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Identifying and Overcoming Barriers to Integrating Sustainability across the Curriculum at a Teaching-Oriented University

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Abstract: This research collects and analyzes student and faculty knowledge and perceptions toward sustainability education at a predominately undergraduate, teaching-oriented university. In-depth, qualitative methods distinguish low- and high-knowledge student and faculty cohorts, identify perceived barriers to sustainability education in each cohort, and recognize strategies to overcome the barriers identified by each cohort. Data collected from recorded and transcribed semi-structured interviews of student and faculty subjects underwent analysis via repeated readings to uncover key themes. Results required developing metrics for student and faculty sustainability knowledge and attitudes across disciplines, determining discipline-specific gaps in sustainability knowledge and differences in attitudes, and relating implementation barriers to general or specific knowledge gaps and attitudes. Findings identified low and high levels of sustainability knowledge within the student and faculty subject population and revealed barriers in pursuing interdisciplinary sustainability curricula across disciplines and among both students and faculty at the study university. Overall, higher sustainability knowledge participants tend to identify barriers related to institutional accountability while lower sustainability knowledge participants tend to identify barriers related to personal responsibility. Distributing barriers and solutions along a continuum from personal responsibility to educational institution responsibility reveals more recognition of barriers at the personal level and more solutions proposed at the institutional level. This result may reflect a common tendency to deny personal responsibility when addressing sustainability challenges.

Keywords: sustainability education; qualitative research; interviews; implementation barriers

1. Introduction

1.1. Context and Background

This research contributes to the broadening understanding of impediments to integrating sustainability education into higher education. Prior studies have investigated structural conditions ranging from educational priorities to disciplinary silos to competing values [1,2]. This study seeks to understand the relationship between a level of sustainability knowledge and perceived barriers to integrating sustainability-based instruction in higher education. Specifically, this project explores the perceptions of students and faculty regarding issues of sustainability education and identifies potential barriers to implementing the teaching and learning of sustainability at the university. As such, this study identifies barriers and solutions to the implementation of sustainability among different sustainability knowledge groups of faculty and students.

The focus institution is California Polytechnic State University, San Luis Obispo (herein referred to as Cal Poly). As a non-PhD granting and predominantly undergraduate university, Cal Poly enrolls approximately 22,000 students in six colleges with an emphasis on hands-on pedagogy to prepare students for the job market and "success in a global economy" [3]. Work aimed at advancing sustainability education and curricula at the university accelerated with the university's signing of the Talloires Declaration in 2004 [4,5]. The resulting action plan committed Cal Poly to "sustainability and environmental literacy in teaching, theory, and practice". The university took steps to advance this plan with the establishment of the Sustainability Learning Objectives (SLOs). The SLOs promote the idea that all graduating students should have some knowledge of fundamental sustainability principles. The Academic Senate Resolution 688-09 establishing the SLOs states [6]:

"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."

In 2014, the California State University (CSU) sought to further advance sustainability education for all its campuses (including Cal Poly) when it updated its sustainability policy [7]. The policy states that the "CSU will seek to further integrate sustainability into the academic curriculum working within the normal campus consultative process." Cal Poly more recently signed the Second Nature Climate Commitment, stating that "Cal Poly is committed to achieving carbon neutrality and climate resilience as soon as possible, and is infusing this work into curriculum, research, and student experience."

To support the advancement of sustainability education on campus, the Center for Teaching, Learning, and Technology at Cal Poly formed an interdisciplinary faculty learning community in 2016 focused on "Teaching Sustainability Across the Curriculum." This faculty group, representing four of six academic colleges, works to improve students' sustainability learning through the creation and promotion of educational experiences based on current best practices. Within the group discussions, anecdotal evidence and faculty experiences pointed to a consensus that implementation of sustainability goals was at best limited in the current campus climate, despite ongoing institutional efforts. Therefore, a campus-wide survey was proposed to assess student and faculty sustainability knowledge and awareness in order to make more informed future decisions.

Concurrent with the development of the survey, Cal Poly applied for certification through AASHE/STARS (Association for the Advancement of Sustainability in Higher Education/Sustainability Tracking, Assessment and Rating System) receiving a silver rating (62.57 of 100 possible points) in February 2017. This rating considers six domains of university sustainability: Institutional

characteristics, curriculum and research, engagement, operations, planning and administration, and innovation and leadership. Cal Poly received only 28.13 of 40 possible points in the curriculum section, with two notable curricular areas contributing to this result—the lack of sustainability-focused and -related academic courses available (6.13 of 14 points) and the absence of assessment of sustainability literacy (0 of 4 points). The results indicate that only 4.9% of courses at Cal Poly are considered sustainability course offerings. Zero points were scored in the category of sustainability literacy assessment, because, at the time of submission, an annual assessment of students' sustainability knowledge did not exist. These scores reveal that while Cal Poly has theoretically dedicated itself to sustainability education, it is unclear how related policies and commitments materialize within the curriculum.

This study seeks to understand how the perception of barriers to and solutions for the integration of sustainability in teaching and learning correlates with sustainability knowledge, in order to identify opportunities for improving sustainability education. To achieve this goal, students and faculty from across the six colleges were assessed using qualitative methods to determine in-depth understanding of both sustainability knowledge and the identification and overcoming of barriers to integrating sustainability in higher education curriculum.

1.2. Literature Review

Multiple studies reported in sustainability education literature contribute to the integration of sustainability in the curriculum [8–10]. Although the need to assess sustainability across campus has been emphasized [11–13], former studies fall short either at pointing to a precise method of assessment or taking into account the context of sustainability knowledge. The literature does, however, reveal that sustainability learning outcomes can vary greatly even within environmental based courses and suggest further research on disciplines and majors that have historically been on the periphery of sustainability education [14]. An immense survey-based, quantitative study in European higher-education institutions also investigated the relationship between different pedagogical approaches and learning outcomes or competences. Results found that none of the competences examined were likely to address sustainability in any three of its dimensions (economic, social, or environmental) [15].

The literature identifies barriers internal to universities that prevent infusing sustainability: Financial constraints, lack of understanding and awareness of sustainability, resistance to change, and difficulty achieving a "coherent institutional approach, where operations, teaching, research, and outreach are synergized" [16]. The literature contains several examples of how silos in academia tend to act against infusing sustainability. According to Miller et al. [17], academic institutions typically organized around scholarly disciplines lack the "epistemological pluralism and reflexivity" required producing sustainability knowledge characterized by "social robustness, recognition of system complexity and uncertainty, acknowledgement of multiple ways of knowing and the incorporation of normative and ethical premises." Others also state that academic silos represent the most insidious barrier, because specialization helps to isolate faculty and "prevents the systems-level integration required to embed sustainability" [16].

Beyond silo-ing, other institutional level barriers have been identified, including institutional priorities and external pressures [18]. For example, perceptual barriers include the competition for funds on campus, the commodification of education, and the exclusion from any faculty evaluation criteria [2]. Institutional barriers to the comprehensive adoption of sustainability in higher education curriculum also include differences in understanding of the concept of sustainability and challenges of working across all areas of university structure [19]. An evaluation of faculty participation in the University of Vermont's Sustainability Faculty Fellows program examined the impact of a funded faculty learning community focused on enhancing sustainability curricula across disciplines [20]. Results identified the largest barriers for faculty included: A packed curriculum, lack of planning

time, lack of department support, difficult to integrate into content, lack of content knowledge, lack of learning activity resources, and class size [20].

Arizona State University's School of Sustainability provides an example of an approach where an institution successfully applied an adaptive cycle to create a sustainability program emphasizing "interdisciplinary collaboration and community engagement" [17]. The literature offers several approaches to distinguish individual from institutional responsibilities towards infusing sustainability. A proposed sustainability compass depicts five axes of individual and institutional elements required to foster sustainability knowledge [17]. Similarly, Sterling's model for integrating sustainability in education distinguishes "bolting-on" by adding separate sustainability courses from the deeper level of integration via "building-in", which educates for sustainability by teaching sustainability issues in discipline-specific courses [21,22].

Our research is built on broad based projects like Lozano et al. [15] with an in-depth textured analysis of student and faculty experiences, in order to examine a level of sustainability knowledge in relation to the identification of barriers and solutions to further integrate sustainability into the curriculum. This approach involves categorizing interview participants' responses based on their level of knowledge in sustainability.

2. Materials and Methods

Given the lack of existing data on sustainability knowledge among Cal Poly students and faculty, qualitative methods were deemed the most appropriate for data collection and analysis. Data were collected using semistructured interviews [23], in which a set of open-ended questions were prepared to guide the interview process but might be asked in a particular order or format. Interview questions were designed to gauge each participant's general sustainability knowledge and behaviors, to assess how sustainability is approached as a learning objective across disciplines, and to identify potential barriers to teaching sustainability across the curriculum. A total of 17 faculty and 39 student interviewees from six colleges at Cal Poly (i.e., agriculture, architecture, business, engineering, liberal arts, and science and math) voluntarily participated in this survey. Students were recruited from large general education (GE) courses within a variety of disciplines and provided minimal assignment extra credit incentives for participation. The large GE courses chosen were defined as courses with over 125 students where all academic departments were represented in the possible student pool. Recruitment announcements were made in four such classes. Third-year and fourth-year students were specifically targeted as they would have more class experience to draw upon.

There are several qualitative data collection practices for conducting interviews based on what type of data the researcher wants to collect [24,25]. This project used a purposeful interview sampling technique, which has been recognized as a powerful tool to capture empirical relationships between different groups of the data [26]. In qualitative research, sample size has been shown to be less important when the participants have personal experience with the project subject, when small numbers of participants are studied intensively, and when the type of participants are chosen purposefully [27]. Moreover, this is not a hypothesis-based study, and the selected method does not aim for deriving statistical significance to test any predeveloped hypothesis. The responses from the semistructured interviews provided considerable data for analysis, including over 10 h of recorded transcripts, which serves the purpose of the study despite the small sample size for both students and faculty.

2.1. Interview Design and Implementation

Interviews were conducted by a small team of student researchers. Prior to commencing data collection, all student researchers participated in an in-depth training session with faculty researchers to ensure interviewer consistency. The same faculty researchers were present during all interviews to further ensure consistency and maintain rigorous oversight of data collection. Each interview took approximately 10–20 min to complete. All interviews were audio-recorded and transcribed. The transcripts were individually coded for emergent themes using a grounded theory approach [28].

This approach allows the researchers to determine patterns on how interviewees perceive sustainability in academia. Coding and analysis relied primarily on assessment by three faculty researchers with experience in qualitative methods to ensure inter-rater reliability. The semistructured interviews were designed to assess each participant's knowledge of, perceived importance of, and exposure to sustainability concepts and practices, with the following questions guiding that conversation:

- How do you gauge your own knowledge on sustainability?
- How do you define sustainability?
- How important do you think sustainability is? Why do you think that?
- Do you think sustainability learning is important to include in the Cal Poly curriculum?
- How does Cal Poly teach sustainability?
- What courses have you taken that discuss sustainability or focus on sustainability? (Students).
- What courses have you taught that present information on sustainability? (Faculty)
- What prevents you from receiving more sustainability instruction at Cal Poly? (Students).
- What prevents you from providing more sustainability instruction at Cal Poly? (Faculty).
- What are some ways to make sustainability education more accessible at Cal Poly?

2.2. Transcript Analysis

The stage of analysis in this study was conducted by utilizing several established techniques. Ryan and Bernard (2003) list several techniques for identifying themes when analyzing qualitative data [29]. Interview transcripts were analyzed for the following themes: Repetitions, indigenous typologies or categories, similarities and differences, missing data, and theory-related material. Recognizing repetitions is one of the most commonly used procedures for identifying themes in interviews [30–32]. Multiple, collaborative readings of the transcripts allowed for the identification and marking of statements that succinctly characterized the repeated themes.

Data analysis relied on coding, an iterative methodology identifying text "that captures and signals what is going on in a piece of data in a way that links it to some more general analysis issue" [33]. Coding schemes provided a framework for identifying emergent themes linking specific data points to the broader concepts under investigation. Following the development of a coding scheme, analyses were then incorporated to identify emergent themes, derive explanations, and actionable responses related to main research objectives [33,34]. In this study, data analysis was conducted by multiple researchers in order to avoid interpretive bias from a single researcher in the coding process, thereby gauging inter-rater reliability and establishing qualitative rigor [35,36].

Transcription analysis consisted of three phased readings. The entire interdisciplinary research team carried out an initial reading to develop a tentative, emergent coding scheme based on the repetition of certain ideas. A second reading was carried out with a smaller group of three researchers, each with expertise in qualitative methodologies. During the second reading, each researcher first coded each transcript for level of sustainability knowledge. These researchers then engaged in group discussions that gauged and normalized transcripts for either high or low sustainability knowledge. The same three qualitative researchers then completed a third reading, individually coding the text according to the coding scheme developed by the entire research team, then analyzing codes for emergent themes related to barriers or solutions. The researchers then engaged in group discussions to reach consensus on the key actionable emergent themes. Data saturation was achieved, indicating that further interviews would have produced similar results [37].

3. Results

All participant responses were reviewed and analyzed for determining high or low level of sustainability knowledge through analysis of the introductory questions "How do you gauge your own knowledge of sustainability" and "How do you define sustainability?" A high or low level of sustainability knowledge was determined through phased readings and defined through

researcher congruence. Researchers referenced common definitions of sustainability including: Cal Poly's definition of sustainability "the ability of the natural and social systems to survive and thrive together to meet current and future needs", the Brundtland Commission's statement on sustainable development "meeting the needs of the present without compromising the ability of future generations to meet their needs", and references to the 'three Es—Environment, Equity, Economy'. High knowledge had a relatively low threshold for connection with agreed-upon definitions. Any mention of a broad understanding of sustainability was rated as high. When identified according to the structure of observed learning outcomes (SOLO) taxonomy, high knowledge responses contain multistructural, relational, or extended abstract statements, whereas low knowledge responses operate at the prestructural or unistructural levels [38]. Thus, participants responding with general or greater information implying broader or more comprehensive perception to the question "How do you define sustainability?" were defined as "high". Responses indicating a high level of sustainability knowledge included:

"Meeting the needs of the present without compromising the ability to meet the needs of the future"

" . . . it's the practice or philosophy that resources should not be used up so that any kind of practice or any materials that are used, should be used in such a way that the resource doesn't get depleted for the foreseeable future or for infinity."

"Sustainability has to do with making sure that the way that humans live, the resources we use . . . the inputs and outputs of our society are things that could continue for thousands of years without a problem."

Responses demonstrating a low level of sustainability knowledge were those that did not recognize a larger philosophy or were simply unrelated to the question asked. For example, if responses simply eluded to activities such as recycling or driving hybrid cars, these would be classified as low knowledge. Of the 39 student responses, 22 were noted as having a high level of sustainability knowledge, and 17 were noted as having a low level of sustainability knowledge. Of the 17 faculty responses, 10 were noted as having a high level of sustainability knowledge, and 7 were noted as having a low level of sustainability knowledge.

Participants were grouped in this way in order to develop a deeper understanding of how their prior interest and/or knowledge regarding sustainability might impact identification of issues associated with sustainability in the Cal Poly curriculum. An a priori assumption was that sustainability 'adherents' (i.e., those students and faculty with prior or continued exposure to sustainability education) would represent a qualitatively different subset of responses with a generally more positive attitude toward sustainability education due to their understanding of the importance of sustainability practices. Given this a priori assumption, the analysis sought to identify whether the barriers and solutions identified by students and faculty were similar regardless of their adherence to or knowledge about sustainability, or whether those with more knowledge about or adherence to sustainability practices would identify different types of barriers for curriculum development.

3.1. Student Responses

3.1.1. Student-Identified Barriers

Table 1 summarizes student responses identifying barriers to sustainability-based education at Cal Poly, including frequencies (total number of student interviewees N = 39). Any statement wherein a student identified a relevant barrier inhibiting their participation in sustainability-based education was coded as a Barrier. A single transcript could contain multiple coded barriers.

Though there is little variation between the "high" and "low" knowledge groups for the most frequently stated barriers in student responses, some interesting key results can be seen in Figure 1, which depicts the data graphically. The top three most frequently stated barriers in both "low" and "high" student groups are *Accessibility*, *Time Constraints*, and *Neglect*. *Accessibility* identifies barriers wherein students note they are unable to access sustainability-related courses. For example, as this student (second-year child development major, with low sustainability knowledge) shares:

Table 1. Student-identified barriers to sustainability-based education at Cal Poly and corresponding frequencies (Total number of student interviewees N = 39).

Barriers	Examples	LSK [1] (N = 17) [3]	HSK [2] (N = 22) [3]
Neglect	Lack of interest or care in topic	12	6
Time constraints	No opportunities in schedule or curriculum	12	8
Major & background	No connection or relation with discipline	1	2
Personal attitude	Insignificant subject, not important	0	4
Conflicts with goals	Concepts not aligned with career goals	1	0
Personal priority	No incentive	5	6
Accessibility	Courses not offered	9	12
Lack of resources	To make courses available	3	1
Approach of promotion	Over advertising and integrating	0	7
Professor motivation	Concern not expressed by faculty	2	3
Professor not equipped	Faculty lack competence	0	1
Lack of institutional investment	Funds unavailable to develop courses, initiatives	1	0
Institutional priorities	Not an emphasis or strategic goal for campus	1	2

[1] LSK = Low Sustainability Knowledge; [2] HSK = High Sustainability Knowledge; [3] Values in columns three and four give the response frequency.

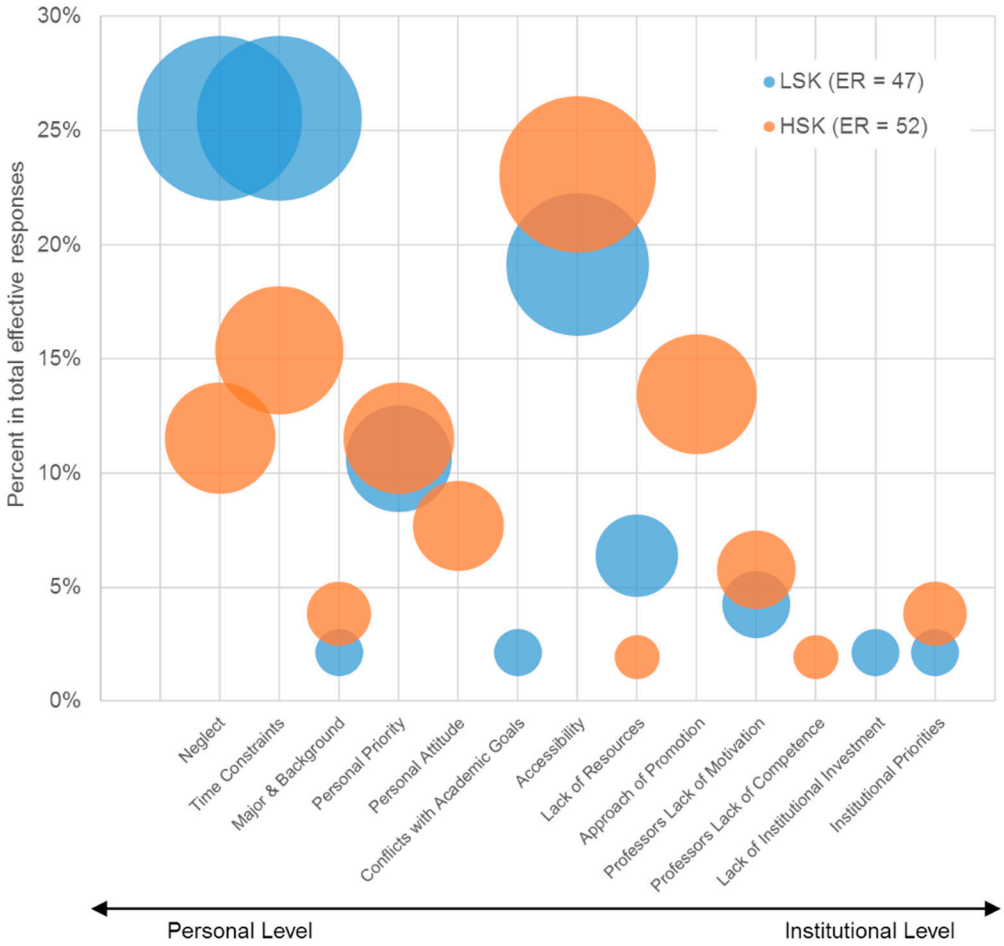

Figure 1. Distribution of percent effective responses corresponding to student-identified barriers to sustainability-based education at Cal Poly. Size of bubbles represent percentage of responses in each knowledge group. (Number of student interviewees N = 39; Total effective responses ER = 99. LSK and HSK indicate low and high sustainability knowledge, respectively).

"I haven't really seen a lot of classes that focus on it, so I'm not enrolling in those classes because I don't know what they're about."

Time Constraints represent a grouping of responses that represent an inability for the student to schedule sustainability-focused courses. As this student (second-year landscape architecture major with high sustainability knowledge) shares:

"Time. I could actively seek out a place to educate myself if I had the time, but with classes and stuff, but if it were a GE, I think we would have time to go, if it was in an actual class that I had to take, then I would be thrilled to have to go to it."

Neglect represents responses where students share attitudes that represent a disinterest in the idea of sustainability, in general. For example, as this student (second-year electrical engineering major, with low sustainability knowledge) shares:

"It's not really on my mind since it's not a problem that's currently affecting me to a great degree..."

Though the top three 'barriers' overlap between groups, those students with 'low' sustainability knowledge most frequently list *Neglect* as a barrier. In fact, *Neglect* is listed twice as often by 'low' as 'high' students. This indicates that *Time Constraints* and *Accessibility* are key barriers across student respondents, and those who lack sustainability-related knowledge may face a self-selection barrier beyond *Accessibility*.

Populating Table 1 data into Figure 1 suggests that most of the student participants appear to have a tendency to address barriers from personal experience, and few student participants can address barriers beyond the personal level. Figure 1 orients barriers on a continuum from personal to institutional level of experience. The bubble diameters display the percentage of responses in each knowledge group describing each barrier. The plot shows that responses derived from participants with low sustainability knowledge significantly skew toward personal level of experience and perception, whereas high-knowledge participant responses lean toward institutional observations.

It is not surprising that students with low sustainability knowledge also appear to neglect this subject, and vice versa. Other common barriers across student groups were mentioned much less frequently. These responses include statements that reinforce the general ideas that *Time Constraints* and competing priorities limit individual ability and/or desire to pursue sustainability-related education. These statements relate to lack of institutional or personal priorities, lack of motivation, and resource constraints (e.g., time, money, available electives). Although the result does not display significant variation, Figure 1 shows that students with better knowledge in sustainability tend to envision barriers from institutional aspects, whereas those with lower knowledge addressed sustainability from a personal perspective.

3.1.2. Student Identified Solutions

Table 2 and Figure 2 summarize student responses identifying solutions to address barriers to sustainability-based education at Cal Poly and the corresponding frequencies. These were generally coded as part of responses to the interview question: "What are some ways to make sustainability education more accessible at Cal Poly?" Any statement wherein a student identified a relevant strategy to enhance participation in sustainability-based education was coded as a Solution. A single transcript could result in multiple solutions.

Despite the fact that several barriers were recognized based on student interviewees' personal perception (Table 1 and Figure 1), all solutions proposed suggested how Cal Poly should tackle the challenges from an institutional level (Table 2 and Figure 2). This discrepancy implies student participants collectively recognize institutional opportunities to promote sustainability yet are less willing to act or make a commitment at a personal level.

Under the "low" and "high" knowledge categories, the top three solution responses in terms of frequency of occurrence are: *Promotion*, *Integration*, and adding a *General Education Option*. Statements coded as *Promotion* include responses identifying the use of fliers, booths, or events to promote sustainability curricula. This result seems ironic, because Cal Poly organized and heavily promoted an Earth Week event during the week prior to our interviews. There is a significant disengagement

between ignorance and the suggestion to "promote" sustainability. As a result, the authors are skeptical about the effectiveness of event promotion in overcoming sustainability barriers on campus.

Table 2. Student-identified solutions to improve sustainability-based education at Cal Poly and corresponding frequencies (Total number of student interviewees N = 39).

Solutions	Examples	LSK [1] (N = 17) [3]	HSK [2] (N = 22) [3]
Promotion	Increase awareness, advertising	8	12
Integration	Add material to existing, disciplinary courses instead of creating new courses or requiring added courses	5	11
Ge option	Add material or courses to existing GE requirements	5	9
Ge required	Add and require a new GE course focused on sustainability	2	2
More classes	Add/schedule additional classes	2	1
Link to major/job	Connect importance and benefit of topic to finding a job or disciplinary knowledge	2	6
Activities & events	Create extracurricular events and activities to increase awareness	2	5
Early awareness	Include information in freshman orientation programs	1	5
Smaller class size	Reduce enrollment to promote discussion, inclusion of subject	1	0
Institutional responsibility	Make priority/goal for campus	1	1

[1] LSK = Low sustainability knowledge; [2] HSK = High sustainability knowledge; [3] Values in columns three and four give the response frequency.

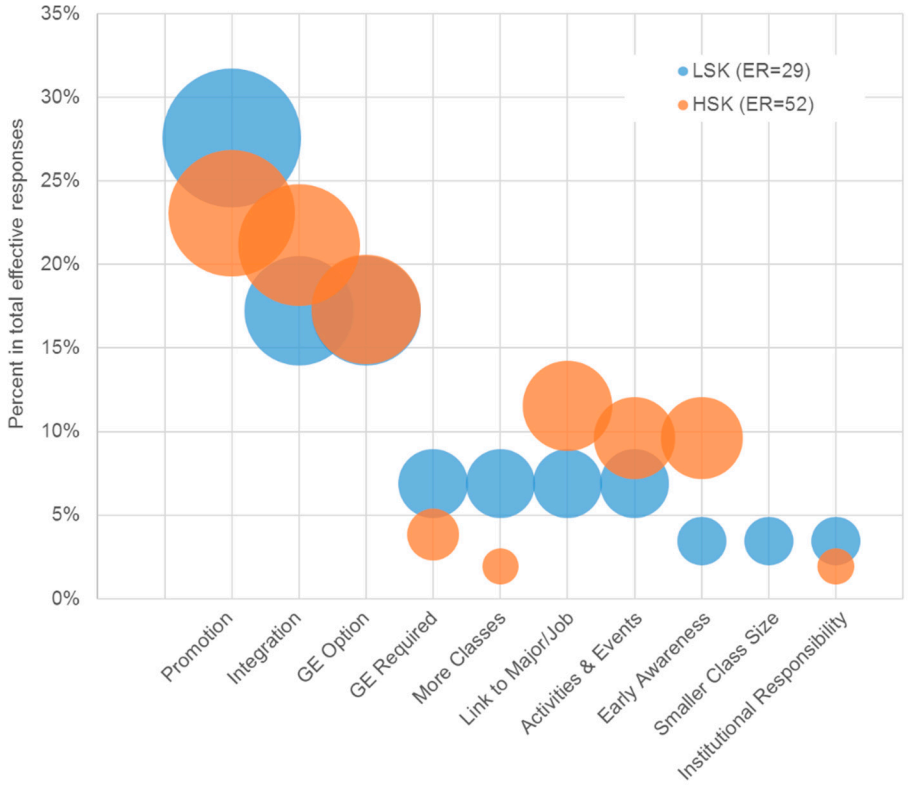

Figure 2. Distribution of percent effective responses corresponding to student-identified solutions to improve sustainability-based education at Cal Poly among low- and high-knowledge (LSK and HSK) student participants. Size of bubbles represents number of responses (Number of student interviewees N = 39; total effective responses ER = 81).

Though the top solutions from the 'low' and 'high' groups once again overlap, the 'high' group lists a greater number of solutions than the 'low' group. Additional responses include *Link to Major/Job*, creating *Activities and Events*, *Early Awareness*, and making it a *General Education Requirement*. The 'low' group also mentioned *Link to Major/Job* and Making it a *General Education Requirement*.

The ideas of *Integration* and *Linking to Major/Job* pose interesting and nuanced solutions derived from the transcript data. *Linking to Major/Job* represents responses where students suggest the importance of sustainability should explicitly link to how it will benefit their future job prospects

and careers. For example, as this student (first-year political science major, with high sustainability knowledge) shares:

" . . . if you did it in the curriculum, not like literally taking a sustainability class, but it could be integrated into certain classes, because it's very applicable to different things."

Integration captures responses where students suggest that instead of creating new courses or new requirements, sustainability education should integrate into already existing curricula, as this student (second-year engineering major, with low sustainability knowledge) notes:

"I'm not feeling taking a required class just for sustainability. Maybe incorporate into classes that are already . . . GEs that are already required."

Required general education (GE) courses comprise approximately one-third of the total units for each degree at Cal Poly. Subjects include lower- and upper-division courses in: Communications, sciences and mathematics, arts and humanities, society, and technology. All references to the *General Education Option* category captures student responses suggesting that a viable solution would be adding additional sustainability-related courses to the curriculum as options for completing general education (GE) requirements. This is slightly more popular (judging from the responses) than the solution of adding an additional GE Requirement. A *GE requirement* would modify the curriculum across the campus to ensure all students complete a sustainability course, whereas the *GE Option* solution would provide students with the ability to fulfill a broad GE requirement by choosing to take a sustainability-related course. The requirement is a more rigid, yet broader ranging solution.

3.1.3. Student Identified Barriers and Solutions by College

Although student responses for barriers and solutions were similar regardless of 'low' or 'high' sustainability knowledge, we note some deviation when examining responses by the six academic college units on campus (Table 3). Respondents span all colleges across campus in similar (though not identical) proportion to the make-up of the university. Due to the intensive nature of qualitative data analysis, sample sizes are small. Though our study reveals important and actionable data on barriers and solutions in sustainability education, the sample size falls short in making comparisons across different colleges. The sample has a lower representation of Science and Math students with high sustainability knowledge and generally few participants from the college of Business. Despite the small sample size, data did reach data saturation, which indicates validity of the overall findings [37]. However, we suggest only drawing tentative and university-specific conclusions from these data.

Table 3. Summary of most frequent student-identified barriers and solutions by sustainability knowledge (high "HSK" or low "LSK") and college.

	Most Frequently Identified Barrier		**Most Frequently Identified Solution**	
College	**LSK**	**HSK**	**LSK**	**HSK**
All (39)	Neglect (11)	Accessibility (12)	Promotion (8)	Promotion (12)
Agriculture (7)	Neglect (2)	Accessibility (4)	Promotion (2)	Promotion (4)
Architecture (6)	Neglect (2)	Time Constraints (3)	Promotion (1)	Promotion (3)
Business (3)	n/a	n/a	GE Option (1)	n/a
Engineering (7)	Neglect (3) Time Constraints (3)	Accessibility (2) Time Constraints (2)	GE Option (2) Integration (2)	GE Option (3)
Liberal Arts (13)	Accessibility (2) Time Constraints (2)	Accessibility (4)	Integration (2)	Integration (2)
Science and Math (3)	Neglect (3) Accessibility (3)	n/a	Promotion (3)	n/a

Despite these limitations, responses from students do reflect the characteristics of collegiate curriculum. For instance, Engineering students often identify *Time* and *General Education Options* as barriers and solutions because of discipline-specific constraints that limit the freedom of engineering students to pursue elective units outside their professional curriculum requirements. This has undoubtedly contributed to an institutional attitude of efficiency. Thus, one feasible approach to increasing sustainability education might arise by adding formal options to an already restricted curriculum.

Meanwhile, Liberal Arts students most frequently identify *Accessibility* and *Integrating* as barriers and solutions. This observation is interesting, because it may reflect the College of Liberal Arts' approach to a more integrated and holistic liberal arts education, despite the major within the college. Again, all conclusions are tentative given the sample size. However, results may indicate that discipline-specific solutions are needed to promote and improve sustainability education on campus.

3.2. *Faculty Responses*

3.2.1. Faculty-Identified Barriers

Table 4 summarizes faculty responses to identifying barriers to sustainability-based education at Cal poly, including frequencies (N = 17 faculty interviews). As apparent in Table 4 and Figure 3, the barriers noted by faculty differ considerably from those identified by students. In addition, faculty responses show variation depending on sustainability knowledge.

Table 4. Faculty-identified solutions to improve sustainability-based education at Cal Poly and corresponding frequencies (Total number of faculty interviewees N = 17).

Barriers	Examples	LSK [1] (N = 7) [3]	HSK [2] (N = 10) [3]
Lack of awareness	Unsure if applies to courses taught, unsure how to incorporate	4	3
Lack of competence	No knowledge of subject	4	2
Instructor philosophy	Subject is controversial	1	2
Personal priority	Other concerns or competing requirements have greater importance	3	5
Time constraints	Quarter system or class meeting pattern doesn't allow for additional topics/information	2	2
Accessibility	No courses offered, available	2	2
Discipline restrictive	Course topic restricts opportunity to integrate	3	7
Lack of guidance	No training, support, directions for including in teaching	1	0
No incentive	No personal benefit, no recognition for incorporating into teaching	0	1
Lack of resources	Funding not available for new courses, electives	0	1
Institutional priority	Not listed as an institutional priority/goal	0	1

[1] LSK = Low sustainability knowledge; [2] HSK = High sustainability knowledge; [3] Values in columns three and four give the response frequency.

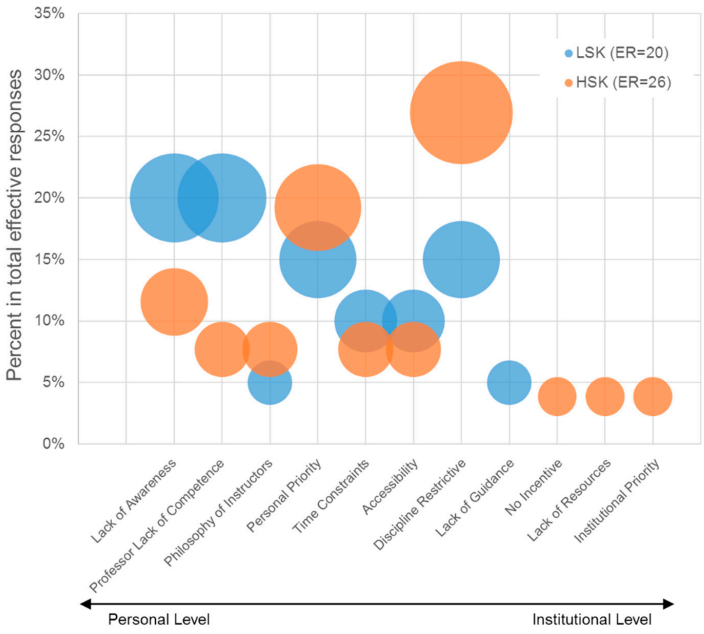

Figure 3. Frequency distribution of faculty-identified barriers to sustainability-based education at Cal Poly among groups with different sustainability knowledge levels (Number of faculty participants: N = 17; effective total responses: ER = 46).

Similar to the pattern observed in Figure 1, faculty members with low knowledge level describe barriers from a personal level, whereas high-knowledge faculty groups address the challenges across

the wider spectrum of aspects (Figure 3). Faculty members with 'low' sustainability knowledge cite a *Lack of Knowledge* or *Lack of Awareness* as major barriers towards advancing sustainability across the curriculum. The attitude of neglect or carelessness in sustainability appears to be a noticeable driving force determining the perception of teaching sustainability among faculty participants with 'low' sustainability knowledge. Less frequently mentioned by 'low' knowledge faculty are *Discipline Restrictive*, *Priority*, *Accessibility*, and *Time*. 'High' knowledge faculty emphasized *Discipline Restrictive* and *Priority*. The theme of *Discipline Restrictive* intends to capture responses from individuals who note that the subject matter of a class or discipline can restrict the integration of sustainability themes. For example, as this faculty member (associate professor in the Mathematics Department, 12 years, with high sustainability knowledge) notes:

"In some courses, it's more natural to fit in than others. When you're teaching students how to do calculus, you don't need to know about sustainability to do the technical thing, but you can include those topics . . . It's important to include in topics. Some topics are easier to include than others."

The theme of *Priority* generally refers to statements indicating that sustainability is not prioritized across certain curricula. This theme echoes student concerns regarding their own time (e.g., time to graduate, time for additional units). From a faculty perspective, this theme refers to institutional priorities for curriculum development. The *Priority* theme differs from those responses coded as *Time*, which refers to the ways in which faculty prioritize their own time in light of competing priorities. For example, a professor whose response was coded for *Time* might not choose to prioritize spending her time developing sustainability curricula. This observation is captured in the following response from a faculty participant (professor, Statistics Department, 18 years, with low sustainability knowledge):

"Especially me who's been here forever, I've been here a long time. I don't always change".

3.2.2. Faculty Identified Solutions

Faculty ideas for barrier-specific solutions to improving sustainability-based education were revealed during the interviews when the faculty were asked how identified barriers might be overcome. Table 5 and Figure 4 summarize the faculty-identified, barrier-specific solutions by 'high' and 'low' sustainability knowledge.

Table 5. Faculty-identified solutions to improve sustainability-based education at Cal Poly (N = 17 faculty responses).

Solutions	Examples	LSK [1] (N = 7) [3]	HSK [2] (N = 10) [3]
Hold students accountable	Require assessment of all students	0	1
Clear definition	Provide shared definition and concepts	0	1
More faculty training	Provide instruction, class support	3	0
Promotion	Increase awareness of activities, events, courses	2	1
Integration	Include information in existing courses, make coursework relevant to sustainability	2	4
Systems thinking in teaching	Add additional information on systems to courses	1	0
Link to major/job	Connect/emphasize relevance to finding a job or disciplinary importance	0	3
Early awareness	Include information in freshman orientation programs	0	3
Promote minors	Advertise existing programs on campus that are focused on sustainability	1	2
Ge option	Add materials or courses to existing GE requirements	0	2
Interdisciplinary solutions	Provide courses, opportunities for faculty from other disciplines to teach together	1	1
Institutional responsibility	Make campus priority, strategic goal	1	5
More resources	Provide funding for additional courses/electives	0	2

[1] LSK = low sustainability knowledge; [2] HSK = high sustainability knowledge;[3] values in columns three and four give the response frequency.

As is apparent in Table 5, faculty solutions varied depending on sustainability knowledge. For example, those faculty members with 'low' sustainability knowledge suggested *More Faculty Training* to help to incorporate sustainability themes in the classroom. Other solutions include *Promotion* and *Integration*. Those faculty members with 'high' sustainability knowledge suggest that solutions or improvements are the responsibility of the institution, (*Institutional Responsibility*), which might also include a responsibility for providing increased training to identify those classes that could most easily integrate sustainability-related themes and/or course buyouts to allow for curriculum development.

Similar to students, faculty in the 'high' knowledge group also frequently express *Integration*, *Link to Major/Job*, and *Early Awareness* as a potential solution for overcoming barriers. Considering together the faculty solutions of *More Faculty Training*, *Institutional Responsibility*, and *Integration* into curriculum could provide a blueprint for how universities might advance sustainability education across the curriculum in a way that not only achieves institutional goals related to sustainability education but does so in a way that enhances the desire to teach and learn about sustainability. Moreover, similar to the discrepant pattern between identified barriers and solutions, personal commitment to take action remains questionable.

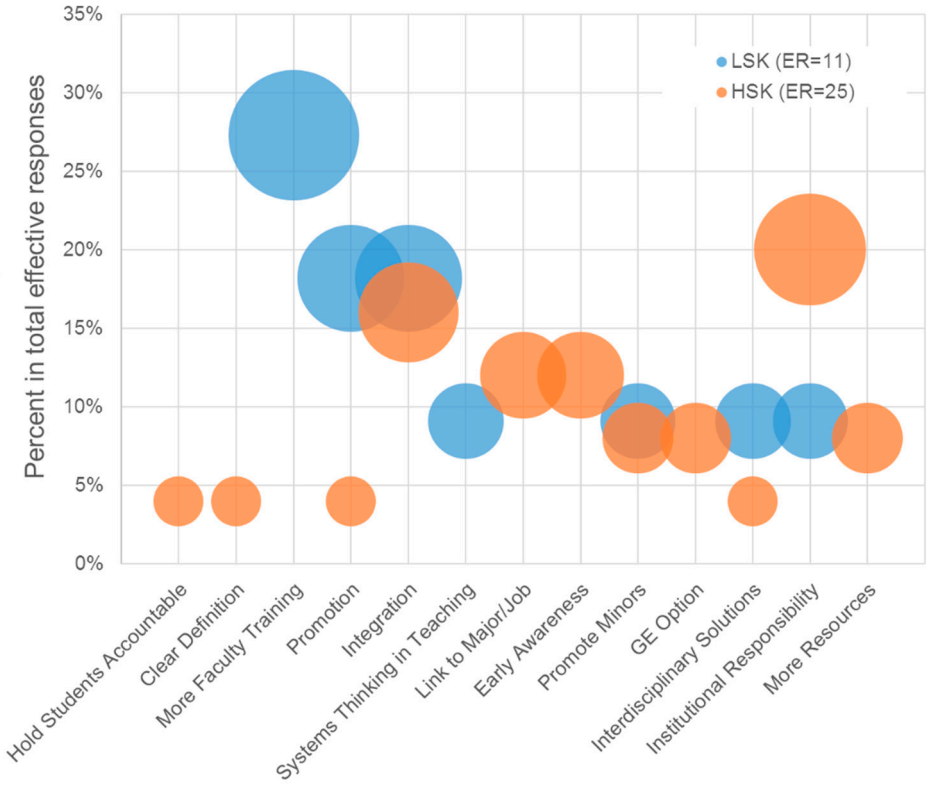

Figure 4. Distribution of percent effective responses corresponding to faculty-identified solutions to improve sustainability-based education at Cal Poly among low- and high-knowledge (LSK and HSK) faculty groups. Size of bubbles represents number of responses (Number of faculty interviewees N = 17; Total effective responses ER = 36).

4. Discussion—Designing Barrier-Specific Solutions

It is well established that interdisciplinary and non-siloed approaches are crucial to the incorporation of sustainability science into the curriculum [10]. However, details of how disciplines work as a system to contribute to sustainably curriculum are less apparent. These results reveal that gaps in the higher education system limit the expansion of an interdisciplinary sustainability curriculum. Findings from this study indicate that both students and faculty with higher sustainability knowledge have the tendency to identify barriers related to institutional accountability. A former study can well support the importance of this aspect, in which its authors found that an institution's internal rules and setting can be the driving force shaping people's behavior and decision-making processes [39]. This is particularly important for the development of solutions, as an institution will need to initiate a holistic strategy to incorporate sustainability into its core values. Being part of the ongoing effort, Cal Poly has incorporated several institutional measures, such as the creation of sustainability learning outcomes for all graduating students. It is important to assess the alignment between institutional measures and actual barriers that need to be addressed.

Noticeably, certain solutions for a singular barrier might be confronted by additional barriers. This is expected because these solutions reflected interviewees' intuitive rationalization, rather than those proposed based on thorough and systematic assessment and reasoning. Similarly, this is also why not all the proposed solutions were ranked from individual to institutional levels (Figures 2 and 4) as was done to identify barriers (Figures 1 and 3). In these cases, all the participants demanded institutional actions, rather than identifying what actions they would be willing to take. This can imply future challenges to make substantial impacts at an individual level even if Cal Poly can implement campus-wide solutions to encourage practicing sustainability. Recognizing personal responsibility to engage in learning sustainability needs to be addressed as one of the key steps to either promote a top–down or bottom–up approach to facilitate learning and teaching in sustainability. In the meantime, we also view this challenge as a new opportunity for establishing the momentum to promote sustainability education. A former study states that one of the possible tactics to improve personal awareness in sustainability is to create a "cognitive dissonance between individuals' values and behaviors" [40]. Therefore, findings from our study can provide ready input to address the dissonance between recognition of challenges and willingness to engage in making changes at a personal level, especially among the groups with lower sustainability knowledge.

Other studies note that expanding sustainability education and behavior must also address personal concerns and take into account increasing awareness of issues, messaging solutions, increasing convenience, and incentivizing change [41]. This resonates with the study's initial understanding of barriers, that the design of specific solutions may be best supported by institutional initiatives and availability to resources. Future areas of study will seek to better understand the role of faculty programs in the design and incorporation of barrier-specific solutions in higher education. As part of an effort to develop solutions to faculty-identified barriers, the authors will pursue a program of solutions, many of which could provide incentives in the form of modest stipends and opportunities for professional development and publication that begin to address identified barriers and solutions. These include:

(1) Developing workshops that provide space, training, and education focused on the development of new course material for existing courses. Workshops would promote identified solutions "integrating" and "linking" with the goal of increasing the number of sustainability-related courses. Workshop activities would include the review of learning outcomes and course structure, while designing additional course materials.

(2) Developing a sustainability learning community to inform faculty from a wide range of disciplines with low sustainability knowledge. Faculty learning communities are established solutions for infusing sustainability concepts into the curriculum and increasing the number of sustainability-related courses [20]. This focused community will align with the barriers and solutions of "discipline restrictive", "more training", and "lack of knowledge". A focus on overcoming seemingly discipline-specific barriers and including sustainability would be addressed through interdisciplinary approaches. The learning community participants would pair faculty with low and high sustainability knowledge as a means to address the identified "lack of knowledge" barrier with "more training" solution.

(3) Developing a year-long "Community of Practice" consisting of a group of interdisciplinary educators with high sustainability knowledge and a shared interest in sustainability in higher education. The community will serve as a platform to exchange ideas, insights, and practices regarding sustainability in education. Meanwhile, it can facilitate the assessment and improvement of sustainability education across university curriculum.

5. Conclusions

A well-known core principle of sustainability education holds that interdisciplinary approaches are crucial, but the details of how these disciplines work as a system to contribute to an overarching sustainability curriculum are less apparent. These results reveal the gaps in Can Poly that

limit the expansion of an interdisciplinary sustainability curriculum, which can resonate with institutes with similar academic setting. Cal Poly's experience indicates that the implementation of a sustainability-related curriculum must rely on multidimensional strategies and approaches. Recognition of barriers ranging from the personal to the institutional level will aid in the design and implementation of any expanded sustainability-related curriculum or program initiatives. Research results confirm that barriers to sustainability education exist across disciplines, participants with varying levels of sustainability knowledge, and among student and faculty groups.

The results from both students and faculty show that participants with higher sustainability knowledge have the tendency to identify barriers to sustainability education by holding organizations accountable, while participants with lower sustainability knowledge have the tendency to identify barriers to sustainability education by holding themselves accountable. This finding well depicts the mentality of students and faculty in supporting sustainability education. The finding also indicates that a campus seeks change to include sustainability education must initiate a holistic strategy to incorporate sustainability into its core values from the institutional level, with which individual awareness can be better promoted. This study's results confirm both approaches will be required to address perceived barriers to implementation. Continued research and understanding of the factors impeding the implementation of sustainability education could help students, faculty, and institutions to develop those holistic strategies.

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