Student Valuations for Opportunity-Based Education

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***Abstract*—This research-to-practice paper describes an experiment designed to understand educational opportunities valued by students. Engineering education has, since the advent of ABET's EC-2000, operated using an outcomes-based paradigm predominantly focused on preparing engineers for the workforce. Engineering departments create curricula based on this paradigm that are more rigid than most other disciplines, thereby limiting the opportunities students have to explore beyond established curricular boundaries. The outcome-based paradigm limits students' agency in engineering education to pursue growth in unique, individual ways.**

Recognizing these challenges, the Electrical and Computer Engineering Department at Bucknell University is adapting Amartya Sen's Capability Approach, which emphasizes student agency. In contrast to top-down approaches to curriculum design that focus narrowly on students' mastery of defined content areas, we focus on enabling students to develop the abilities needed to live a life aligned with their values. Rather than ensuring students achieve mandated outcomes, the focus is on providing opportunities, which students actively choose to transform into achievements.

This study sought to better understand the opportunities that students value. The department first created a capabilities list that classified several opportunities that are of potential importance in engineering education. To gather feedback from students in the department, we offered two focus groups to discuss our capabilities list and a follow-up survey to formally elicit student valuation of capabilities. In addition, we offered an experimental course that promoted an opportunity-based engineering education model that nurtures both academic and personal growth. Student reflections from this class were analyzed using inductive coding with multiple coders, categorizing portions of students' reflections that align with our capabilities list. This study reveals the opportunities students highly regard to be better equipped to live a life they value.

***Keywords*—Capability Approach, Student-centric, Opportunity based education**

I. Introduction

What do students want from their education in engineering? How does it align with their personal values? Is there room for student agency in engineering, with its rigid structures and inflexible timelines?

The engineering curriculum is notoriously regimented, characterized by higher than average required credit hours, daisy-chains of pre-requisites, and little time or energy for electives or life outside of class. Faculty set challenging curriculum criteria crafted to meet ABET requirements and workforce expectations. Students become expert box-checkers, collecting the courses, credentials, and resume-boosters that they believe will make them competitive on the job market. Too seldom do we ask our students what *they* want from their education, and whether engineering is helping them to meet their goals.

In this paper, we decided to ask. Research shows 1) that engineering students have a wide range of pathways and interests [1]–[3], 2) that successful completion of an engineering degree program often requires aligning engineering and personal identities [4], [5] and 3) that offering flexibility in the curriculum helps to facilitate varied pathways [6]. Accordingly, our department has begun exploring ways to increase student agency in engineering. Through survey research, focus groups and reflective assignments, we asked students to help us understand what aspects of the engineering degree program they most valued. Our findings were in some ways expected—engineering students highly value developing technical skills and career development. However, we were surprised by the number of students engaged in creative pursuits who sought to integrate these activities into their engineering work.

II. Literature Review

Engineering education is structured in a top-down manner, under influence from many distinct, yet interconnected, authorities. As the accrediting body for all engineering programs in the U.S., ABET requires outcomes-based criteria intended to maintain high quality education across the nation. Professional organizations offer input on the content of disciplinary curricula, helping to shape which areas of knowledge and skills should be emphasized in a rapidly-changing technological world. Industry has a voice through advisory panels and hiring practices. And engineering faculty, after collecting all advice and opinions, make the final decision on what is included and excluded from engineering degree programs.

Students are often perceived as passive agents in the education system. This perception is exacerbated by metaphors such as the "STEM pipeline", which portray students as droplets of water being carried along with the flow from K-12 to employment. As novices in engineering, students trust the faculty to set wise and reasonable requirements. For the most part, students are willing to follow our advice, believing that we have their best interests in mind. However, conflicts arise when the rigorous course requirements lead to burnout [7], or when the identities they are building as engineers do not align with their perception of themselves [2], [4], [5]. Too often we try to resolve pipeline "leaks" by seeking to "fix the student" rather than assessing whether the problem may be that engineering itself is too rigidly and narrowly defined [1], [8].

As a result, many have begun recommending new metaphors, such as "pathways" and "ecosystems", that position students as active agents in a dynamic system [3], [9]–[11]. A pathways model helps us understand and account for multiple ways of moving through the pipeline, including later starts, occasional exits and re-entries, and diversions into other areas of knowledge. The "APPLES" large-scale study of student pathways reveals that engineering students do not see themselves as "engineers only" and that they value a more holistic model of engineering—a factor that may be especially true for women and minorities [1]. While there are many students who have thrived under the "engineering-focused" model, our highest achieving students often pursue interests and careers outside of engineering [1, p. 147]. For this reason, the authors caution that a "one size fits all" model of engineering education is unlikely to work and that departments should look for ways to accommodate a greater range of student pathways [2, p. 2]. Furthermore, a holistic understanding of education may be particularly important for STEM students who often experience their undergraduate curriculum as a fragmented series of discrete courses in terms of acquired knowledge and skill sets [12].

In an effort to facilitate greater agency amongst students as they are navigating our program, we have adopted Amartya Sen's "capability approach" [13]. The capabilities approach is a social justice framework that seeks to expand human freedoms in many domains, including higher education [14], [15]. The central question within this framework is whether individuals are able to live a life that they value. Recognizing that individuals in different life circumstances will define value in different ways, Sen insists upon allowing individuals to set the terms of their own wellbeing. In engineering, some of our students may define success as landing a job in a particular industry or company, such as Google or NASA. For other students, success might look like simply getting an "engineering job" that supports their family. While Sen acknowledges that performance should be measured and tracked at the community level, each community should define for themselves what counts as "a good life." Rather than constructing top-down performance metrics for a given community, individuals in the community must have input into what they value and what is measured. This has been especially important in the human development field, where metrics defined by Western institutions do not necessarily reflect the values of non-Western communities. In a similar way, the metrics that we have defined in engineering–as professors and figures of authority–from our own understandings of "success" and "wellbeing" may not always match the perspectives of our students.

The core components of the capabilities approach are "capabilities" and "functionings" [13], [16]. Capabilities are the real freedoms and opportunities which individuals have access to. Functionings are the outcomes that result from those opportunities. In our team we have come to refer to capabilities and functionings colloquially as "opportunities" and "achievements," respectively. Students in a university may have a wide set of capabilities, such as the ability to learn calculus, the ability to receive training in 3D printing, the ability to study abroad. They will not (and cannot) take advantage of all opportunities available to them. Instead, they select the capabilities that they most value to transform into functionings: understanding calculus, using the 3D printer, or studying abroad.

In order to count as a true capability, an opportunity must be realistically achievable. For example, if a student has access to the study abroad office, but doesn't have the financial resources or curricular flexibility to take advantage of it, it is not a real capability. Other components of the capabilities approach, including "resources" and "conversion factors" help us understand some of the obstacles students may face in achieving their desired functionings [16]. Resources include time, money, and materials. Conversion factors refer to the ability an individual has to convert capabilities into functionings. These may be individual (i.e. personality traits), social (i.e. family background), or environmental (i.e. geographic location).

For the purposes of this paper, we are not yet evaluating these more complex components. At this early stage in our research, our main goal is to ascertain which capabilities our students most value in engineering education. Future work will explore whether these capabilities are "real" for different populations of students. What kinds of opportunities do they most desire? What do they value least? What pathways outside the traditional "engineering-focused" pathway should we work to facilitate?

III. Methods

A. Creating Our Capability List for Engineering Education

In his work on establishing a general capability approach, Sen resisted creating a "universal" capability list due to the necessity of engaging in public debate and discussion when applying the approach in a specific context [17]. However, established capability scholars have created capability lists for a wide range of applications, such as social justice [18], gender inequality [19] and education [15], [20]. Most of the existing work applying the capabilities approach in an educational context has occurred in the Global South. Therefore, to evaluate the capabilities deemed essential for a particular engineering department situated in a highly-selective, liberal arts college in the United States, best practices advise us to create our own capability list specific to our local context.

To make our own list, we followed processes recommended in capabilities literature [15], [16], [20], combining top-down analysis of existing literature and education policy recommendations, with bottom-up individual needs. We began by considered capabilities suggested by several different capability scholars [13], [18]–[21]. We then added more context-specific capabilities by examining our university and departmental mission statements and documents, general higher-education literature, literature specific to engineering education, ABET

TABLE I
DEMOGRAPHICS OF STUDENT COHORTS

	Focus Group / Survey Participants	ePortfolio Submissions
Sample Size	7	8
Sophomore Class	0	3
Junior Class	3	3
Senior Class	4	2
Men	4	4
Women	2	3
Non-binary	1	1
White	5	5
Students of Color	2	3
First Gen. Students	5	4

TABLE II
AVERAGE OF CAPABILITY RATINGS, BY STATEMENT NUMBER ($n = 7$)

Range†	Capabilities
0.0 – 1.9	15
2.0 – 2.9	14
3.0 – 3.9	
4.0 – 4.9	13
5.0 – 5.9	9 12 18 20 25 28 49
6.0 – 6.9	6 7 21 22 24 29 31 44 45 47
7.0 – 7.9	1 2 3 8 16 19 23 27 30 32 33 34 38 39 43 48
8.0 – 8.9	4 5 11 17 26 35 37 40 42 46
9.0 – 9.9	10 36 41
10	

†0 represents lowest value, 10 represents highest value.

outcomes, interviews with stakeholders, and ethnographic observations of the department. The capabilities were discussed and debated among the research team and finally sorted into a hierarchy, starting with the more basic capabilities that should be available to every individual regardless of context, and becoming more specific to students within *our* engineering department at *our* university. While our capability list is therefore specific to engineering, it makes an effort to consider broadly the opportunities needed to be a successful learner. The resulting capability list includes 49 statements and can be found in the Appendix, Table VIII.

We presented our compiled list to students in two distinct situations: 1) focus group sessions followed by a survey and 2) a small experimental course. Both involved small groups of students from different academic years within the department.

B. Focus Group & Survey Methods

To gather detailed feedback on the proposed capabilities list, all students in the department were invited to participated in voluntary focus groups. Focus groups are often used as a tool to solicit feedback from the community and anticipate their needs [22]. In contrast to individual interviews, focus groups often uncover collective understandings as participants confirm, clarify, and challenge each others' interpretations. When used in the planning stages of proposed changes, focus groups can highlight differences in interpretation of the goals of the project, generate suggestions on how to move forward, and anticipate potential pitfalls [22, p. 14]. To encourage participation, students were offered compensation in the form of a gift certificate. Two focus groups were conducted, with a total of seven participants completing our survey. Demographic information for the participating students is provided in Table I. Focus group discussions were led by the first and second authors, with the remaining authors serving in other roles, such as time-keepers and note-takers.

At the beginning of each focus group session, students were briefly introduced to concepts related to capabilities. They were then asked to engage in a "pile-sort" activity [23]. Each student was provided with a full set of the proposed capabilities on index cards and instructed to sort them into three piles based on perceived importance: high, medium, and low. The first pile included items that students could not imagine life without, while the second pile consisted of things of medium importance—things that students felt were "nice to have" but not essential. The last pile contained items of low importance that students didn't care much about.

After sorting the cards, students were asked to share a card from each category with the group and discussions on these capabilities were guided by questions posed by the focus group leader. Each student shared at least one capability that they placed in each of the high, medium and low importance categories. Students were encouraged to question, challenge, and change the meaning of the capabilities on the cards. In both sessions, discussion was robust and informative.

At the end of the focus group, students were asked to complete an online survey. In the survey, they were asked to rank each of the 49 capability statements on a Likert scale from 1 to 10 (least valuable to most valuable). Although we did collect demographic information, the sample size was too small to analyze demographic trends in responses; we will pursue these investigations in future studies.

C. Reflective Assignments from an Experimental Course

In the Spring of 2024, we offered an experimental course to a small group of students to explore approaches aimed at enhancing student agency and better understand the opportunities that students value. Eight students in the department volunteered to take this course and were enrolled. As can be seen from the class demographic information shown in Table I, the course consisted of a diverse set of students including every class year except the first year. Throughout the course, students were encouraged to bring in extracurricular learning activities and pursue personal interests that contributed to both academic and personal growth.

Students in the course completed weekly reflective assignments which they documented in a course ePortfolio. Additionally, students were required to attend and reflect upon at least four campus events throughout the semester and complete two personal "quests," defined as a multi-week activity that supports development and results in an externally recognizable achievement. The reflections and artifacts of these course components were also included in the course ePortfolios. The

TABLE III
STANDARD DEVIATION OF
CAPABILITY RATINGS, BY STATEMENT NUMBER ($n = 7$)

Std. Dev.†	Capabilities
0.0 – 0.5	26 36 37
0.5 – 1.0	4 10 15 16 17 35 38 39
1.0 – 1.5	3 5 6 14 18 19 21 29 30 32 34 40 41 42 48
1.5 – 2.0	1 2 11 23 24 25 27 31 33 43 46 47
2.0 – 2.5	8 9 12 13 20 22 28
2.5 – 3.0	7 44 45 49

†Lower values indicate higher agreement.

capability list was ready for student input around the middle of the semester. The capabilities were presented and students were asked to connect many of their weekly reflections, their last two campus events, and the second quest to the capabilities list and explain the connections.

Several entries in each students' course ePortfolio were coded using NVivo qualitative data analysis software. Two members of our research team conducted independent coding of each students' submissions using the same capabilities list that was presented in the focus groups. Any capabilities identified as important by our students that weren't included in our original list were added to the codebook. Any inconsistencies were discussed and resolved through consensus, supporting intercoder reliability [24]. Since the capability list is rather long, our discussions centered around ensuring that students' statements were coded to the same categories and that no capabilities were overlooked. Each time a new capability was added, the coders discussed whether a new category was necessary, and where it belonged in the capabilities classification. The coders considered the coding density and number of references for each student to identify their most essential capabilities. The capabilities cited by the most students and those with the most references are also considered.

IV. RESULTS

A. Survey Results

The capabilities survey asked students to tell us which capabilities they valued most and least. Students were asked to rank each capability on a scale of 1–10 (least valuable to most valuable). Table II reports the average Likert ratings for each capability by statement number (see the Appendix for the statement list).

The highest ranked capabilities are related to their ability to develop technical skills (36, 37, 40, 42), find employment (4, 5, 46), and obtain mentorship (17, 26). However, students also highly valued working across disciplinary backgrounds (35) and the ability to learn continuously throughout their lives (41). They also valued having time for leisure activities (10) and for managing their lives outside of school (11).

The capabilities students ranked least valuable tended to fall into two categories: 1) those related to social context, ethics, and sustainability (12, 13, 14, 15, 28, 49), and 2) those related to their own agency and ability to navigate engineering in a way that is appropriate for them (18, 20, 25).

Sample Response Distribution "Student A"

← Lowest Value to Highest Value →

1	2	3	4	5	6	7	8	9	10
12	14	11	1	5	3	7	8	9	10
13	44	20	2	6	4	16	19	26	17
15	45	28	18	32	21	27	24	40	35
22			23	47	25	39	30	42	36
49			33		29	43	31		
			46		34		37		
			48		38				
					41				

Sample Response Distribution "Student B"

← Lowest Value to Highest Value →

1	2	3	4	5	6	7	8	9	10
		20	14	21	17	5	1	2	4
			15	22	19	6	3	11	10
			27	28	31	12	7	25	36
				33	40	13	8	29	37
				34	45	18	9	39	42
						24	16	46	43
						26	23		
						30	41		
						32	47		
						35	49		
						38			
						44			
						48			

Fig. 1. Comparison of Two Student Responses

However, if we are interested in exploring alternative, nontraditional pathways, averages are not always the best metric. Upon examining the standard deviation, indicating values that had the most disagreement amongst students, some of these least valued capabilities surfaced as capabilities that were highly valuable to some individuals (see Table III). In this paper, we refer to these as "alternative capabilities" to contrast them with the "mainstream capabilities" with the highest average rankings.

There were three major patterns that emerged when examining these "alternative capabilities." First, some students valued communication skills more highly than others (44, 45). Some students also valued a higher level of flexibility and support in the program (7, 8, 9, 20, 22). And finally, some students highly valued capabilities related to social context, ethics, and sustainability (12, 13, 28, 49).

As an example of this pattern, Fig. 1 compares two students with differing values. Student A ranks capabilities similar to our average ratings: they highly value technical skills (35, 36), professional development (17, 40, 42) and leisure time (10). Student B also places technical skills (36, 37), professional development (42, 43, 46), and leisure time (10) toward the top of their list; however, they rank capabilities related to social context, ethics, and sustainability (12, 13, 29, 49) much higher than Student A.

While these results are not statistically significant due to the small sample size, they nonetheless are important early indicators of student values. An expansion of the survey to reach more of our students would help confirm or refute the average values. The three "alternative capability" patterns should be explored in greater depth in future work.

B. Focus Group Results

The focus groups were a chance for us to gain insights into how students interpreted the capabilities statements, which we

TABLE IV
CODES ADDED TO CODEBOOK

Code Description	Code Reference	Unique Students Using Code
Health, Exercise & Nutrition	A	7
Learning about other Cultures	B	3
Maintain Family Connection	C	1
Learning about other Disciplines	D	3
Career Search	E	4
Personal Finance	F	3
Apartment Hunting & Property Ownership	G	3
Develop Marketing Skills	H	1
Navigating Promotion & Advancement	I	1

TABLE V
NUMBER OF STUDENTS IDENTIFYING EACH CAPABILITY, BY STATEMENT NUMBER ($n = 8$)

# Students	Capabilities										
8	16										
7	4	10	17	A							
6	2	18	22	27	39	46	48				
5	6	33	36	41	42	47					
4	11	13	20	45	49	E					
3	5	37	40	B	D	F	G				
2	7	12	19	24	25	34	38	44			
1	1	3	8	14	15	23	26	35	C	H	I
0	9	21	28	29	30	31	32	43			

anticipated might be quite different from our own intended meanings.

In the first focus group, students were confused about whether the department had control over some of these capabilities. In particular, some of the first few statements involve physical and mental health, and campus safety (1, 2, 3) which they saw as out of the purview of the engineering department. As such, the pile-sorts in the focus group setting tended to give low rankings to things that they saw as outside the boundaries of engineering. We attempted to resolve this issue in the second focus group by telling students they could sort things into "within the department's control" and "outside the department's control".

In all focus groups, capabilities related to social context (12, 13, 14) were rated as "low". Students felt that activism (15), in particular, was incongruous with engineering.

Students also did not see themselves as active agents in their education. Statement 20, "Opportunities to be included in curricular decisions (transparency)", was ranked toward the bottom for both focus groups. In a discussion of Statement 24, "Be able to make consequential curricular decisions and be responsible for their outcomes," one participant stated that she wants guidance from professors on her course selection and she trusts that professors will make good judgments on behalf of students. In a similar vein, students in the second focus group were confused by Statement 35, which was worded as "Opportunity to work on teams that have expertise from different disciplinary areas and on which you are the expert in your knowledge area." The students did not see themselves as experts yet, and were uncomfortable with that characterization.

C. *ePortfolio Results*

The ePortfolio entries coded for each student include four weekly journal entries, two campus event reflections and the write-up of their final quest. During coding, we found students discussing capabilities that we did not have on our capability list. For example, while our initial code list had a code for physical health related to being not injured or sick (1), we found students focusing more on general physical health, exercise and nutrition (A). We added a code that better corresponded to the ways students were discussing their physical health and found evidence of this new code in all but one of the students' ePortfolios. Table IV presents all capabilities added to our codebook based on student entries, along with the number of students who referenced each of these codes in their ePortfolios.

To determine the relative importance of capabilities based on the ePortfolio entries, we analyzed three metrics. The first metric considers the importance of a capability by the number of students who referenced it at least once in their coded ePortfolio entries as shown in Table V. From this metric, we observe that students highly value increased flexibility and support (2, 18, 22, 27, A). Additionally, social aspects that are part of their student experience (16, 17, 48) and their prospects of finding employment (4, 46) are commonly mentioned by students. Capabilities including time for leisure activities outside of engineering (10) and opportunities for creativity (39) emerged as capabilities valued by most students.

As demonstrated in Table V, eight capabilities from our initial list were not coded in any student ePortfolios. Notably, there is a trend where capabilities related to ethics were not mentioned in students' reflections (28, 29, 30, 31).

The second quantitative metric used to assess students' perceived value of capabilities, as evidenced through their ePortfolio entries, involves tallying the frequency of each capability references across all student submissions. This metric operates under the assumption that capabilities valued most highly by students will be referenced most frequently. The results are shown in Table VI. As anticipated, many of the capabilities with the highest overall frequency were also those referenced by the most individual students in our previous metric. The codes for related to greater flexibility and support (2, 22, 27, A), leisure time (10) and opportunities for creativity (39) once again emerged as highly valued. Additionally, codes pertaining to the social aspects of the educational experience (16, 17) were referenced frequently. However, a few distinct codes emerged as highly valued by select students, including opportunities within broader contexts (33), communication (45), and employment (46).

After coding each student's submission, the top five capabilities for each student were identified based on coding density. These lists, representing most important capabilities to each student, served as the final metric of our ePortfolio analysis. The capabilities included in the students' lists are shown in Table VII. Consistent with our other ePortfolio

TABLE VI
CODING FREQUENCY IN EPORTFOLIOS ($n = 8$)

# References	Capabilities							
> 20	2	16	17					
11–20	10	22	27	33	39	45	46	A
6–10	4	5	11	18	20	36	41	48
4–5	6	13	42	47	49	D	E	H
3	12	24	37	40	44	B	F	G
2	7	19	25	26	34	38		
1	1	3	8	14	15	23	C	I
0	9	21	28	29	30	31	32	43

TABLE VII
NUMBER OF STUDENTS WITH EACH CAPABILITY IDENTIFIED WITHIN THEIR TOP FIVE LIST ($n = 8$)

# Students	Capabilities										
5	16										
4											
3	10	17	39	A							
2	2	4	27	33	46	E					
1	3	5	18	20	36	37	40	45	47	49	H

metrics, relationships involving peers (16) and mentors (17) emerged as highly valued. Additionally, the code we created for health, exercise and nutrition (A), leisure time (10) and opportunities to be a creator (39) appeared in three students' top five lists, aligning with the findings of our other ePortfolio coding metrics. Another capability that was added to our initial list and featured in more than one student's top five capabilities was related to career exploration (E).

D. Combined Results

We observe both alignment and discrepancies between the results from our ePortfolio coding and survey data. Both datasets indicate that leisure time (10), preparing for the future (17, 46) and having opportunities to create (39) are capabilities that are highly valued by our students. Additionally, the results suggest a consensus regarding the lower importance of capabilities such as accessing facilities at convenient times (9) and some of the capabilities related to broader context (28 and 31).

However, some capabilities were referenced more frequently in student portfolios but did not result in the highest average ratings on the survey (2, 16, 22, 27, 39). On the other hand, certain capabilities received high ratings on the survey but were less frequently represented in the student ePortfolio samples (11, 36, 37, 41).

V. DISCUSSION

Returning to our original research questions, what does this data tell us about which capabilities students value most? And how do these values differ from our expectations? Our findings reveal three "mainstream" value sets and five "alternative" value sets.

The three "mainstream" value sets include: 1) professional development, 2) technical skills, and 3) social relationships. Capabilities related to these areas were valued highly across most of our students, in both survey and reflection data. Professional development capabilities were consistently rated of highest value and students spent a lot of time discussing and developing these capabilities in their reflection assignments. Of the new capabilities generated by students in their ePortfolios, the majority of these categories fell into this area, including job searching skills, financial planning, and apartment hunting.

Students also highly valued technical skills—but not necessarily the same technical skills we intend to teach them as professors. Engineering disciplinary knowledge (32)—something of high value to professors and something we spend a great deal of time on in class—appears in the middle of students' survey rankings and is entirely absent from their reflections. When they mention technical skills (36, 37) in their ePortfolios, they describe applying programming and software knowledge in their interest areas, such as music creation. This is not to say that students do not value Fourier transforms, but they do not yet see how these are relevant to their interests.

Capabilities related to social relationships (16, 17) were also consistently valued across most students. Students enjoy developing friendships with their peers in engineering and spend significant time participating in athletics and student organizations. Mentorship from faculty and alumni are frequently cited as being of high importance, particularly as it pertains to their ability to pursue internships and careers in engineering.

From this data, we are also beginning to see the outlines of five "alternative" value sets - interests and pathways that some students value highly that are outside of the mainstream. These five values sets are: 1) creativity, 2) health, 3) communication, 4) adaptability, and 5) social context and sustainability.

Many of our students were drawn toward creative pursuits. While the ability to be creative (39) appears in the middle ranges of the survey data, this capability was very prevalent in the ePortfolios. Some of our students actively integrated their engineering knowledge into these creative projects, through programming and software skills, while for others there was less connection.

Another alternative value set involved managing their personal health. This included capabilities related to physical health and nutrition (A) and mental health (2, 22). Students with a high interest in this area also frequently cited time management (27) as being highly important to them - they perceived that being able to manage their time would help them to feel less stressed and improve their health overall.

A third subset of students highly valued communication skills. This included capabilities related to persuasion (44), communicating ideas (45), and group work (48). One student who was strongly interested in this track created a quest related to developing marketing expertise in social media platforms. Similar to the other alternative value sets, communication-related capabilities fall in the middle of the survey data, but emerge more strongly in the ePortfolios. Of the three, persuasion (44) is the least-frequently cited. This may be related to engineering disciplinary norms that privilege objectivity [7], and a belief that data should speak for itself.

Some students appreciate additional flexibility and support in the engineering degree program. Codes related to flexibility refer to abilities to balance their education with their lives outside of engineering (11, C) and the ability to navigate the engineering program in alignment with their interests and values (8, 18, 25). In terms of support, financial assistance was indicated as important to some students (7). Those valuing greater flexibility and support represent a smaller subset of students compared to other alternative pathways, perhaps because students do not question the rigidity of the engineering program and feel there is little they can do to change it. This preference may also be more common among students who are marginalized based on aspects of their identities, such as gender, race, or socioeconomic status, and thus by definition are in the minority. Nonetheless, we feel this indicates a desire among students for greater agency in navigating their degree and it may grow as students begin to recognize and value their own agency.

Finally, there is a group of students who value learning about social context (12, 13, 14) and sustainability (49). These may be two separate pathways, but there is some overlap so we have grouped them together here. In the survey data, we found that while many students ranked these capabilities toward the bottom of their list, a few placed them in the "medium importance" range. In the ePortfolios, sustainability (49) emerged as a major focus of one students' quest and was mentioned as an interest in three others. Some students also described activities that combined their engineering interests with music, theater and marketing applications (12, 14). Students also described interests in studying abroad (14) and appreciated events on campus that helped them learn about other cultures (B).

Unfortunately, capabilities related to engineering ethics (28, 29) consistently appear as of low value to students. This is concerning, but reflects the numerous studies that observe the short shrift ethics are given in engineering programs and the shallow ways in which they are commonly taught [25]–[27].

Additionally, capabilities to participate in activism (15), whether related to engineering or not, are almost universally panned. As we learned in our focus groups, our students feel that engineering and activism are not compatible. This echoes the findings of Cech [28], who has argued that engineering ideologies of meritocratic competition undermine social justice efforts on the grounds that they are "too political". We continue to explore ways to articulate the value of activism to engineering students, as this is an important exercise in learning how to wield influence and make positive change in the world.

Finally, we note a significant resistance amongst our students to embrace their own agency in the engineering program. Capabilities related to agency (20, 30) received low rankings in the survey. Similarly, the focus group conversations indicated that students generally accept that the rigidity of the engineering program is "the way it is" and some students may even prefer having professors pre-determine their pathways in engineering. However, in the experimental course, students to seemed to appreciate being given the opportunity to have input into their degree program (20). In their ePortfolios, many expressed excitement about being able to provide feedback on a future course that would be offered to next years' students. We are hopeful that by offering students more options to be included in discussions about the curriculum and by cultivating their awareness of multiple ways of navigating an engineering degree program, we can cultivate a greater sense of agency, curiosity, and exploration in our program.

A. *Limitations*

The sample sizes for our focus groups, surveys, and ePortfolio activities are all very small; therefore, these results are merely indicators for future research. We plan to revise the survey and distribute it amongst a larger number of students to produce data that may be generalizable to our institution, and perhaps to other liberal arts colleges. We also have not been able to explore the impacts of gender, race, or socioeconomic status on student pathways. While our initial findings indicate no gender or racial differences in preferences for creativity, health, or communication, we did see some indication that flexibility and attention to social context was important to both women and students of color. This could be explored and verified in future research.

We also caution against extending these findings too broadly. Our institution is a small, liberal arts college; the students who enroll are, on average, of high socioeconomic status and are seeking a liberal arts education. Thus, the capabilities that students value may be significantly different at institutions that serve minority populations and/or have a research-intensive or vocational focus. Capabilities scholars recommend that each capabilities list be tailored to reflect the needs and values of each new context, rather than attempting to generate universal lists.

VI. Conclusion

In this paper, we have developed an initial capability list defining the opportunities that should be available for every student in our engineering department. We solicited feedback from students to refine our list by asking them to identify the aspects of the engineering degree program that they most value. In small focus groups, students sorted capabilities based on importance and engaged in discussions regarding their meaning and significance. The focus groups were followed-up by an online survey where students ranked each of the 49 capability statements. Analysis of the means and standard deviations of each statement revealed the "mainstream" capabilities that students consistently ranked as highly important, as well as "alternative" capabilities where there was more disagreement, but which were highly valued by some students.

The focus group and survey results were compared with analysis of student ePortfolio reflections from an experimental course designed to trial our ideas for opportunity-based education and promoting student agency and holistic growth. Entries from students' responses were coded for alignment with our capabilities list, with opportunities mentioned by students not on the capabilities list added to the codebook. Each student's overall entries were analyzed to identify their most essential capabilities and these lists were compared. We also compared the statements aligned with the most students' reflections, those most frequently referenced, and those not included in the ePortfolios.

We conclude that some opportunities highly valued by students align with our expectations particularly in areas such as professional development, technical skills and social relationships. However, we also observed greater variation in the value placed on certain opportunity categories, with some valued more highly by some students and less by others. These include opportunities relating to creativity, health, communication, adaptability, and sustainability, which are essential to some students. Additionally, we found that some of the opportunities were surprisingly undervalued by students, notably those related to engineering ethics, activism and their own agency. Future work involves revisiting and revising our capability list based on this initial feedback, as well as distributing our revised survey to a larger number of students. This will further extend these results and improve our understanding of the opportunities students most value, as well as the impacts of demographic factors.

Appendix

The supplementary table (Table VIII) provides the 49 statements of the initial capability list used for eliciting student feedback in this study.

Acknowledgment

This work was funded by the National Science Foundation under EEC–2022271. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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TABLE VIII
LIST OF CODES

Code	Description
Physical and Mental Health and Security	
1	Freedom from physical injury or illness
2	Freedom from emotional disturbance and dysfunction
3	Freedom from bullying, harassment, sexual harassment and/or assault
Opportunity to be Employed and/or Economically Self-Sufficient	
4	Access to a Meaningful Occupation
5	Being able to obtain relevant, employer-recognized credentials.
6	Opportunities to engage in paid, relevant, technical work while a student
7	Access to sufficient financial aid
Sufficient Control Over Own Time	
8	Being able to construct a course schedule that meets your needs
9	The ability to access facilities at convenient times
10	Being able to engage in leisure activities outside of engineering
11	Ability to accommodate student life circumstances outside of the university (i.e. family emergencies, etc.)
Connecting Engineering with Society	
12	Being able to work on an engineering project that is grounded in a relevant social context
13	Being able to access opportunities to combine engineering with study abroad, service learning, or community development.
14	Opportunities to learn about engineering as a social and political discipline
15	Opportunities to engage in activism or other political activities
Sustain Meaningful Social Relations, Networks and Sense of Belonging	
16	Opportunity for friendships, trust, and belonging with fellow students
17	Being able to access mentorship from engineering faculty and practitioners
Peer and Professional Respect and Dignity	
18	Being able to develop an engineering identity appropriate to one's goals, culture, and background
19	Be evaluated by appropriate, transparent, and equitable assessment practices
20	Opportunities to be included in curricular decisions (transparency)
21	Able to access and learn the norms and values of engineering culture
Emotional Integrity	
22	Opportunities to engage emotions as a part of the learning process. Ability to manage and work through emotional issues. Ability to bring passions into one's efforts.
23	Access to built environments that feel inclusive and welcoming
Navigate Obtaining an Engineering Degree	
24	Be able to make consequential curricular decisions and be responsible for their outcomes
25	Be able to navigate an engineering degree program in ways that aligns with one's own background and experiences.
26	Be able to obtain honest feedback on your development as an engineer
27	Opportunities to learn to effectively manage time
Develop Engineering Judgement, Ethics and Wisdom	
28	Opportunities to learn engineering ethics
29	Opportunity to assess and manage engineering risks
30	An ability to exercise agency in applying engineering skills
31	Opportunities to learn about engineering beliefs and epistemology, and recognize limitations
Access, Learn and Abstract Disciplinary Knowledge	
32	Knowing methods and techniques to address engineering problems, engineering epistemology
33	Be able to transfer learning to other contexts by abstracting knowledge and experiencing multiple contexts
34	Be able to learn, access, and evaluate information (information literacy)
35	Opportunity to work across different disciplinary backgrounds while distinguishing each person's contributions
Applying Disciplinary Knowledge and Skills	
36	Opportunity to develop and use relevant technical skills, e.g. programming
37	Ability to access and receive training for tools and technology (e.g., test equipment)
38	Opportunity to practice engineering reasoning: mathematical, spatial, temporal, logical, qualitative
Creativity, Problem-Solving and Design	
39	Ability to be creator - use knowledge to do something meaningful
40	Freedom to choose when and how to apply engineering knowledge / skills
Continue to Develop Professionally	
41	Ability to learn continuously through one's life.
42	Opportunity to engage deeply in a particular area of specialty (build expertise to the level you desire)
43	Opportunity to manage a project
44	Be able to persuade others and be convincing
45	Being able to develop and practice communicatiang ideas to multiple audiences and for multiple purposes
46	The ability to pursue and obtain internships
47	Opportunities for leadership
48	Opportunity to work effectively in a group to accomplish goals
Contribute Meaningfully to Sustainability	
49	Opportunity to learn sustainable practices