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Engineering Faculty Views on Sustainability and Education Research: Survey Results and Analyses*

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Increasing interests in both engineering education research and sustainability education motivated development of a survey instrument aimed at measuring engineering educators' attitudes and dispositions toward these endeavors. An online survey instrument was distributed to engineering faculty and instructors at a medium-sized land-grant university within the United States, with results briefly summarized in the 2017 Conference Proceedings of the American Society for Engineering Education (ASEE). The survey is presented here in its entirety, along with statistical analyses of the previously summarized results and discussion of responses to open-ended items. The survey instrument was effective in measuring engineering faculty support toward both engineering education research and sustainability education. The survey items also factored to measure attitudes toward climate change, teaching practices and curriculum as well as use of research-driven pedagogies. Statistical analyses of the survey structure are also presented along with suggestions for its further development and potential use.

Keywords: engineering faculty attitudes; sustainability education; survey development

1. Introduction and Approach

Increasing attention toward both engineering education research and integrating sustainability within engineering education is strongly evidenced by research literature and research funding agency support, e.g., [1–11]. Sustainability is crucial for the engineering profession, as supported both by ethical codes published by various engineering professional societies and in accreditation requirements of engineering programs, e.g., the Accreditation Board for Engineering and Technology (ABET). ABET criteria include the ability of students to demonstrate an understanding of sustainability and take it into account during engineering practice, which prompted accredited engineering programs to incorporate sustainability into their curricula. Moreover, each of the 14 Grand Challenges for Engineering [12] have significant sustainability implications. Similar to ethics education, engineering programs often incorporate sustainability in one or more of the following three ways [13] and leverage one or more of six pedagogical approaches (professional codes, humanist readings, theoretical grounding, ethical heuristics, case studies, and service learning) [14]: (1) introducing professional codes and discussing ethical philosophies (e.g., Utilitarianism, Kantian ethics, virtue ethics, ethics of care) as stand-alone courses, often offered by non-engineering departments; (2) brief discussions of ethics and professional responsibilities and ethics with references to public safety and connected with subject matter from engineering courses; often including case-studies of engineering failures or exploring trade-offs, e.g., cost and safety; and/or, (3) course modules on ethics and engineering professional responsibility, typically less than a few class sessions in a capstone course and attempting to reference other engineering course content.

Unfortunately, many engineering education programs appear to fall short with sustainability as demonstrated by many studies showing a marked decrease in students' sense of professional responsibility and other sustainability-related measures during multi-year engineering education programs [15, 16]. Sustainability-related courses that are taught in non-engineering departments run the risk that students will perceive them as something "outside" of what they do in engineering and they may also be less informed by the specific issues and experiences that engineers may encounter [17]. While engineering societies in virtually every field have established codes of ethics, historically these have focused on rules for professional conduct, neglecting broader issues related to the social, ethical, and environmental (sustainability-relevant) implications of engineering [18]. As a result, they fail to help students understand or exercise the full range of engineering professional responsibilities. Moreover, rule-based approaches may inadvertently stifle the very sort of skills that engineers need, such as creativity, flexibility, comfort with

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ambiguity, and identifying multiple answers to problems [19]. Using case studies can be effective, but is less so when such cases focus only on dramatic failures that most engineering students are unlikely to encounter, or when they are divorced from the everyday sorts of decisions that arise in their particular subdiscipline [20, 21]. Engineering courses that have a few modules on sustainability or professional responsibilities have shown little improvement on engineering students' ability to engage in moral reasoning, possibly because only a small portion of the class is devoted to this skill [22, 23]. Much of the literature suggests that improving students' abilities to identify and analyze sustainability issues requires that sustainability education be integrated into the engineering curriculum in multiple classes, connect to specific disciplinary contexts [22, 24–27], and not be offered solely as an optional or elective coursework [28]. Nonetheless, there are several challenges to meet these requirements, mainly an identified need to better train engineering educators [29].

Engineering was one of the first professions to seriously address its relation to sustainability and to climate change. Historically, it was also one of the first professions, alongside medicine, to embrace pedagogical research as an accepted aspect of the discipline. Effectively integrating research findings into education practice may be enhanced by favorable attitudes of engineering faculty toward engineering education research conducted by their colleagues. To measure engineering educator attitudes and dispositions toward both engineering education research and integrating sustainability within engineering education, a survey instrument – originally used to evaluate university faculty thoughts on education for sustainability [30] – was adopted and modified. The original survey consisted of 50 items focused on education for sustainability within higher education and was administered to university faculty across several disciplines. For brevity and focus on engineering education, select items from the original survey were adopted in the modified survey and added to items related to attitudes toward engineering education research. In 2016, the modified survey was administered online via Qualtrics, and an email invitation was sent to 141 individual engineering faculty at a medium-sized land-grant university within the United States: 61 completed the survey with 6 partial responses (~48% response rate). The 61 completed surveys were used in the following statistical analyses. The survey results were briefly summarized in a 2017 ASEE conference paper [31] and are analyzed in more depth here, along with the survey itself.

The modified survey instrument included the following 20 items asking respondents to rank their agreement (5-point Likert scale) from 1 = strongly disagree to 5 = strongly agree with 3 = neutral. The survey also included demographic variables including academic position/rank, age, and gender, as well as opportunities for open-ended responses and comments. Items #1–5 addressed facets of engineering teaching concern. Items #6–13 and #15–19 addressed facets of sustainability teaching concern, including social impacts and climate change. One attention confirmation question (#14) was also included in the survey but was not included in the statistical analyses.

1. I have access to and support for integrating research-driven pedagogies in the classroom.
2. I apply research-driven pedagogies in my teaching.
3. Engineering education is a valid research endeavor for engineering faculty.
4. I would support an engineering education research center at our institution.
5. I support using college resources to establish an engineering education research center.
6. All engineering curricula should integrate sustainability topics.
7. I incorporate contemporary societal issues into my teaching.
8. Integrating sustainability into my teaching distracts from content acquisition.
9. My teaching involves getting students to see the long-term impacts of their discipline.
10. I feel pressure to incorporate sustainability into my teaching.
11. Sustainability education is not well received by students.
12. Connections between sustainability and my discipline do exist, but they have not yet been clearly articulated.
13. Sustainability is too diffuse a concept at present to teach.
14. If you are reading this, select "Neutral."
15. Climate change is predominately human caused.
16. Climate change poses serious threats to human society.
17. Engineering faculty colleagues resist teaching about sustainability.
18. I am unsure how to incorporate sustainability into my teaching.
19. Teaching about sustainability helps students see connections between the discipline and larger societal/global issues.
20. I am waiting for institutional or professional leadership on sustainability issues.

Additionally, written responses were collected from three open-ended prompts, which were used to contextualize quantitative survey data:

1. Do you have any additional comments about engineering education research?
2. If you wish, comment on any of the above questions about sustainability education in engineering.
3. If you wish, describe ways in which you incorporate sustainability into your courses.

2. Survey Results and Analyses

Because the survey items were measured using a 1-to-5 Likert scale, the responses were measured using an ordinal scale, making the median the most appropriate measure of central tendency. However, because of the relatively large number of respondents ($N = 61$), the mean and median should be reasonable estimates of each other. The Pearson r (18 df) correlation between the means and medians was 0.88, $p < 0.001$. Use of the mean in addition to the median also provides a measure of variability (i.e., standard deviation). Descriptive statistics on the responses to each item are given in Table 1 and include the median, mean, standard deviation, and response frequencies for each item.

To create consistency in the interpretations of the responses to the survey items, several items were reverse coded so that high Likert-scale values represented strong agreement with or positive affect toward the content of the item. Conversely, low Likert-scale values represented low agreement with or negative affect toward the content. Items 8, 10, 11, 12, 13, 17, 18, and 20 were reverse coded. For example, item 8 reads: Integrating sustainability into my teaching distracts from content acquisition. Answering "5", strongly agree, indicates that the respondent feels that integrating sustainability into the classroom is a distraction to achieving stated learning objectives; however, answering "1", strongly disagree, indicates that the respondent feels that integrating sustainability is not a distraction to achieving stated learning objectives. By reverse coding this item and the others previously mentioned, high values become associated with positive outcomes and low values become associated with negative outcomes. In addition to creating consistency in the interpretations of the responses, the reverse coding allows for the combining of items that measure similar constructs.

Using the reverse coded data, faculty responded positively to all the items. All medians and means were 3.00 or greater. More specifically, for 12 of the items the medians were 4.00, and for 4 of the items the medians were 5.00. Only 3 of the items had a median of 3.00. Moreover, the faculty were consistent in their responses as indicated by the uniform standard deviations, which were approximately 1.00 across the items.

2.1 *Demographic Variables*

An independent samples, Kruskal-Wallis test, a non-parametric statistical analysis, was conducted with the ordinal data on the following independent variables: Gender (Male, Female or Prefer not to Answer); Academic Rank/Position (Tenure Track, Non-Tenure Track, Assistant, Associate or Full Professor); and, Age Range (20–35, 36–45, 46–55, 56–65, 66+).

2.1.1 *Gender*

Statistically significant differences on gender were found for items: #4 (*I would support an engineering education research center at our institution:* $p = 0.023$); #6 (*All engineering curricula should integrate sustainability topics:* $p = 0.015$); #16 (*Climate change poses serious threats to human society*: $p = 0.058$); and, #19 (*Teaching about sustainability helps students see connections between the discipline and larger societal/global issues*: $p = 0.017$). Statistical details on response differences to these four items per gender are presented in Table 2.

Both males ($n = 45$) and females ($n = 15$) responded positively on these four items; however, an examination of the frequencies of responses and their means and standard deviations indicated that females responded more positively than males on these four items. On all four items, females responded almost exclusively with 4's and 5's. In comparison to males, females were significantly more positive about supporting engineering education research (#4). One open-ended response from a female engineering faculty reflected this:

- "It helps busy professor do their jobs more effectively and is incredibly valuable. Its *(sic)* nice to have someone distill the current research into a ready to deploy classroom technique."

Table 1. Aggregate survey responses and statistics

	Survey Item (* = Reverse Coded)																		
Response	1	2	3	4	5	6	7	8*	9	10*	11*	12*	13*	15	16	17*	18*	19	20*
1	4	4	1	1	4	2	2	0	2	0	0	2	1	1	1	1	3	1	1
2	5	7	3	3	3	10	5	7	3	1	2	21	8	1	1	4	26	1	14
3	15	9	2	6	11	15	8	15	7	18	21	8	14	7	4	33	7	5	14
4	23	25	16	14	14	22	28	25	36	16	16	15	24	13	14	17	15	28	19
5	14	16	39	37	29	12	18	14	13	26	22	15	14	39	41	6	10	26	13
Mean	3.62	3.69	4.46	4.36	4	3.52	3.9	3.75	3.9	4.1	3.95	3.33	3.69	4.44	4.52	3.38	3.05	4.26	3.48
SD	1.13	1.18	0.9	0.97	1.21	1.09	1.03	0.94	0.91	0.89	0.92	1.27	1.02	0.89	0.83	0.82	1.24	0.81	1.12
Median	4	4	5	5	4	4	4	4	4	4	4	3	4	5	5	3	3	4	4

Table 2. Response differences by gender

	Item 4		Item 6		Item 16		Item 19	
Response	Male	Female	Male	Female	Male	Female	Male	Female
1	1	0	2	0	1	0	1	0
2	3	0	10	0	1	0	1	0
3	4	1	12	3	4	0	5	0
4	13	1	14	7	12	2	23	5
5	23	13	7	5	27	13	15	10
Mean	4.2	4.8	3.31	4.13	4.4	4.87	4.11	4.67
SD	1.04	0.56	1.12	0.74	0.92	0.35	0.86	0.49
Median	5	5	3	4	5	5	4	5

Many male engineering faculty were also very positive on supporting engineering education research, as evidenced both by survey responses and open-ended comments:

- "Having resources (training, examples, support, etc.) available would significantly increase/ improve the chance of including research into the classroom."
- "Discussions/presentations on the topic at MSU would be useful."
- "It is about time!"

While many male engineering faculty agreed with these sentiments, some expressed opposing viewpoints on the efficacy of engineering education research as expressed in several of their open-ended responses:

- "I have done both engineering education "research" and more traditional product/materials/investigative research: From those efforts and the work of others I've determined that engineering education research is a soft side effort, aligned only loosely with effective teaching."
- "I do believe engineering education is a valid research endeavor as even a mutual component of more traditional research, however, I am not sure I feel it would be valid as an engineering faculty's only research endeavor."
- "I believe that engineering education research is increasingly skewed towards the trendy – so called innovations (which usually aren't), and diversity – while marginalizing the realm of actual engineering learning."

Female engineering faculty responding to this survey also felt more strongly than males about integrating sustainability into their curricula (#6), that teaching sustainability helps students see connections between engineering and societal/global issues (#16), and that climate change is a serious threat to society (#19). These results resonate with literature evidence showing women as leaders in sustainability [32]. These findings are also supported by literature investigating ecofeminism perspectives in engineering education, often aimed at integrating sustainability values and to promote diversity [33–35]. However, one female faculty added a caveat to this support by commenting:

- "I don't see how sustainability is related to new or improved teaching methodologies. I feel there is a more compelling need for reviewing/improving teaching methodologies in general and not related to one single topic."

2.1.2 Academic Rank

An independent-samples, Kruskal-Wallis test showed no statistically significant differences for Academic Rank. Survey respondents represented an approximately equal distribution of academic ranks and were primarily tenure-track faculty (n = 50) versus non-tenure track (n = 11).

2.1.3 Age Range

An independent-samples, Kruskal-Wallis test showed significant differences for items #8 (Integrating sustainability into my teaching distracts from content acquisition: p = 0.036 (reverse coded) and #13 (Sustainability is too diffuse a concept at present to teach: p = 0.037) (reverse coded). For item 8, although there were only nine faculty members in the greater than 56 age range, they responded exclusively with 4 or 5, indicating that integrating sustainability into their teaching did not distract from content acquisition. Faculty in the other age ranges were less certain about whether sustainability was a distraction. For item 13, again the nine faculty members in the greater than 56 age range responded almost exclusively with 4 or 5, indicating that they did not believe that sustainability was too diffuse a concept to teach. As with item 8, faculty in the other age ranges were less certain about this. Response frequencies are provided in Table 3.

2.2 Relations Among Survey Items

Relations among the survey items were examined using Spearman's Rho correlation, a statistic designed for measuring the relations among ordinal variables. The correlation matrix is given below in Table 4. Items were not reverse coded for calculat-

Table 3. Items with differences among respondent age

	Item #8 (Reverse Coded) and Age Ranges					Item #13 (Reverse Coded) and Age Ranges				
Response	**20-35**	**36-45**	**46-55**	**56-65**	**66+**	**20-35**	**36-45**	**46-55**	**56-65**	**66+**
1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
2	**0**	**3**	**4**	**0**	**0**	**2**	**2**	**4**	**0**	**0**
3	**3**	**5**	**6**	**0**	**0**	**2**	**4**	**7**	**1**	**0**
4	**5**	**11**	**5**	**3**	**1**	**2**	**11**	**5**	**4**	**1**
5	**3**	**3**	**3**	**4**	**1**	**5**	**5**	**1**	**2**	**1**

ing these correlations. Significant correlations are highlighted in grey and are significant at either the $p < 0.01$ or $p < 0.05$ levels. All correlations greater than or equal to ± 0.25 are significant. As would be expected, the items that were reverse coded are positively correlated with other reverse coded items and negatively correlated with non-reverse coded items. Many of the correlations ranged from moderate to large, and these correlations appear to cluster items around the intended constructs that were the focus of the survey. For example, items 1 and 2 concern research driven pedagogies and correlate 0.64. Items 3, 4, and 5 concern supporting engineering education research and correlate 0.51, 0.55, and 0.75, respectively. Items 15 and 16 concern climate change and correlate 0.58. Items 7 and 9 concern teaching and correlate 0.39. Finally, items 8, 11, 12, 13, 18, and 20 concern sustainability, and the correlations among these variables range from 0.34 to 0.56. However, there are some correlated items that do not fit into a pattern. Items 19 and 6, both dealing with sustainability, were substantially correlated (0.64), but did not significantly correlate with the other sustainability items. Also, item 10 dealt with sustainability, however, it had low but significant correlations with other sustainability items.

2.3 Survey Structure and Interpretation

Although the number of participants in the survey was somewhat low ($N = 61$) and the nature of the data is ordinal, an exploratory factor analysis was conducted to provide a tentative investigation of discernable patterns in the responses. A valid exploratory analysis would require many more participants; therefore, the results of this analysis are intended only to show possible trends. However, they do provide some insights into the structure of the survey and identify items that may cluster together or that may not fit well within the survey as currently constructed.

A principal component analysis was conducted with varimax rotation. Only loadings greater than 0.45 were accepted for inclusion for each component. As can be seen from Table 4, the items loading on each component were significantly correlated with one another, with the exception of item 10, which had the smallest loading. Table 5 shows the seven components and their loadings, and Table 6 describes the components with respect to the items that load most heavily on them.

Each of the seven components exceeded eigenvalues greater than 1 and explained 75.49% of the variance in the items. Component One included items 8, 11, 12, 13, 18, and 20. All of these items concerned supporting sustainability education. Component Two included items 3, 4, and 5. These items concerned supporting engineering education research. Component Three included items 15 and 16, both items concerning climate change. Component Four included items 7, 9, and 10. These items concerned teaching practices and curricula. Com-

Table 4. Correlation matrix and Spearman Rho Correlations among All Survey Items

Question	Correlated with Questions																	
	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20
1	.64**	.30*	.21	.30*	.04	.15	-.03	.04	-.01	-.21	-.10	-.04	.06	.07	.02	.05	-.01	.03
2		.32*	.23	.20	.24	.38*	-.15	.14	-.04	-.28*	-.24	-.14	-.06	.07	-.01	-.25*	.11	-.07
3			.51**	.55**	.11	.11	-.14	.02	.06	-.28*	-.19	-.21	.17	.24	-.10	.02	.08	-.02
4				.75**	.33**	.12	-.16	-.09	.03	-.26*	-.08	-.01	.15	.23	-.02	.10	.27*	.19
5					.37**	.06	-.20	.03	.11	-.22	-.13	-.10	.15	.31*	.05	-.04	.27*	.19
6						.24	-.32*	.20	-.01	-.32*	-.24	-.29*	.18	.30*	-.03	-20	.64**	.11
7							-.34**	.39**	.10	-.29*	-.36**	-.21	-.04	.06	-.02	-.41**	.28*	-.11
8								-.29*	.22	.34**	.24	.54**	-.19	-.17	.20	.44**	-.31*	.32*
9									.03	-.22	-.41**	-.24	.13	.04	-.07	-.28**	.28*	-.19
10										.34**	-.13	.26*	.09	.02	.12	.13	-.10	.19
11											.45**	.49**	-.03	-.17	.05	.33**	-.20	.19
12												.56**	.07	-.03	-.06	.41**	-.28*	.31
13													-.09	-.06	.08	.30*	-.23	.39**
15														.58**	.18	.16	.33**	.18
16															.10	.05	.41**	.18
17																-.07	-.03	.30*
18																	-.12	.36**
19																		.19

* $p < 0.05$; ** $p < 0.01$.

Table 5. Rotated factor matrix showing the component loadings on each of the 7 components

	Component						
	1	2	3	4	5	6	7
Item 13	.850	-.081	-.120	.055	-.039	.029	.031
Item 8	.659	-.242	-.091	-.054	.066	-.158	.239
Item 12	.640	-.176	-.006	-.441	-.059	.045	-.280
Item 11	.610	-.160	.050	-.018	-.361	-.263	-.077
Item 20	.608	.141	.141	-.178	.040	.389	.340
Item 18	.593	.070	.250	-.297	.027	-.257	-.110
Item 5	-.115	.884	.107	-.021	.105	.208	-.010
Item 4	-.044	.828	.016	-.008	.152	.331	.008
Item 3	-.205	.736	.073	.137	.322	-.246	.046
Item 15	-.011	.028	.932	-.047	.005	.045	.043
Item 16	.050	.110	.806	.144	.116	.294	.053
Item 9	-.150	-.088	.170	.772	.115	.072	-.106
Item 7	-.129	.120	-.073	.755	.262	.277	-.013
Item 10	.403	.365	.112	.466	-.292	-.310	.259
Item 1	.032	.179	.137	.042	.883	-.086	.010
Item 2	-.109	.206	-.026	.276	.815	.103	.017
Item 6	-.185	.262	.277	.191	-.002	.705	-.010
Item 19	-.082	.143	.514	.306	-.011	.663	-.002
Item 17	.042	.005	.064	-.040	.021	.008	.928

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 17 iterations.

ponent Five included items 1 and 2, which concerned research pedagogies. Component Six included items 6 and 19. Although these two items dealt with sustainability as did the items contributing to Component One, their focus was directed more to the integration of sustainability into the curriculum and to see larger societal and global issues. Only item 17 loaded on Component Seven, which makes interpretation of this component difficult.

3. Discussion

Results indicated that the engineering faculty surveyed are generally supportive of engineering education research and using institutional resources to support it. Results also indicated that the faculty surveyed are generally supportive of integrating sustainability within engineering education (i.e., their classes), but also desire training opportunities to do so effectively. However, the survey provided

Table 6. The Seven Components, Identifying Labels, and Items Loading on Each

Component	Label	Items Loaded
1	Supporting Sustainability Education	13. Sustainability is too diffuse a concept at present to teach. 8. Integrating sustainability into my teaching distracts from content acquisition. 12. Connections between sustainability and my discipline do exist, but they have not yet been clearly articulated. 11. Sustainability education is not well received by students. 20. I am waiting for institutional or professional leadership on sustainability issues. 18. I am unsure how to incorporate sustainability into my teaching.
2	Supporting Engineering Education Research	5. I support using college resources to establish an engineering education research center. 4. I would support an engineering education research center at our institution. 3. Engineering education is a valid research endeavor for engineering faculty.
3	Climate Change and Sustainability	15. Climate change is predominately human caused. 16. Climate change poses serious threats to human society.
4	Teaching Practices and Curricula	9. My teaching involves getting students to see the long-term impacts of their discipline. 7. I incorporate contemporary societal issues into my teaching. 10. I feel pressure to incorporate sustainability into my teaching.
5	Research-Informed Pedagogies	1. I have access to and support for integrating research-driven pedagogies in the classroom. 2. I apply research-driven pedagogies in my teaching.
6	Sustainability and Connecting to Larger Issues	6. All engineering curricula should integrate sustainability topics. 19. Teaching about sustainability helps students see connections between the discipline and larger societal/global issues.
7	?	17. Engineering faculty colleagues resist teaching about sustainability.

rich data to help move beyond these generalizations.

There was a small but comment-rich fraction of respondents who are skeptical of the effectiveness of engineering education research and its legitimacy as a professional endeavor for engineering faculty. A similarly small fraction of respondents are skeptical about human caused climate change and its threat to humans, and some expressed concerns about defining sustainability and conflating sustainability with global warming, which they perceived as a political issue. Open-ended comments supporting this perspective included:

- "I think the term "sustainability" always gets inherently linked with global warming. As soon as it does, there is a political undertone to the topic. I feel like as soon as anything political emerges in a topic, engineering faculty stay away from it. At least I certainly do. Getting around that political issue is a challenge for getting sustainability into our curriculum. But I think it is a very important topic and want to figure out how to teach it."
- "Sustainability is a buzzword that means different things in different circles. Without a concrete definition, your questions are unreasonably vague and any data will be prone to mis-interpretation *(sic)* and skewing."
- "I don't know exactly what sustainability is referring to in this survey. I am assuming you are referring to designing sustainable systems like using renewable energy and not wasting resources, etc. Particularly sustainability that helps correct climate change. If so, my answers are good!"

Some faculty commented that sustainability ought to be inherent to engineering, and made connections to engineering ethics,

- "Good engineering practices promote sustainability and this should not be considered a new thing for faculty to incorporate into their classes."
- "We have a course on professional ethics, but each of us should also be taking opportunities to point out ethical dilemmas that might present themselves in the context of our courses. I'd imagine that sustainability falls into a similar category, and in fact has substantial ethical implications. I think it would be engaging for faculty and students to try to figure out how to address sustainability questions together."

Yet others commented on the disconnection of sustainability from engineering, and perceived compromises or challenges related to its integration,

- "I don't see how sustainability is related to new or improved teaching methodologies. I feel there is a more compelling need for reviewing/improving teaching methodologies in general and not related to one single topic"
- "Not needed in basic EM (engineering mechanics), fluids classes. In thermo, efficiency is the key, but not enough time to cover everything."
- "My reaction to some of these questions is rather different depending on whether I read it as "I" need to be teaching sustainability, or "we" need to be teaching sustainability. I find I'm fully on board with "we" need to teach it, and much more cautious if "I" must figure out how to work that into my classes."

The survey provided some indication about demographic differences that contributed to this diversity. Although both male and female respondents were positive in their responses, there were significant differences in responses indicating that females were more positive than males regarding support for engineering education research, integrating sustainability into their classes, and that teaching sustainability helps students see connections between engineering and societal/global issues. In addition, females felt more strongly that climate change is a serious threat to society, which is also supported by many other studies, e.g., [36, 37].

Older faculty felt more strongly that sustainability was not too diffuse a subject to teach and that it would not distract from other course content (#8, #13). Although the low number of older faculty respondents makes this difficult to interpret, some studies have suggested generalizable relationships between age and environmental sustainability-related psychological variables, e.g., [38].

This study prompted questions for further investigation, many of which align directly with a recent systematic review of the literature on integrating sustainability into engineering curricula [39], which suggested the following research questions:

- How does the interaction between a teacher's and student's knowledge and value frameworks influence the integration of sustainability into the curricula?
- How can faculty be motivated to integrate sustainability into the curricula?
- How are accreditation requirements related to sustainability realized in practice?
- What sustainability related hard and professional (soft) skills does industry require from engineering students?
- What are appropriate measures to capture the competencies and learning outcomes associated with integrating sustainability into engineering curricula?

While the present study provides only hints toward answering these questions, the survey instrument developed may have utility in investigating them further.

3.1 Survey Structural Analyses

Overall, the principal components analyses indicate that most of the items were probing the intended constructs. Items 13, 8, 12, 11, 20, and 18 did well at picking up on sustainability concerns and indicated that the faculty thought or felt very positively about having sustainability included in their classrooms. Items 6, 10, 17, and 19 also dealt with sustainability and indicated that faculty thought or felt positively about additional sustainability issues; however, they loaded on components other than the first component of sustainability. If these items are intended to probe issues of sustainability, some consideration may need to be given to rewording them so that they conform more with the construct of sustainability. Alternatively, these items may conform more closely with a component that somehow differs from the first sustainability component.

Items 1 and 2 did well at probing research-driven pedagogies, and the responses to them indicated that faculty thought or felt positively about using research-driven pedagogies in their classrooms.

Items 3, 4, 5 did well at probing supporting engineering education research, and faculty responses indicated that they thought or felt positively about such support.

Items 7, 9, and possibly 10 did well at probing a teaching construct, and faculty responses indicated that they thought or felt positively about incorporating contemporary societal issues into the classroom, considering the long-term impact of engineering, and did not feel pressured to incorporate sustainability into their teaching. In fact, no one strongly agreed that they felt pressured.

Items 15 and 16 did well at picking up on the climate change construct. Faculty responses indicated that they predominantly believe that climate change is human caused and poses a serious threat to human society.

Item 17 indicates that faculty were somewhat ambivalent about resisting teaching about sustainability. The question is a little unclear in its meaning, which may be why so many neutral responses were given and why it did not load with other items. Rewording of the question in future surveys may be helpful to convey the intended meaning.

Finally, item 14 was an instructed response item (IRI) intended as an attention confirmation, with all respondents selecting the instructed response and one respondent expressing their amusement on its use in an open-ended response. However, the efficacy of IRIs within surveys is in context of their specific implementation and several important considerations have been suggested to avoid unintended impacts [40].

4. Conclusions

A survey instrument was developed and the results were analyzed; it was effective in measuring engineering faculty support toward both engineering education research and sustainability education. The survey items also factored to effectively measure attitudes toward climate change, teaching practices and curriculum as well as use of research-driven pedagogies. The survey results helped motivate a new engineering education research center and provided baseline assessment of faculty attitudes and dispositions toward integrating sustainability in engineering curricula. A few survey items appeared to need rewording or reworking so that they better conform to intended constructs of interest. The survey could be improved, modified for specific contexts, and used to measure faculty attitudes and changes thereof over time, with potentially important implications for assessing the integration of sustainability into engineering curricula.

References

1. M. Borrego and J. Bernhart, The Emergence of Engineering Education Research as an Internationally Connected Field of Inquiry, *Journal of Engineering Education*, **100**, pp. 14–47, 2011.
2. L. Klotz, G. Potvin, A. Godwin, J. Cribbs, Z. Hazari and N. Barclay, Sustainability as a Route to Broadening Participation in Engineering, *Journal of Engineering Education*, **103**, pp. 137–153, 2014.
3. C. F. Murphy, D. Allen, B. Allenby, J. Crittenden, C. I. Davidson, C. Hendrickson and H. Scott Matthews, Sustainability in Engineering Education and Research at U.S. Universities, *Environmental Science and Technology*, **43**(15), pp. 5558–5564, 2009.
4. K. H. D. Tang, Correlation between Sustainability Education and Engineering Students' Attitudes towards Sustainability, *International Journal of Sustainability in Higher Education*, **19**(3), pp. 459–472, 2018
5. A. M. Hasna, Sustainability classifications in engineering: Discipline and approach, *International Journal of Sustainable Engineering*, **3**(4), pp. 258–276, 2010.
6. Richard Dodds, Roger Venables, *Engineering for Sustainable Development: Guiding Principles*, London: The Royal Academy of Engineering, 2005.
7. A. Kamp, *Engineering Education in the Rapidly Changing World: Rethinking the Vision for Higher Engineering Education*, The Netherlands: Delft University of Technology, 2016.

8. N. C. Hawkins, R. W. Patterson, J. Mogge and T. F. Yosie, Building a Sustainability Road Map for Engineering Education, *ACS Sustainable Chemical Engineering*, **2**(3), pp. 340–343, 2014.
9. M. C. Felgueiras, J. S. Rocha and N. Caetano, Engineering education towards sustainability, *Energy Procedia*, **136**, pp. 414–417, 2017.
10. S. Murcott, Engineering education for sustainability: Reflections on ''the greening of engineers'' (A. Ansari), *Science and Engineering Ethics*, **7**(1), pp. 137–140, 2001.
11. M. E. Abu-Goukh, G. M. Ibraheem and H. M. E. A. Goukh, Engineering Education for Sustainability and Economic Growth in Developing Countries (the Sudanese Case), *Procedia – Social and Behavioral Sciences*, **102**(C), pp. 421–431, 2013.
12. *Grand Challenges for Engineering: Imperatives, Prospects, and Priorities: Summary of a Forum*, The National Academies Press, Washington, DC, 978-0-309-43896-4, 2016.
13. A. Colby and W. M. Sullivan, Ethics Teaching in Undergraduate Engineering Education, *Journal of Engineering Education*, **97**(3), pp. 327–338, 2008.
14. D. R. Haws, Ethics Instruction in Engineering Education: A (Mini) Meta-Analysis, *Journal of Engineering Education*, **90**(2), pp. 223–229, 2001.
15. A. R. Bielefeldt and N. E. Canney, Changes in the Social Responsibility Attitudes of Engineering Students Over Time, *Science and Engineering Ethics*, **22**(5), pp. 1535–1551, 2016.
16. E. A. Cech, Culture of Disengagement in Engineering Education?, *Science, Technology & Human Values*, **39**(1), pp. 42–72, 2014.
17. *Ethics Education and Scientific and Engineering Research: What's Been Learned? What Should Be Done? Summary of a Workshop*. Washington, DC: National Academy of Engineering (in English), 2009, p. 58.
18. R. R. Kline, Using history and sociology to teach engineering ethics, *IEEE Technology and Society Magazine*, **20**(4), pp. 13–20, 2001.
19. K. Kazerounian and S. Foley, Barriers to Creativity in Engineering Education: A Study of Instructors and Students Perceptions, *Journal of Mechanical Design*, **129**(7), pp. 761–768, 2007.
20. B. Stappenbelt, Ethics in engineering: student perceptions and their professional identity, *Journal of Technology and Science Education*, **3**(1), pp. 3–10, 2013.
21. B. Newberry, The dilemma of ethics in engineering education, *Science and Engineering Ethics*, **10**(2), pp. 343–351, 2004.
22. M. J. Drake, P. M. Griffin, R. Kirkman and J. L. Swann, Engineering ethical curricula: Assessment and comparison of two approaches, *Journal of Engineering Education*, **94**(2), pp. 223–231, 2005.
23. D. R. May and M. T. Luth, The effectiveness of ethics education: A quasi-experimental field study, *Science and Engineering Ethics:* **19**(2), pp. 545–568, 2013.
24. J. A. Cruz and W. J. Frey, An effective strategy for integrating ethics across the curriculum in engineering: An ABET 2000 challenge, *Science and Engineering Ethics*, **9**(4), pp. 543–568, 2003.
25. A. El-Zein, Sustainability and ethics as decision-making paradigms in engineering curricula, *International Journal of Sustainability in Higher Education*, **9**(2), pp. 170–182, 2008.
26. J. Li and S. Fu, A Systematic Approach to Engineering Ethics Education, *Science and Engineering Ethics*, **18**(2), pp. 339–349, 2012.
27. Ibo van de Poel and David Goldberg, *Philosophy and Engineering: An Emerging Agenda*, Springer Dordrecht, Netherlands, 2010.
28. M. J. Casañ, M. Alier and A. Llorens, Teaching Ethics and Sustainability to Informatics Engineering Students, An Almost 30 Years' Experience, *Sustainability*, **12**(14), 5499, 2020.
29. N. E. Canney, M. Polmear, A. Bielefeldt, D. Knight, C. Swan and E. Simon, Challenges and Opportunities: Faculty views on the state of macroethical education in engineering, in *American Society for Engineering Education (ASEE) Annual Conference and Exposition, Columbus, OH*, 2017.
30. K. Shephard and M. Furnari, Exploring what university teachers think about education for sustainability, *Studies in Higher Education*, **38**(10), pp. 1577–1590, 2013.
31. P. Gannon, R. Anderson and C. Plumb, Board #40: Research Initiation: Effectively Integrating Sustainability within an Engineering Program, in *American Society for Engineering Education (ASEE) Annual Conference and Exposition, Columbus, OH*, 2017.
32. J. Harrison and L. Klotz, Women as Sustainability Leaders in Engineering: Evidence from Industry and Academia in the U.S, *International Journal of Engineering Education*, **26**, pp. 1–8, 2010.
33. R. Rao, A. Pawley, S. Hoffmann, M. Cardella and M. Ohland, An Ecofeminist Grounded Analysis of Sustainability in Engineering Education: Skill Set, Discipline, and Value, *International Journal of Engineering Education*, **29**, pp. 1472–1489, 2013.
34. D. Riley, A. L. Pawley, J. Tucker and G. D. Catalano, Feminisms in Engineering Education: Transformative Possibilities, *NWSA Journal*, **21**(2), pp. 21–40, 2009.
35. R. Paul, L. Behjat, M. Eggermont, and R. Brennan, Learning from Ecofeminism: Deconstructing the Dualistic 'Soft' vs. 'Hard' Nature of Engineering Education, *Proceedings of the Canadian Engineering Education Association (CEEA)*, 2020.
36. A. M. McCright, The effects of gender on climate change knowledge and concern in the American public, *Population and Environment*, **32**(1), pp. 66–87, 2010.
37. A. Leiserowitz, N. Smith and J. R. Marlon, *Americans' Knowledge of Climate Change*, Yale University, New Haven, CT: Yale Project on Climate Change Communication, Leiserowitz, 2010.
38. B. M. Wiernik, D. S. Ones and S. Dilchert, Age and environmental sustainability: a meta-analysis, *Journal of Managerial Psychology*, **28**(7/8), pp. 826–856, 2013.
39. M. Thürer, I. Tomašević, M. Stevenson, T. Qu and D. Huisingh, A systematic review of the literature on integrating sustainability into engineering curricula, *Journal of Cleaner Production*, **181**, pp. 608–617, 2018.
40. T. Gummer, J. Roßmann and H. Silber, Using Instructed Response Items as Attention Checks in Web Surveys: Properties and Implementation, *Sociological Methods & Research*, **50**(1), pp. 238–264, 2021.

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