a surprise that a majority of general students rated the importance of sustainability as a 4 or 5, but a majority of students still score below 7, not reaching a high SKS of 8 or higher. Similar to many HEIs having a theoretical dedication to sustainability that does not materialize into academics, students may have a theoretical dedication to sustainability, viewing it as an important topic, but lack actual knowledge and skills regarding sustainability. This additional finding emphasizes that general students find sustainability important and given the opportunity would likely improve their sustainability literacy scores, but do not seem to have the ability to take sustainability related classes and act on their beliefs.

The results of this research reveal a significant interaction between importance rating and number of courses taken, meaning that the effect of courses taken on SKS depends on the effect of importance rating, and vice versa. For example, general students who take 3 or more courses in sustainability tend to have a higher SKS if they rate sustainability as important (3, 4, 5), while those that that rate sustainability as less or not important (0, 1, 2) tend to score lower. Despite a small sample size of students who take 3 or more courses and rate the importance of sustainability as low (n = 4), this shows that while general students can gain sustainability knowledge by taking more sustainability courses, students also need to believe that sustainability is important, which is considered to be an aspect of attitude and perceived value. As self-motivation is a product of attitude and perceived value (Mubeen & Reid, 2014), it can be considered a powerful tool for sustainability education. Additionally, a previous study at Iowa State University regarding environmental knowledge found a positive correlation between positive attitudes towards

environmental issues and environmental knowledge levels (O'Brien, 2007). Students with

positive attitudes toward a subject, such as sustainability, can be welcoming and more open to

new ideas and information, helping to facilitate learning. As about 96% of general students rated

the importance of sustainability as a 3 or higher, a majority of general students have the potential

to significantly increase their SKS if they take 3 or more courses in sustainability.

5.3 Academic Setting and Perceived Barriers and Opportunities

As previously mentioned, understanding the barriers to implementing sustainability into

academics can help HEIs overcome sustainability-related challenges (Blanco-Portela et al., 2017).

In addition to identifying barriers, identifying potential opportunities to implementing

sustainability into academics can help inspire an action plan towards tangible change at HEIs.

5.3.1 Implications of Perceived Barriers

The prior study at Cal Poly found that students in both "low" and "high" sustainability

knowledge groups most frequently stated accessibility, time constraints, and neglect, or personal

disinterest in the subject, as barriers (Pompeii et al., 2019). As taking a structured sustainability

curriculum makes sustainability courses easily accessible and fits the courses within general

education requirements, honors students were hypothesized to diverge from the findings of the

previous study. H_4 hypothesizes that honors students would not perceive time and accessibility as

main barriers to implementing sustainability into academics, however, the research findings show

that general students and honors students both perceive lack of promotion, lack of time, and lack

of relevance to discipline as major barriers to implementing sustainability into academics. Similar

to the previous study, students with both relatively lower and higher sustainability knowledge,

general students and honors students in this case, both perceive the same top 3 barriers to

implementing sustainability into academics. Time constraints, or lack of time, is the only main

perceived barrier that is common between the current and previous study. This emphasizes that students either do not know how to or do not want to fit sustainability courses into their course schedules. In both scenarios, time constraint is considered an individual barrier, rather than an institutional barrier. If students do not prioritize sustainability and try to fit sustainability-related courses in their schedules, then they will be less likely to take the courses. Again, while a structured sustainability curriculum which counts towards general education requirements would be expected to reduce this barrier, honors student results lack clarity as time constraints was identified as the second most important barrier. Perhaps honors students felt like they did not have time for additional courses on top of what they already are required to take. Additional research is required to see if honors students felt like time was a constraint during the pre-curriculum survey, knowing that they had sustainability courses already fit into their schedule.

As mentioned, students also commonly perceive lack of relevance to discipline or major as a barrier (See Figure 13). These results show that students may believe that sustainability is important but may not clearly understand how sustainability is directly related to their line of work. This may be due to the fact that a majority of students do not recognize the economic and social aspects of sustainability. Many students may only associate sustainability with the environment itself, lacking a fundamental understanding about sustainability, the three pillars, and its relation to a multitude of disciplines. With that being said, students who currently do not have access to sustainability-related courses in their department or major, an institutional barrier, will likely not be able to comprehend the relevance of sustainability, and its three pillars, to their discipline. At Cal Poly, students in colleges with greater access to sustainability-related courses seem to choose relevance as a barrier less often than those with lesser access. For example, CAFES is home to 26% of all SusCat courses and only 25% of the CAFES student respondents choose lack of relevance as a barrier, while OCOB holds only 4% of all SusCat courses and 51% of these student respondents chose lack of relevance as a barrier. However, inclusion of the three pillars of sustainability in major-specific courses, such as in business courses, and promotion of

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the economic and social aspects within sustainability education in general, can potentially help students understand the relevancy of the concepts to their own disciplines. Additionally, as honors students also perceive this as a major barrier, perhaps the sustainability curriculum needs to specifically include information about why sustainability is applicable to everyone and in every field of study.

Different from the previous study, the current study shows that students commonly perceive a lack of promotion as a major barrier. While the Cal Poly SusCat is open to the public online, it is not well-promoted when students register for courses each term. This is an institutional barrier that prevents students from even knowing that sustainability related courses are an option for them. Additionally, in order to list a course on the SusCat, faculty members must be self-motivated to initiate the process, which adds another barrier. A recommendation is to have a committee reach out to faculty members and work to ensure that all sustainability courses that are offered, are accounted for on the list. Again, while students perceive sustainability to be an important concept, and may want to learn more about it, they are not necessarily given the tools or all the information to do so. However, another possible reason why lack of promotion could be seen as a major barrier is because students may not pay attention to sustainability-related news. If students do not understand the relevance of sustainability to their major or discipline, then they may not be paying attention to sustainability-related promotion.

In regard to the barriers with different observed versus expected values, all notable differences were in the honors student group. It is unsurprising that none of the honors students perceived not caring about sustainability as a barrier as none of them rated the importance of sustainability as less than 3. Also, honors students know how to find sustainability courses more than expected perhaps as a result of having extra resources or guidance from the Honors Program. However, honors students perceive elective constraints as a barrier significantly more than what would be expected for the honors group under a normal distribution. This again could be a result of honors students having already taken sustainability courses, feeling unable to take more

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sustainability courses on top of what has already been completed as required by the Honors Program. Another potential explanation is that due to the design of the Honors Program, honors students, who have to take at least 5 honors program electives (*University Honors Program*, 2020a), do not have elective units available within their program of study to continue to explore their interest in sustainability through academics. While these were all notable differences for honors students, they were not the main perceived barriers of either group. The following discussion of perceived opportunities will be tailored to address the main perceived barriers specifically.

5.3.2 Implications of Perceived Opportunities

The previous study found that students in both "low" and "high" knowledge groups perceived promotion, integration into existing classes, and inclusion of a GE option as major opportunities to implementing sustainability into academics, with including a GE requirement as a less frequently chosen opportunity (Pompeii et al., 2019). As honors students take a structured sustainability curriculum, it was expected that these students would perceive including a required sustainability GE as the best option. However, the findings only partially support H_5 and emphasizes that both honors and general students most frequently chose integration into existing courses as the main opportunity to implementing sustainability into academics, followed by making sustainability a GE requirement and advising how sustainability education relates to career opportunities. While implementing a sustainability GE is a top opportunity perceived by undergraduate students, it is not the most feasible option as creating a new general education requirement not only has institutional barriers, but state-wide barriers. Additionally, the knowledge scores of general students are not significantly higher after taking just one course, compared to taking zero courses. As a result, the recommendation for a single sustainability GE

course is not supported by this study, rather a sustainability curriculum which includes a minimum of three courses.

Ultimately, the results highlight that integration into existing courses is the best opportunity to implementing sustainability into academics. This perceived opportunity can overcome the perceived major barrier of time constraints, and eliminate the perceived barrier of lack of promotion, as the information would already be woven into existing courses that students would take anyways. Weaving sustainability information into existing courses for each discipline or major also incorporates the opportunity of advising how sustainability education relates to specific careers and career opportunities. Having sustainability in major-related courses will help implement both opportunities and also address the perceived barrier of not seeing the relevance of sustainability to specific majors or disciplines. Students can perhaps start to see why sustainability is relevant to their field of study and future work, starting to take a personal responsibility and understanding that sustainability related challenges are not only the responsibility of sustainability-focused students, but of everyone.

Further, integrating sustainability into existing courses can increase the opportunity for sustainability education, in which a majority of general students can take a minimum of three sustainability-related courses throughout their undergraduate education. However, weaving sustainability concepts into existing courses can be difficult and requires more effort from faculty to first learn about sustainability themselves, then to incorporate the concepts into the curriculum. To make this a more attractive option for faculty, HEIs can help by providing and promoting faculty resources to incorporate sustainability into course syllabi. At Cal Poly, faculty resources currently exist and can be tailored to emphasize sustainability. For example, the Center for Teaching, Learning, & Technology (CTLT) is a teaching support team at Cal Poly that provides workshops and programming for educators to meet their teaching goals and overcome challenges. If university-level decision-makers and directors of the CTLT emphasize sustainability in their workshops and programs, then educators will be provided the tools and skills necessary to

incorporate sustainability into existing courses. By increasing the opportunity for undergraduate students to take a minimum of 3 sustainability related courses, by weaving sustainability into existing courses, HEIs can help reach the goal of increasing overall undergraduate SKS.

While this particular study, through the findings regarding sustainability knowledge, largely supports the implementation of integrating sustainability within existing course offerings and major requirements, this does not mean that multiple actions should not be pursued in sustainability education. Previous research has even called for a combination of best practices when implementing sustainability within academics. For example, one study supports the inclusion of graduation course requirements, 1st year education, and interdisciplinary education as part of a comprehensive strategy for including sustainability education at HEIs (Stewart, 2010). However, because of the nature of the survey data, further analysis of other potential best practices, other than a sustainability curriculum which includes a minimum of 3 sustainability-related courses supported by the integration of sustainability into existing courses, is outside the scope of this study.

Chapter 6

CONCLUSION

The findings of this research indicate that Cal Poly undergraduate students that take a 1-course structured sustainability curriculum, in the Honors Program, have significantly higher SKS compared to the general population of students who do not choose to take a course of study in sustainability, and are not required to do so by the university. The results also show that honors students have high pre-curriculum SKS that make it improbable to achieve the same level of high SKS if the Honors Program experience was simply duplicated for general students. However, the findings reveal that there is not a significant difference between honors students that take a structured set of three sustainability courses and students in the general population who choose to take 3 or more sustainability related courses. That being said, currently only a limited number of students in the general population voluntarily choose to take 3 or more sustainability related courses within their undergraduate experience. This suggests that, while honors students may only need to take 1 sustainability-course, university efforts need to be made to increase the number of students in the general population that take 3 or more sustainability-related courses in their undergraduate experience. Results of the analysis also reveal that there is not a significant difference in scores based off of a student's college of enrollment of year in school. This suggests that sustainability education should be provided for students in all colleges and all years in school.

The results of the analysis also indicate that there is a significant interaction between two variables, 1) ranking score for the importance of sustainability and 2) the number of sustainability courses students take. These results show that students who rank the importance of sustainability as high and take 3 or more sustainability-related courses, tend to achieve a higher SKS. The data also shows that a majority of students perceive sustainability to be important, which means that if these students were to take 3 or more sustainability courses, they would have the potential to

significantly increase their SKS. This suggests that university-level decision-makers need to implement efforts that increase the opportunities and likelihood for general students to take a minimum of 3 sustainability-related courses in their undergraduate experience.

Analysis of perceived barriers and opportunities to sustainability education show that students in the general population and honors students perceive similar top barriers and similar top opportunities to implementing sustainability into the curriculum. Students perceive time constraint, lack of relevance to major, and lack of promotion as barriers to sustainability education. On the other hand, students perceive integration into existing courses and creating a sustainability GE as potential opportunities to implement sustainability education. As the most frequently selected opportunity and as a way to reduce or eliminate all top barriers, these results support the integration of sustainability into existing courses as a way for more undergraduate students to take a minimum of 3 sustainability-related courses in their undergraduate experience.

The overall recommendation for the integration of sustainability into existing courses, with the aim of all students taking at least 3 sustainability-related courses, is considered a highly effective design for sustainability education and a desired best practice for increasing students' level of sustainability knowledge. However, this recommendation is also acknowledged as just one part of the bigger picture of sustainability at HEIs. While university efforts can be tailored to providing resources to faculty to encourage implementation of sustainability concepts into existing curriculum, this is not the single solution to the challenge of sustainability education. A single program or effort cannot solely help students become sustainability literate, global citizens. Rather, this study emphasizes taking the first step towards creating sustainability-literate, global citizens through integration of sustainability concepts, a highly effective opportunity that reaches a majority of students and focuses on increasing sustainability knowledge.

Continued research of the impact of integrating sustainability into existing courses, in addition to the impact of other sustainability-related curricular efforts, can further help HEIs determine the best path towards implementing sustainability in academics. The current study can

be built upon by a future assessments at Cal Poly or other HEIs, with a few changes and an update to the assessment (See Appendix A. Survey). As mentioned, one of the demographic questions asked for a self-assessed number of sustainability-related courses. This type of "self-assessed" demographic question is subjective and answered based off students' personal definitions of what they believe sustainability-related courses are. While other sustainability assessments have used self-reporting and similar subjective wording when asking about the number of sustainability-related courses students have taken (Horvath et al., 2013), a more objective measurement is recommended. A more objective measurement that asks students to choose from a verified list of sustainability-related courses, such as the Cal Poly SUSCAT, can ensure a more reliable number of sustainability related courses students have taken while at Cal Poly. Additionally, it is possible that student respondents that fall under the "Other" college category might have chosen to categorize themselves under only one college, rather than choosing the two colleges that their major falls under. While this does not necessarily confound the results, it leads to the lack of representation of the "Other" category. To get an accurate representation of students in this category and to perform a more detailed analysis on students by college, perhaps future assessments can specify what the "Other" college category includes. Another alternative is to simply ask for a student's major and to later group them into colleges. As for year in school, it might be best to ask students to report their academic level, ranging from freshman to senior undergraduate standing. As the current study uses year in school, which doesn't directly correlate to academic level, altering the question would allow for comparison of results versus other studies that use academic level as a variable. For example, a student at Cal Poly could be in their 1_{st} year in school, but have sophomore standing, whereas students in their 2_{nd} year in school are typically of sophomore standing. Additionally, in order to have fully comparable results to across HEIs, it may be in the best interest of AASHE to develop a standardized way of assessing student sustainability literacy.

After integrating sustainability into existing courses at Cal Poly, with the help of the CTLT and faculty efforts, an additional assessment using an updated survey is recommended to further understand the implications on general student knowledge and to gauge further opportunities for progress in sustainability education. To design an ideal curricular structure for sustainability education, further research at other institutions is necessary to supplement the findings of the current study at Cal Poly. Similar research regarding undergraduate sustainability knowledge and perceptions of sustainability education at other institutions can help unify the network of HEIs with the same goal of developing sustainability-literate graduates.

Ultimately, creating sustainability education for all students, by integrating sustainability into existing courses, is just the beginning of many tangible actions to be taken towards long-term and comprehensive sustainability efforts at HEIs. University-level decision makers should begin to design such sustainability education that increases the number of students in the general population that take a minimum of 3 sustainability-related courses. Doing so can help in the materialization of the university's theoretical dedication to sustainability in academics for all students.

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PUBLICATION PLANS

This professional project will be published by California Polytechnic State University, San Luis Obispo at the library and online in the Digital Commons. Also, the results will be written into a manuscript to submit to sustainability related or higher education specific journals.

A. Survey

INFORMED CONSENT
What college are you in?
Are you in a second college?
Major:
Major not listed? Fill in here:
Second Major:
Minor:
Year at Cal Poly (choose one):
Are you a transfer student?
Gender:
Gender: Comments
Permanent zip code:

1. Define Sustainability:
    - Protecting the environment
    - Ensuring the needs of today are met without harming the ability of future generations to meet their needs
    - Reducing, reusing, and recycling
    - Providing resources to those in need
    - I don't know

2. Arrange the following four activities in order from largest environmental impact to smallest environmental impact: W. Keeping a cell phone charger plugged into an electrical outlet for 12 hours X. Producing one McDonald's quarter-pound hamburger Y. Producing one McDonald's chicken sandwich Z. Flying in a commercial airplane from Washington D.C. to China
    - W, Y, X, Z
    - Z, W, X, Y
    - Z, Y, X, W
    - Z, X, Y, W
    - Don't know

3. What factors influence the human population's impact on Earth?
    a. Size of the population
    b. Amount of materials used per person
    c. Use of technology that lessens our impact
    d. A, B, and C
    e. A and B
    f. B and C
    g. A and C
    h. Don't know

4. Which of the following is a leading cause of the depletion of fish stocks in the Atlantic Ocean?
   - Fishermen seeking to maximize their catch
   - Reduced fish fertility due to genetic hybridization
   - Ocean pollution
   - Global climate change
   - Don't know

5. Which of the following statements about water is true?
   - Globally, water for personal use such as washing dishes, doing laundry, and bathing is the major user of water resources.
   - , doing laundry, and bathing is the major user of water resources.
   - Globally, freshwater reserves (aquifers) are used faster than they are replenished.
   - Floods and severe weather will increase the availability of clean drinking water.
   - Because water is a free and abundant resource, it is not a major concern for most countries.
   - Don't know

6. Of the following, which would be considered living in the most environmentally sustainable way?
   - Recycling all recyclable packaging
   - Reducing consumption of all products
   - Buying products labeled "eco" or "green"
   - Buying the newest products available
   - Don't know

7. Imagine that we had to pay for all the costs associated with the goods we use every day. What would go into calculating the true costs of a product?
   - The cost of raw materials to make the product
   - The cost of environmental damage caused by production
   - The cost of healthcare for employees who manufacture the product
   - All of the above
   - Don't know

8. Which of the following best characterizes sustainability?
   - Social Justice
   - Environmental Stewardship
   - Economic Security
   - All three
   - Don't know

9. Define economic sustainability:
   - Distributing money and resources equally so that all can obtain basic human needs
   - Distributing money and resources based on what people can afford to buy
   - Eliminating money from the world so as to wipe out all greed

- When cost equals revenue
- I don't know

10. Which of the following is an example of social sustainability?
    - Corporations build factories in developing countries where environmental laws are less strict
    - The government dams a river, flooding a rural community, in order to generate hydropower for a nearby metropolitan area
    - Urban citizens pass a bill to have toxic waste taken to a rural community
    - Indigenous community is involved in setting a quota for the amount of wood that can be taken from a protected forest near their village
    - I don't know

11. How important do you think sustainability is? Not Important 0 1 2 3 4 5 Very Important

Additional Comments:

12. How important do you think it is to include sustainability learning in the Cal Poly classroom? Not Important 0 1 2 3 4 5 Very Important

Additional Comments:

13. How well does Cal Poly teach sustainability? Not Important 0 1 2 3 4 5 Very Important

Additional Comments:

14. What are some ways to infuse sustainability education in the classroom at Cal Poly? (Chose up to 3)
    - Better marketing of sustainability classes
    - Integrate sustainability topics into already existing classes
    - Offer more sustainability classes in major
    - Make sustainability a GE requirement (would not increase number of required units)
    - Advise how sustainability education relates to career opportunities
    - The university should make it a priority by allocating more funds to sustainability education
    - Professors should allocate more time to sustainability education
    - Add first year sustainability education opportunities
    - I don't think we should make sustainability education more accessible
    - Other, Explain:

15. What prevents you from receiving more sustainability instruction at Cal Poly? (Chose up to 3)
    - I don't have enough time
    - It doesn't fit with my major or academic goals
    - I don't care about sustainability
    - I don't know how to find the courses
    - Cost
    - I don't have enough electives
    - Cal Poly does not offer enough sustainability courses
    - Courses are not well promoted
    - Professors lack motivation
    - Professors lack competency in subject

- The university does not prioritize funding
- Other, Explain:

16. During your time at Cal Poly, how many courses have you taken that address the topics presented in this survey?
    - 0
    - 1-2
    - 3 or more

OPTIONAL: In what way(s) might Cal Poly better engage students in discussion and making decisions about what sustainable practices might be promoted on campus?

B. Definitions

Sustainable Development

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987)

Sustainability Literacy

"The knowledge, skills, and mindsets that allow individuals to become deeply committed to building a sustainable future and assisting in making informed and effective decisions to this end" (United Nations, 2018)

Structured Sustainability Curriculum

A single or series of sustainability-focused courses required for students to meet graduation requirement, which aim to develop fundamental and foundational student sustainability knowledge, awareness, and interest

High Sustainability Knowledge

The positive progress of student sustainability knowledge by the time that they leave their undergraduate university, rather than a threshold it is based off of statistical significance

C. Abbreviations

HEIs – Higher Education Institutions

Cal Poly – California Polytechnic State University, San Luis Obispo

SKS – Sustainability Knowledge Score(s)

AASHE – Association for the Advancement of Sustainability in Higher Education

STARS – Sustainability Tracking, Assessment, and Rating System

SusCat – Sustainability Course Catalog

CAFES – College of Agriculture, Food, and Environmental Sciences

CAED – College of Architecture and Environmental Design

CENG – College of Engineering

CLA – College of Liberal Arts

OCOB – Orfalea College of Business

COSAM – College of Science and Math