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Acknowledging Unique Needs: Empowering Student Choice in the Creation of Their Pathway Through a First-year Experience Course

Frank J. Marsik, University of Michigan

Frank Marsik is the Faculty Director of First Year Student Engagement in Undergraduate Education within the University of Michigan, College of Engineering. He received his PhD from the University of Michigan. In addition to serving as the primary instructor for "Engineering 110: Design Your Engineering Experience", he also teaches a number of meteorology courses within the Department of Climate and Space Sciences and Engineering and is the Director for an NSF-funded Research Experience for Undergraduates site program.

Dr. Claudia G. Cameratti-Baeza, University of Michigan

At CRLT, Claudia works with the Foundational Course Initiative (FCI) as Pedagogy & Instructional Design Consultant. In this role, she partners with departmental instructional teams and fellow FCI consultants to support the University's large introductory courses, create productive teaching and learning experiences, and improve equity across the institution. Claudia Cameratti-Baeza earned her B.Sc. at Pontificia Universidad Católica de Chile (Chile) in Educational Psychology in 200. Following that she completed her M.Sc. in Cognitive Development at Universidad Diego Portales (Chile). During the first years of her professional life, Claudia focused her work in teacher education and the creation of different resources to support the learning of teaching at different levels. In 2006 she became the associate director of faculty development at the Pontificia Universidad Católica de Chile School of Engineering, where she led initiative oriented to improve instructional practices in engineering education. In 2011, she went to complete a Ph.D. in teaching and teacher education at the University of Michigan School of Education. During her Ph.D., Claudia enjoyed teaching and instructional design at the Ann Arbor Languages Partnership (A2LP), as well as participating in research groups exploring teacher learning and development.

Elizabeth Mann Levesque, University of Michigan

Elizabeth Mann Levesque earned her B.A. and Ph.D. in political science at the University of Michigan. After completing her undergraduate degree, Elizabeth taught middle school social studies in Miami, FL as a Teach for America corps member. She returned to Michigan for her graduate studies where she specialized in American politics and political institutions and engaged in research on early childhood education and K-12 education policy. Her dissertation on presidential policymaking at the state level was recognized with a Rackham ProQuest Distinguished Dissertation Award, and as a Graduate Student Instructor Elizabeth received a John W. Kingdon Teaching Award from the Department of Political Science. Subsequently, as a fellow at the Brown Center on Education Policy at the Brookings Institution, she studied a wide range of education policy issues, including civics education, employer and community college workforce development partnerships, and federal regulation related to the Every Student Succeeds Act. At CRLT, Elizabeth works on the Foundational Course Initiative as a student support and classroom climate consultant.

Stacie Edington, University of Michigan

Stacie Edington is the Director of Honors and Engagement Programs within the University of Michigan, College of Engineering. She received her Bachelor of Arts in Sociology from the University of Michigan and her Master of Science in Executive Leadership from the University of San Diego. In addition to serving on the instructional team for "Engineering 110: Design Your Engineering Experience", she teaches the Engineering Honors Seminar, directs the College of Engineering Honors Program and oversees the Michigan Engineering Common Reading Experience.

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Abstract

This complete evidence-based practice paper will discuss the transformation of an introductory engineering elective course, focusing on how the incorporation of choice supports the course learning goals. This analysis will provide insight into how choice may be leveraged within first-year engineering courses to foster self-authorship, decision-making, and the development of a Personal Action Plan.

ENGR 110: Design your Engineering Experience is an introductory, two-credit elective course that serves the first-year engineering class at the University of Michigan. The design of this introductory course helps foster student autonomy as students explore the breadth of opportunities available to engineers in both their education and careers. Students learn an engineering design process as a mechanism for making personal and academic decisions, and through a scaffolded course structure, choose exploration and engagement activities aligned with their goals and interests.

As part of the University of Michigan's Center for Research on Learning and Teaching Foundational Course Initiative, ENGR 110 has undergone a course redesign process. A central motivation for this work is the recognition that first-year engineering students enter college with unique questions regarding their choice of engineering majors, co-curricular engagement and future career options. Investing in pedagogical practices that support student autonomy has been associated with positive impacts on student learning. As highlighted by Self-determination theory (SDT), when psychological needs like autonomy, competence, and relatedness are met through different learning activities, they function as a motivational asset, central to the development of a sense of belonging and persistence in engineering programs [1]. The transformation of ENGR 110 is informed both by the needs of first-year engineering students and pedagogical practices designed to foster autonomy.

The redesigned course addresses three themes: "What is Engineering?", "Exploring Michigan and Michigan Engineering", and "Self-Understanding". Within these themes, students gain exposure to engineering disciplines, engineering contributions to society, the interdisciplinary nature of engineering, engineering as both a technical and social discipline, experiential learning opportunities, personal strengths, ethics, values, social identity, visioning and decision-making. The content that students explore within these themes is intended to encourage the development of self-authorship, a critical foundation to decision-making for first-year students [2]. At the end

of the course, students design a Personal Action Plan for their educational experience at the University of Michigan.

The structure of the course has been substantially revised to align with these themes as part of the Foundational Course Initiative. The course includes two primary structural elements: synchronous, weekly discussion sections and asynchronous, self-paced online modules. This format is designed to provide choice within a well-defined structure and to support the course learning goals, particularly those related to self-authorship, decision-making, and the development of a Personal Action Plan.

The synchronous weekly discussion sections, led by near-peer mentors, provide structured opportunities for students to explore their interests, values, and goals while building a community of peers who are partaking in the same type of exploration. Within this supportive environment, students choose from a wide variety of asynchronous modules to explore the field of engineering. Students first complete a series of mandatory Foundation Modules that introduce students to core course themes. Students then proceed to the Exploration Modules and Engagement Modules. Importantly, students choose which Exploration and Engagement Modules to complete. Through Exploration Modules, students learn about engineering disciplines and experiential learning opportunities within the University of Michigan and the College of Engineering. Engagement Modules invite students to interactively investigate career and educational pathways through experiences such as interviewing faculty and alumni, attending field- and discipline-specific talks, and sitting in on upper-level courses. The course culminates with students writing a Personal Action Plan, in which students synthesize what they have learned by writing a vision for a future career and identifying a potential pathway through the University of Michigan and the College of Engineering aligned with this vision.

We will analyze the extent to which the content and structure of the redesigned course supports the course learning goals, with a particular focus on how choice shapes students' experience in the course. Data will primarily consist of student responses to pre/post surveys fielded over the course of several semesters. We will also describe the ways in which these data informed course design decisions to contribute to student learning and achievement of course goals.

Introduction

ENGR 110: Design your Engineering Experience is an introductory, two-credit elective course that serves the first-year engineering class at the University of Michigan. This paper analyzes how the *choice* afforded students within the course supports their exploration of engineering and their self-understanding, two of the core learning goals of the course.

The paper proceeds as follows. First, we describe the motivation for introducing choice into the course. Next, we describe the course learning goals and structure, as well as the research basis that informs this design. Then, drawing on data about student choices in the course, student feedback, and student assignments, we investigate the following hypotheses:

- H1: If given the option, students will pursue different paths to explore their interests.
- H2: By creating their own paths, students will deepen their self-understanding about their strengths and interests with respect to engineering.

We discuss the implications of this analysis, which provide insight into how choice may be leveraged to foster student exploration and self-understanding. We find that when given the opportunity to choose their own paths through the course, students do indeed take advantage of this opportunity. Specifically, we observe multiple pathways through the course via the Exploration and Engagement Modules, explained below. Student survey responses and self-reflection within the Personal Action Plan assignment further suggest that students deepened their self-understanding through the course. Ultimately, this research suggests that incorporating choice in first-year engineering courses may be a useful alternative to a "one size fits all" approach, given that the former allows students to explore their different interests and goals with respect to engineering.

Motivation

As part of the Foundational Course Initiative, a university-wide initiative which seeks to transform large, foundational first-year courses, ENGR 110 has undergone a course redesign process. A central motivation for this work is the recognition that first-year engineering students enter college with a wide variety of questions regarding their choice of engineering majors, co-curricular engagement, and future career options. For example, some students have a clear idea of what they want to major in, and others are just beginning to explore the many disciplines within the field of engineering. Some students may be familiar with different engineering career paths, while many others are not. Some students may have a clear grasp of the academic requirements of their intended major, while many are seeking insight and guidance.

Recognizing this breadth across first-year engineering students, in the course redesign process, the course team recognized that a "one size fits all approach," in which all students are introduced to all departments through weekly lectures, might not adequately address the variety of questions, goals, and interests across students. In particular, while many students may value a broad survey of the engineering disciplines, others may wish to explore several departments in depth. Further, the types of inquiries that are helpful to students are likely to vary. For example, while some students may wish to connect with alumni to learn about their career paths, others may prioritize connecting with current students to learn about on-campus opportunities.

To meet a wide variety of students' needs with respect to academic and career exploration, the course design team created a new course structure to provide students with *choice* over what to explore and how to explore it. Specifically, students choose which disciplines and co-curricular opportunities to explore through online modules. Students also choose which in-person or virtual engagement opportunities to participate in. These choices, provided to students within a defined structure of common course requirements, are designed to support the core course goals.

Further, this course design is informed by research on student autonomy, which suggests that providing opportunities for students to exercise autonomy within clearly defined structures can increase intrinsic motivation. Brooks and Young [3] suggest that developing a sense of autonomy and personal agency in the learning experience is associated with increased levels of motivation to participate in academic activities and satisfaction among students. The authors observe that despite these positive associations between autonomy and motivation in theory and practice, college students experience a lack of choice and opportunities to exercise such autonomy.

Course learning goals and structure

To provide context for the subsequent analysis, this section describes the learning goals and structure of the course. As mentioned above, the course team has recently engaged in a course redesign process as part of a university-wide, Foundational Course Initiative. Through this process, the course team defined the following learning goals and themes. The learning goals of the course are:

1. Explain the role of engineering in society, articulating the importance of a mindset that values diverse perspectives and experiences, and ensures equitable access and participation in all aspects of engineering education, design and practice.
2. Apply design thinking principles and decision-making skills to evaluate personal, academic, and professional interests; make decisions; and create your planned academic path within the University of Michigan.
3. Describe different career opportunities associated with a variety of the engineering disciplines offered within Michigan Engineering.

4. Begin to develop an engineering identity by identifying personal strengths and learning about the opportunities available to you during your undergraduate experience.
5. Speak in an intentional way about your academic plan, including selection of major and plans for your engagement with experiential learning opportunities.

This paper focuses on how introducing choice within the course supports exploration and self-understanding, as specified in learning goals 3 and 4, respectively. While this analysis focuses on these particular goals, the course learning goals are mutually reinforcing in theory and in practice. For example, students learn decision-making skills, which in turn enable them to make informed choices and make the most of opportunities for exploration. Further reflecting this interconnectedness, three central themes of the course emerge from the learning goals:

1. What is Engineering?
2. Exploring Michigan and Michigan Engineering
3. Self-Understanding.

As suggested by these themes, through the course, students gain exposure to engineering disciplines, engineering contributions to society, the interdisciplinary nature of engineering, engineering as both a technical and social discipline, experiential learning opportunities, personal strengths, ethics, values, social identity, visioning and decision-making. The content that students explore within these themes is intended to encourage the development of self-authorship, a critical foundation to decision-making for first-year students [2]. At the end of the course, students design a Personal Action Plan for their educational experience at the University of Michigan and within the College of Engineering.

The course team redesigned the structure of the course in alignment with these learning goals and themes. The redesigned course includes two primary structural elements: synchronous, weekly discussion sections and asynchronous, self-paced online modules. The synchronous weekly discussion sections, led by near-peer mentors (junior- and senior-level engineering undergraduate students), provide structured opportunities for students to explore their interests, values, and goals, while building a community of peers who are partaking in the same type of exploration. This community structure has always been viewed as a key element of the course, but proved to be even more important when the University of Michigan moved to a hybrid (in-person/virtual) teaching structure in response to the Covid-19 pandemic.

Within this supportive environment, students choose from a wide variety of asynchronous modules to explore the field of engineering. Students first complete a series of mandatory Foundation Modules that introduce students to core course themes. Students then proceed to Exploration Modules and Engagement Modules. Importantly, students choose which Exploration and Engagement Modules to complete.

Through Exploration Modules, students learn about engineering disciplines and experiential learning opportunities at the University of Michigan and within the College of Engineering. The Exploration Modules include eleven departmental modules, each of which introduces one of the departments within the College of Engineering. The Exploration Modules also include seven Immersed Program Modules, each of which introduces an experiential learning opportunity in the College. Students are required to complete five Exploration Modules total, and of these, at least two must be departmental modules. The modules include pre-assignments to prepare students to engage with the modules, prompts and resources to help students explore the particular department or Immersed Program experiential learning opportunity, and reflection questions upon completion of the modules.

Through Engagement Modules, students interactively investigate career and educational pathways. Engagement Modules are divided into the following categories: Perspectives on Engineering, Co-curricular, Academic, and Career. Several of these modules are tagged as "mentorship" opportunities. Each module requires the student to participate in a specific "engagement," such as interviewing faculty and alumni, attending field- and discipline-specific talks, or sitting in on upper-level courses. Students are required to complete five Engagement Modules. Of these, they must complete one Perspectives on Engineering module, one mentorship opportunity, and attend office hours with an instructor for the course (an Academic module). As with the Exploration Module, students are required to complete pre- and post-assignments to prepare them for the module and reflect on their learning, respectively.

The course culminates with students writing a Personal Action Plan. This plan incorporates a reflection on the choices students made as they created their pathways through the course, a personal engineering statement focusing on the personal qualities that they seek to exhibit as an engineer, a personal vision (one-year or five-year), and the proposed initial step(s) they plan to take in fulfilling that vision.

Analysis: How does choice support exploration and self-understanding?

This course structure is designed to support the course learning goals. In the subsequent analysis, we investigate the extent to which providing students with the option to choose which modules they complete supports exploration and self-understanding. As noted earlier, we hypothesize the following:

- H1: If given the option, students will pursue different paths to explore their interests.
- H2: By creating their own paths, students will deepen their self-understanding about their strengths and interests with respect to engineering.

These hypotheses reflect the rationale for incorporating choice over which modules to complete in the course. With respect to H1, as described in the Motivation section above, we recognize that first-year students enter college with a wide variety of interests, strengths, goals, and perspectives. Student feedback collected through focus groups, mid-semester feedback sessions, and surveys indicates that students desire an opportunity to tailor their exploration of the College of Engineering to their own interests, strengths, and values. Additionally, it became clear to the course team that the students' preferred modes of information delivery were driven by which modes best fit their personal learning styles. Reflecting on the variety of first-year students' interests and their desire to engage in exploration that reflects their own interests, the course team chose to depart from a traditional, "one size fits all" approach in which the course introduces all students to all departments within the College of Engineering with the same modes of delivery and with equal depths of exploration. The Exploration and Engagement Module design, in which students choose which modules to complete, reflects the hypothesis that when given the option, students will pursue different paths to explore their interests (H1).

With respect to H2, the course team recognized that within a traditional, "one size fits all" approach, students are not granted agency over determining what to explore and how to explore it. Consequently, they have few opportunities to consider how their own interests, strengths, and values might inform their academic and career exploration. In contrast, a course that offers choice can provide opportunities for students to develop self-understanding.

In designing a structure aligned with the course learning goals, the course team was guided by research which suggests that granting students autonomy, transparently defined and within clear structures, can result in increasing levels of intrinsic motivation and self-authorship. Developing self-authorship, or the agency to define one's own values, social identities and interactions with others, is a key contributor in meeting the challenges of adult life [4]. Moreover, as highlighted by Self-determination theory (SDT), when psychological needs like autonomy, competence, and relatedness are met through different learning activities, they function as a motivational asset, central to the development of a sense of belonging and persistence in engineering programs [4]. With regards to creating opportunities for student autonomy, Evans and Boucher [5] suggest the provision of choice and the removal of external controls in student learning experiences. They suggest including instances in which students can set their own goals considering their personal values, strengths, and interests, identifying important steps to achieve those goals, and taking initiative in progressing toward those goals in order to determine one's own future. Drawing on this research, the course team designed the Exploration and Engagement Module structure to provide students with opportunities to create their own paths, and in doing so, deepen their self-understanding about their strengths and interests with respect to engineering (H2).

Through analyzing these hypotheses, we examine the extent to which choice within the course structure supports the course learning goals of exploration and self-understanding.

Hypothesis 1

We begin with analyzing *H1: If given the option, students will pursue different paths to explore their interests.* First, we note that in the post-survey data from Fall 2020, 97.8% of students indicate that they like being able to choose which exploration and engagement modules to complete (N=715). At a general level, then, these survey responses indicate that students like the opportunity to tailor the course to their interests.

To understand which path students took to explore their interests, we analyze descriptive data of the Exploration Modules students selected during the Fall 2020 semester. These data provide insight into the variety of pathways that students defined for themselves. In this analysis, we only included the data associated with those students who had completed the final assignment, the Personal Action Plan. This approach allowed our results to represent those students in our class who fully-completed the course. This resulted in a sample size of N=739 students, with the data from 26 out of the 765 students enrolled in the course (3.4%) being removed. Given the flexibility of student choice offered by the course, the number of Department Exploration Module assignments that were completed (N=2122) differed from the number of Immersed Program Exploration Modules that were completed (N=1553). The data processing for this portion of the study was performed using Microsoft Excel 365 (2020) and IBM SPSS V27 software packages. The acronyms used in the figures included in this section are defined more fully in the Appendix.

Overall Exploration Module Assignment Choices

A total of 2122 Department Exploration Module assignments were completed during the Fall 2020 offering of the course. As seen in Figure 1, the three most commonly explored academic departments were Electrical Engineering and Computer Science (N=416 assignments completed), Mechanical Engineering (N=359 assignments completed), and Aerospace Engineering (N=288 assignments completed). This result was not surprising, as these three departments had the highest number of declared department majors within the College of Engineering during the FA2020 semester: Electrical Engineering and Computer Science (N=2076 students), Mechanical Engineering (N=762 students), and Aerospace Engineering (N=371 students). It should be noted that students typically declare their majors during their second year on campus, so students enrolled in ENGR 110 do not contribute to these totals in a significant way.

A total of 1553 Immersed Program Exploration Module assignments were completed during the Fall 2020 offering of the course. As shown in Figure 2, the three most commonly explored programs were Engineering Abroad (N=430 assignments completed), Work Experience (N=345

assignments completed), and Student Organizations (N=345 assignments completed). It should be noted that each of the Immersed Program Module categories provided an overview of multiple program offerings.

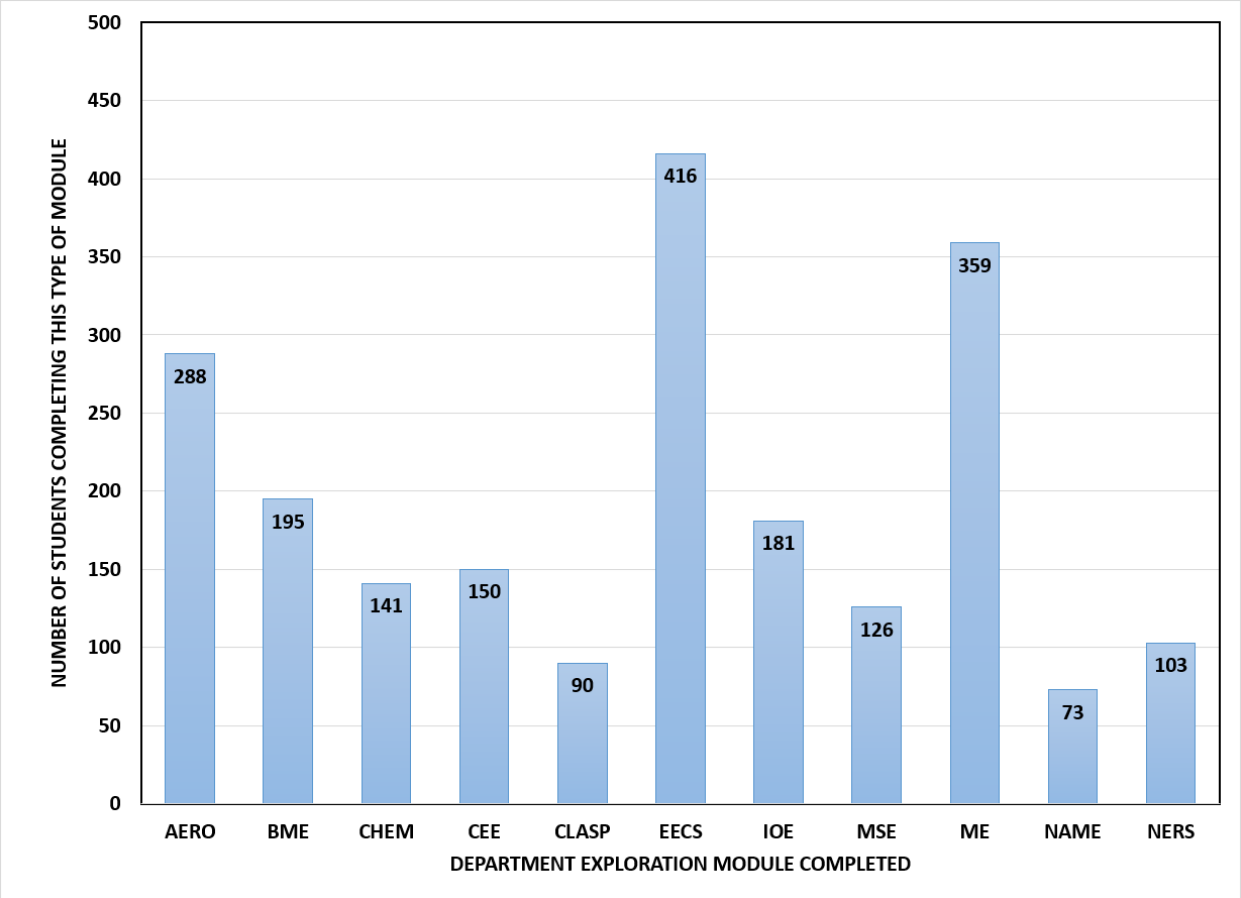

Figure 1. Total number of Department Exploration Modules completed for each department by students in the FA2020 offering of the course. Students were required to complete a minimum of two Department Exploration Modules.

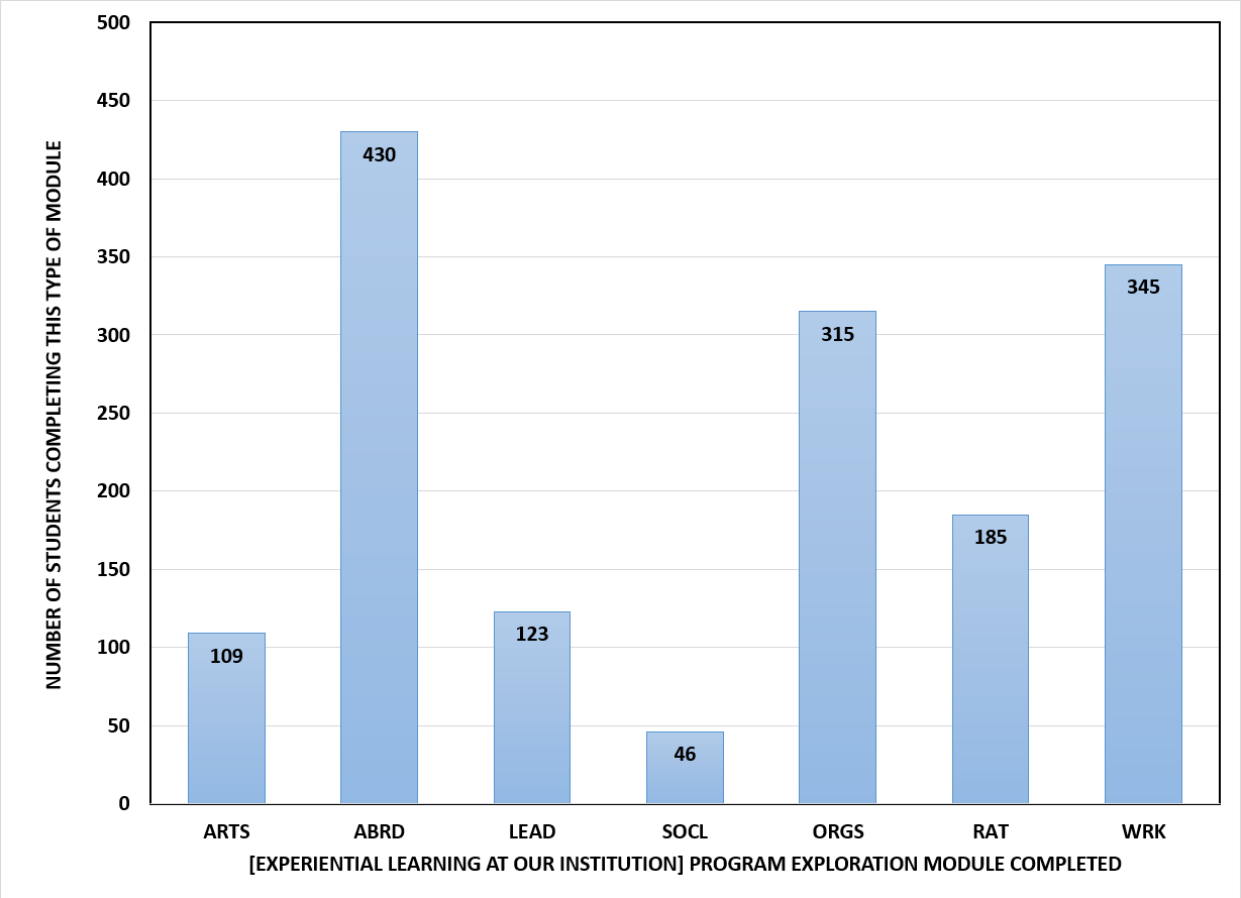

Figure 2. Total number of Immersed Program Exploration Modules completed for each program category by students in the FA2020 offering of the course. Students were required to complete a minimum of two Immersed Program Exploration Modules.

Exploration Module Assignment Choices by Departments Chosen

The Exploration Module assignment choices were further analyzed by considering the frequencies with which each Department Exploration Module and Immersed Program Exploration Module were completed by students by parsing the data as a function of Department Exploration Modules chosen. As an example, for all students choosing to complete the Aerospace Department Exploration Module as one of their choices, we determined the frequency with which they completed each of the Department Exploration Modules and Immersed Program Exploration Modules. As shown in Figure 3, those students who chose to explore the Aerospace Engineering Department Exploration Module, also predominantly chose to complete the Electrical Engineering and Computer Science and Mechanical Engineering Department Exploration Modules, similar to the overall results presented in Figure 1. Likewise, those students who chose to explore the Aerospace Engineering Department Exploration Module, also predominantly chose to complete the Engineering Abroad, Student Organizations and Work Experience Immersed Program Modules (Figure 4), similar to the overall results in Figure 2.

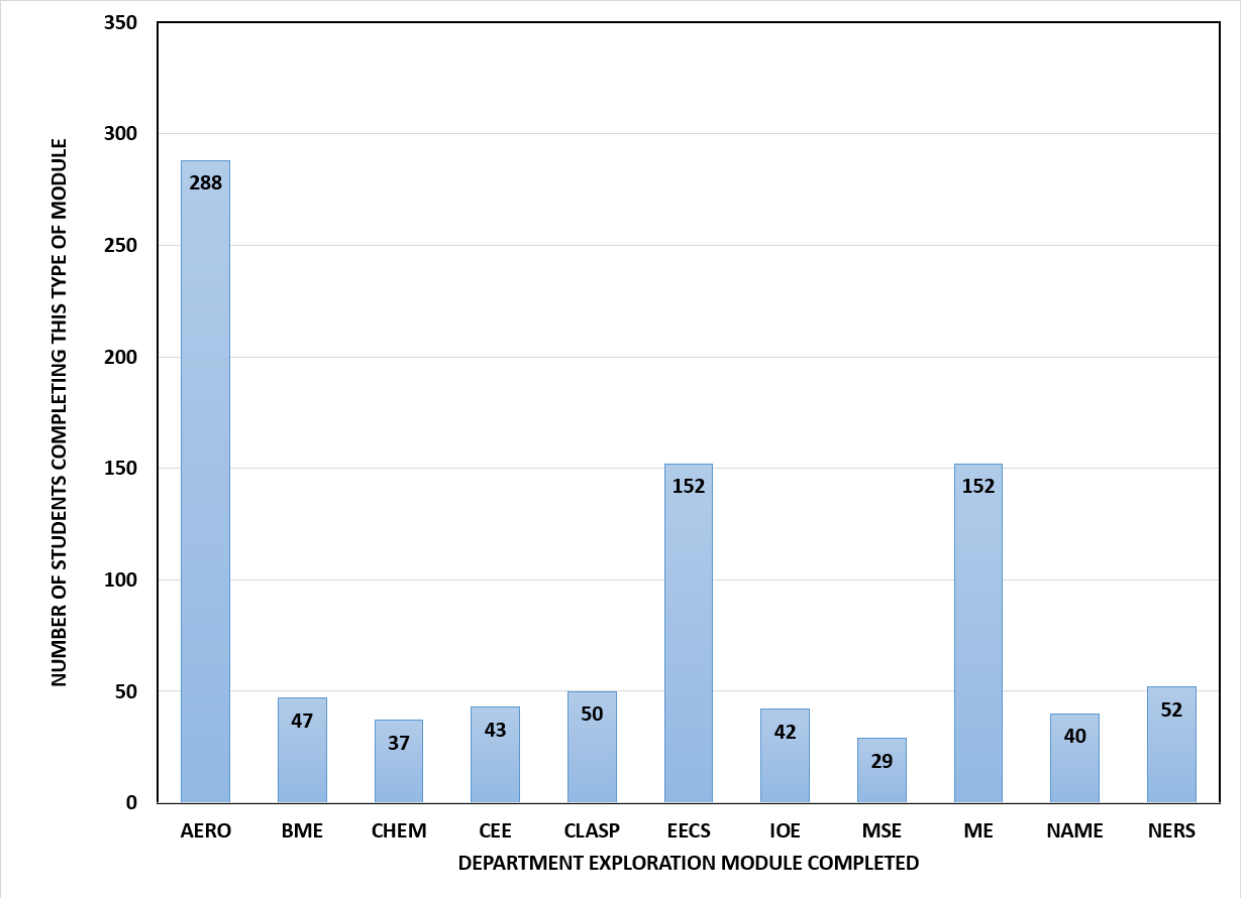

Figure 3. Total number of Department Exploration Modules completed by students who chose to complete the Aerospace Engineering Department Exploration Module in the FA2020 offering of the course.

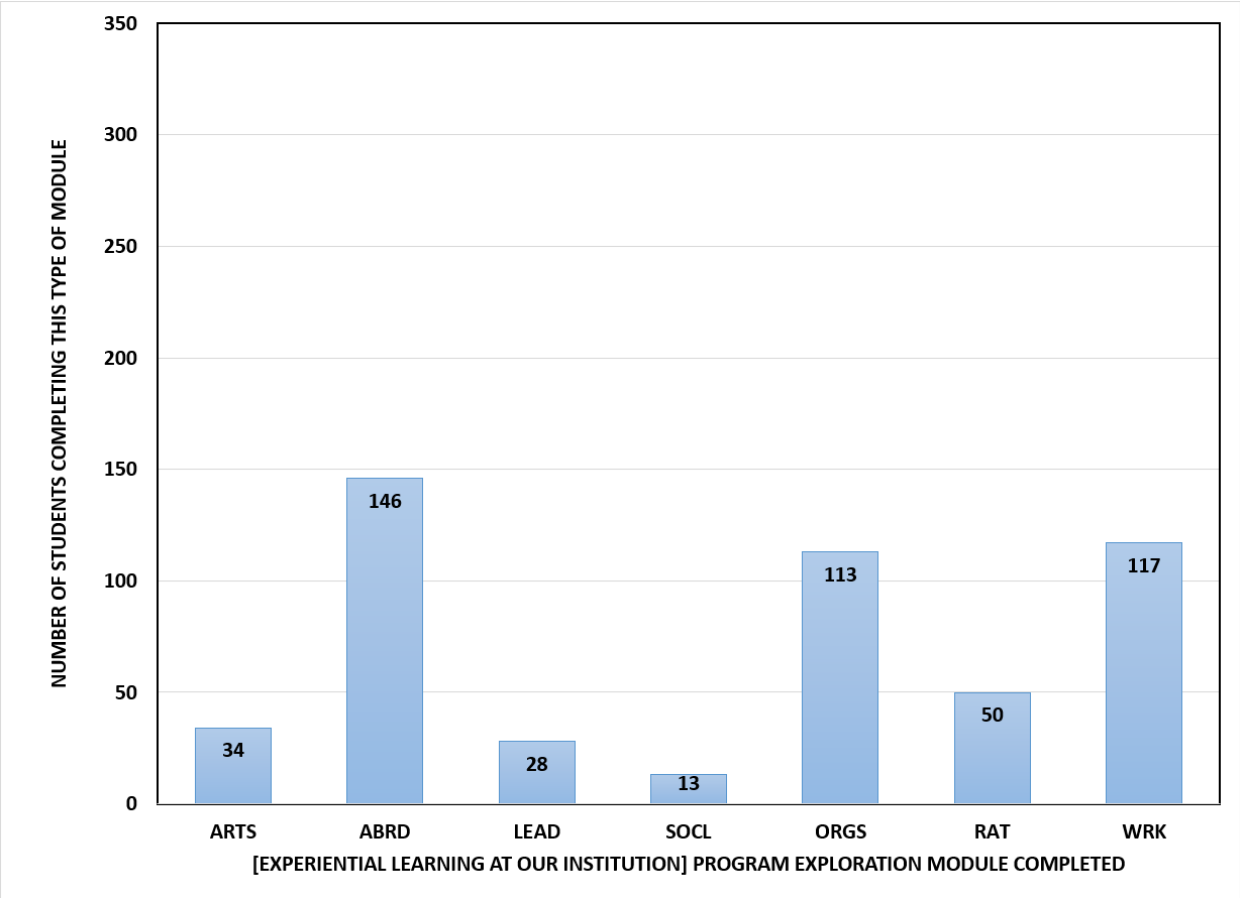

Figure 4. Total number of Immersed Program Exploration Modules completed by students who chose to complete the Aerospace Engineering Department Exploration Module in the FA2020 offering of the course.

Our analysis showed that students choosing the Electrical Engineering and Computer Science and Mechanical Engineering Department Exploration modules also predominantly chose to complete the same Department Exploration modules (AERO, EECS, and ME) and the same Immersed Exploration Modules (Engineering Abroad, Students Organizations, and Work Experience). In short, students who were interested in these three departments appeared to have a common predominant interest in the same academic departments and Immersed Programs. With respect to the Immersed Program choices by this group of students, we found that the interest in Research and Teaching Immersed Programs was approximately half of that for the Students Organizations and Work Experience programs.

In our analysis, one other predominant grouping of Department Exploration Module choices was observed. This grouping consisted of those students who chose to explore either Biomedical Engineering, Chemical Engineering and/or Materials Science and Engineering as one of the Department Exploration Modules to complete. In Figures 5 and 6 below, we present the total

number of Department Exploration Modules and Immersed Program Exploration Modules completed by students who chose to complete the Chemical Engineering Department Exploration Module. As can be seen, while Aerospace Engineering, Electrical Engineering and Computer Science and Mechanical Engineering were popular choices for this subgroup of students as well, the predominant Department Exploration Modules chosen by this group included Biomedical Engineering and Materials Science and Engineering. With respect to the Immersed Program Exploration Modules completed (Figure 6), this subgroup also predominantly chose to complete the Engineering Abroad, Student Organizations and Work Experience Immersed Program modules, similar to the overall results in Figure 2. However, students who chose to complete the Chemical Engineering Department Exploration Module were much more likely to also complete the Research and Teaching Immersed Program Module. This characteristic was also present for students choosing to complete the Biomedical Engineering and Materials Science and Engineering Department Exploration Modules. In fact, for those students who completed the Biomedical Engineering Exploration Module, the frequencies with which they completed the Student Organizations, Research and Teaching, and Work Experience Immersed Program Exploration Modules were nearly the same (63, 61 and 61 modules completed, respectively).

These results suggest that in a relative sense, the students with interest in engineering disciplines with more of a physical science emphasis were more likely to be interested in exploring Research and Teaching as possible career paths, or as pathways to increased skill set development for their respective disciplines of interest (Table I). Qualitatively, the fact that these departmental interest clusters exist shows that students did, in fact, choose varying paths through the course material as a result of their varied interests.

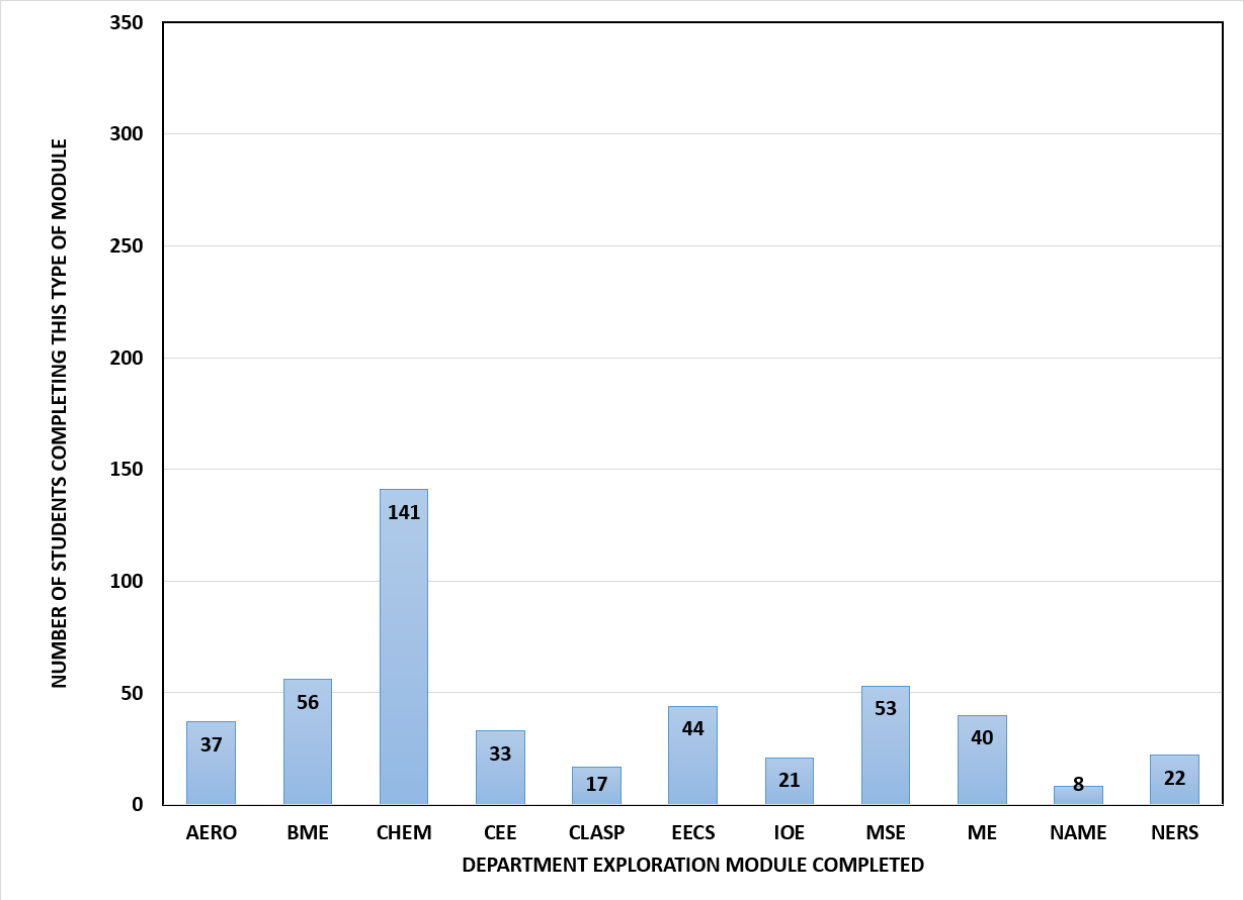

Figure 5. Total number of Department Exploration Modules completed by students who chose to complete the Chemical Engineering Department Exploration Module in the FA2020 offering of the course.

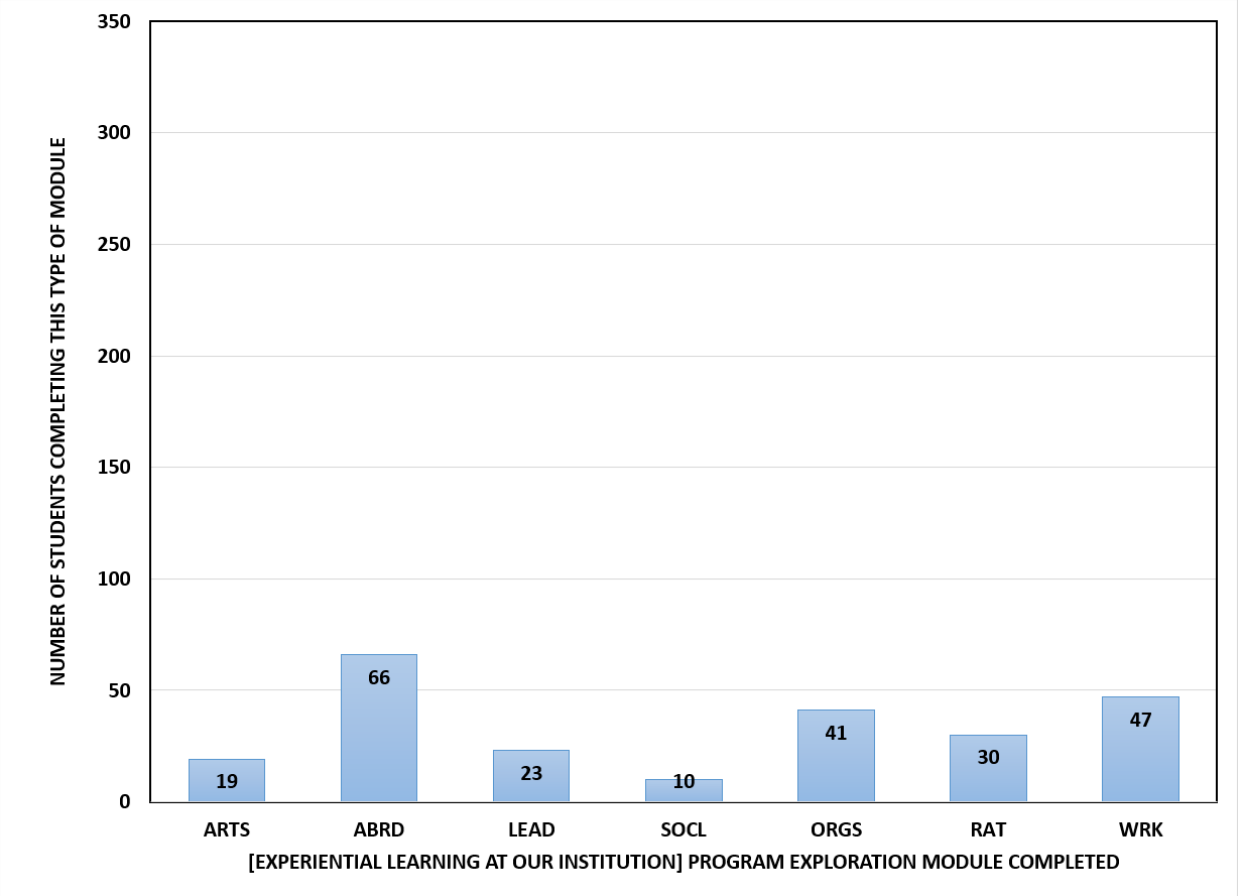

Figure 6. Total number of Immersed Program Exploration Modules completed by students who chose to complete the Chemical Engineering Department Exploration Module in the FA2020 offering of the course.

Table I. Percentage of Exploration Module Choice as a function of the Department Exploration Choices

	ARTS	ABRD	LEAD	SOCL	ORGS	RAT	WRK	RATIO RAT/WRK
BME	15	60	17	9	32	31	31	100
MSE	10	48	11	5	30	25	37	68
CHEM	13	47	16	7	29	21	33	64
NERS	10	39	12	2	23	16	27	57
CLASP	11	51	12	0	24	18	33	53
EECS	13	54	15	4	44	26	51	51
NAME	8	51	8	7	22	15	32	48
AERO	12	51	10	5	39	17	41	43
ME	13	54	12	6	45	18	43	42
CEE	15	52	15	7	31	13	34	39
IOE	11	55	25	4	35	15	45	35

Hypothesis 2

Next, we proceed to examine *H2: By creating their own paths, students will deepen their self-understanding about their strengths and interests with respect to engineering.* First, we analyze survey data from the Fall 2019 and Fall 2020 offerings of the course. This analysis provides initial insight into students' experiences in the course with respect to self-understanding. Second, we analyze a sample of students' Personal Action Plan assignment submissions from Fall 2020 to investigate how students' self-understanding developed as a result of crafting their own pathways through the course.

We begin with an analysis of survey data collected via College-wide pre/post surveys of the entire first-year cohort in the College of Engineering. For context, students enrolled in the course in Fall 2019 attended weekly lectures in which representatives from departments gave presentations about their departments. Students did not exercise choice over what departments to explore, and experiential learning opportunities were generally not included in these presentations. Thus, the Fall 2019 and Fall 2020 surveys allow for comparison along two dimensions: the experiences of students enrolled in the course between 2019 and 2020, and the experiences of students enrolled in the course and those not enrolled in the course across both semesters.

It is important to note that, for several reasons, it is not possible through this analysis to identify a causal relationship between the introduction of choice via Exploration and Engagement Modules and students' self-understanding. First, in addition to the introduction of these modules, there were fundamental differences between the course in Fall 2019 and Fall 2020. These changes were a product of both the course design process and the transition to a virtual semester due to the Covid-19 pandemic. Further, the course enrollment more than doubled between Fall 2019 and Fall 2020, increasing from about 350 to about 800 students, as the College of Engineering sought to provide students with an entry point to the College community during a virtual semester. In addition, because students self-select into the course, it is not possible to treat the students not enrolled in the course as a traditional control group. Nonetheless, these survey data do provide initial insight into how students developed self-understanding in the course during Fall 2020 as compared to Fall 2019, and compared to their peers who did not enroll in the course.

Survey Methodology

In 2019 and 2020, pre-surveys were sent to all incoming first-year students via email about a week before the semester began. Post-surveys were sent to all students via email during the final week of classes of the term. Response rates among students in the course and students not in the course each year are summarized in the table below.

In Fall 2020, students in the course were given time in class to complete the post-survey. Students in the course in 2019, and students not in the course during Fall 2019 and Fall 2020, were not given time in class to complete the post survey. This difference likely explains the higher post-survey response rate among students enrolled in the course in Fall 2020. It is also likely that response rates among students not enrolled in the course are lower on post-surveys compared to pre-surveys, as students are focused on finishing the semester and may experience "survey fatigue" at the end of the semester, as compared to the beginning.

Table II. Student survey response rates as a function of academic term and ENGR 110 enrollment status.

Fall 2019 (Enrollment: 340 students)		Fall 2020 (Enrollment: 765 students)	
Cohort	**N**	**Cohort**	**N**
Enrolled in course (pre)	193	Enrolled in course (pre)	437
Enrolled in course (post)	58	Enrolled in course (post)	715
Not enrolled in course (pre)	538	Not enrolled in course (pre)	383
Not enrolled in course (post)	196	Not enrolled in course (post)	128

To examine student self-understanding via the survey data, we examine student responses to several close-ended questions. These questions are not direct measures of self-understanding. Nonetheless, they provide insight into students' self-perceptions on several dimensions.

First, we examine changes with respect to students' plans for their engineering education and career in the near- and short-term. In Fall 2019 and Fall 2020, students were asked to rate their agreement with the statement "I have a clear plan for my Engineering education/career" with respect to the following time periods: next year, next two years, through graduation, and beyond graduation. As Figure 7 shows, in Fall 2019, there was a slight increase in short-term clarity among students in the course (next year, next two years), but a slight decrease in long-term clarity (through graduation, beyond graduation). Students enrolled in the course reported on average larger gains in clarity over their plans for the next year, pulling about "even" with students not enrolled in the course by the end of the semester. At the end of the semester, on average, students not enrolled in the course report more clarity for each time period. This difference may be due to self-selection of students into ENGR 110, wherein students with less certainty over their future may be more likely to enroll in the course. This difference may also reflect that students in the course gain a sense of the complexity of career decisions via the course.

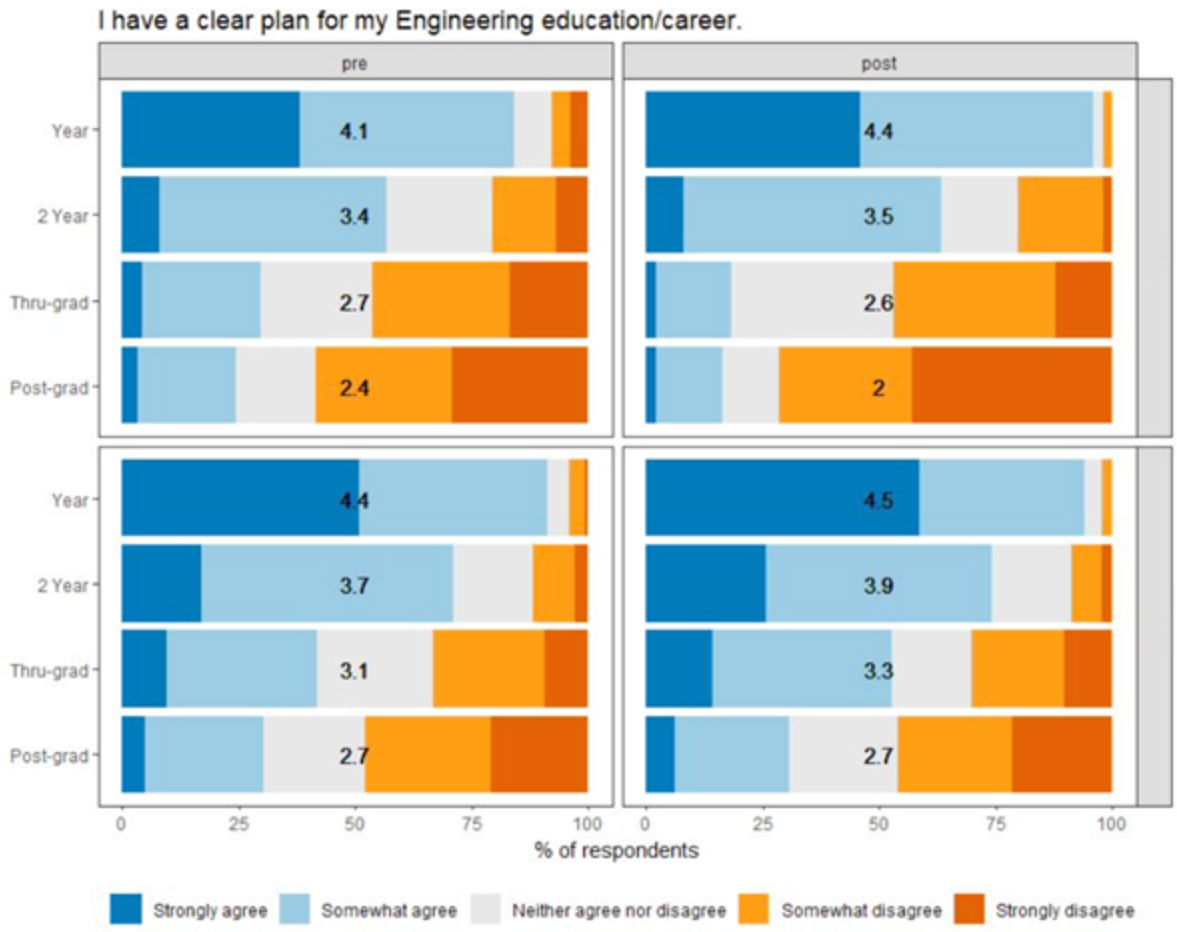

Figure 7: Fall 2019 assessment responses to the statement: "I have a clear plan for my Engineering education/career". The top four rows represent those students who were enrolled in the course, while the bottom four rows represent those students who were not enrolled in the course.

As the comparable figure for Fall 2020 indicates, students in the course exhibited a different response to this question compared to Fall 2019. In Fall 2020, among students in the course, we see a slight increase in clarity for all time periods. The post-survey averages are very similar across the two groups of students. In this semester, it appears that students in the course began the semester with slightly less clarity than their peers, and reported gaining clarity over the course of the semester. In contrast, among students not in the course, we see a slight decrease in clarity in three of the four time periods. This difference between students not in the course in Fall 2019 and Fall 2020 may in part reflect the uncertainty introduced by the Covid-19 pandemic, as well as the virtual nature of the Fall 2020 semester that likely precluded typical exploration of the College.

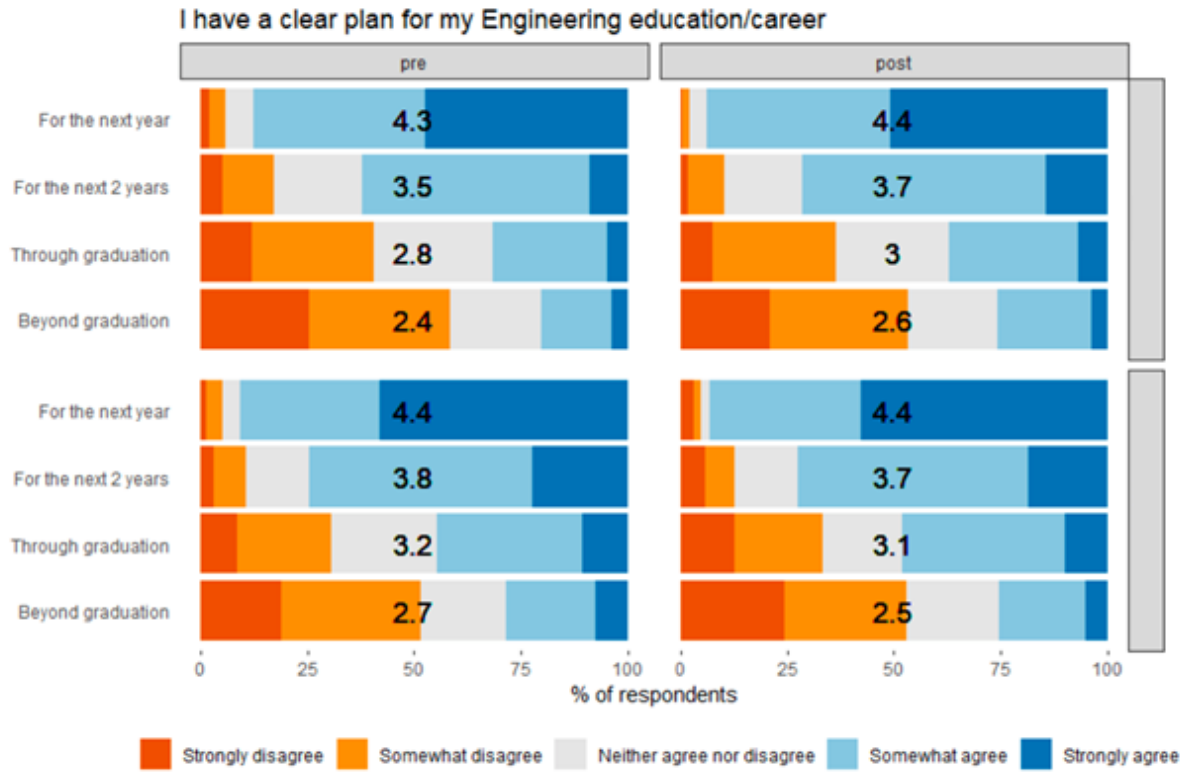

Figure 8: Fall 2020 assessment responses to the statement: "I have a clear plan for my Engineering education/career". The top four rows represent those students who were enrolled in the course, while the bottom four rows represent those students who were not enrolled in the course.

Next, we analyze student responses to two questions about their engineering identity. Among other items, students were asked to rate their agreement with the following statements:

- I feel I know what an engineer does. (Question drawn from the Pittsburgh Freshman Engineering Attitudes Survey [6], [7])
- In general, being an engineering student is an important part of my self-image. (Question drawn from Chachra et al.[8]).

These questions offer insight into how students think about themselves in the context of engineering. Beginning with the statement "I feel I know what an engineer does," as Figure 9 below indicates, in Fall 2019 we see an increase for all students from the beginning to the end of the semester, with students not in the course on average slightly more likely to agree with the statement than students in the course at the end of the semester.

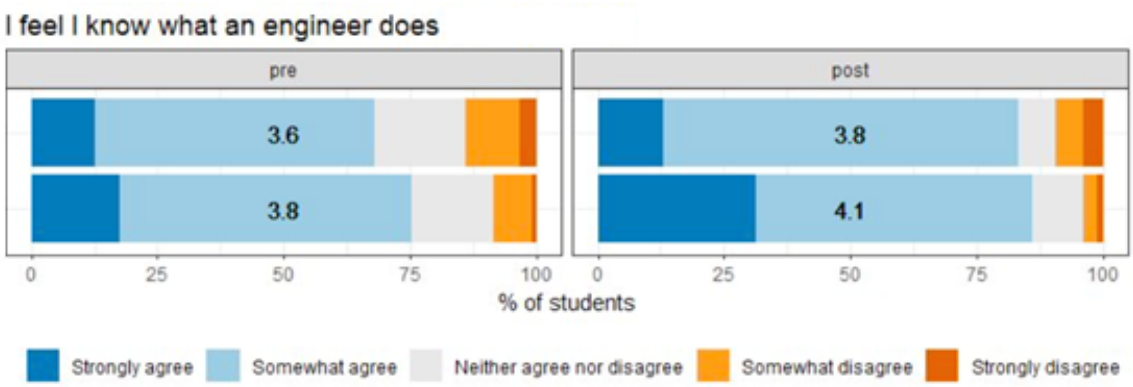

Figure 9: Fall 2019 assessment responses to the statement: "I feel that I know what an engineer does". The top row represents those students who were enrolled in the course, while the bottom row represents those students who were not enrolled in the course.

In Fall 2020, a different picture emerges. As Figure 10 shows, we again see an increase for students in the course in Fall 2020, but no increase among students not in the course. In addition, the increase for students in the course is larger than for any other group across the two semesters, and the average response in the post-survey among students in the course is also slightly higher than any other group across the two years. It is not possible to say whether the large, positive shift on this question among students in the course in Fall 2020 is due specifically to the introduction of choice over Exploration and Engagement Modules, but it does seem that students in the course gained more clarity over what an engineer does compared to students in the course the previous semester and compared to their peers not enrolled in the course during Fall 2020. These data may suggest that during the Fall 2020 semester, in an environment where physically exploring the campus and meeting peers and mentors was very challenging, the course provided students with avenues for exploration that were otherwise unavailable.

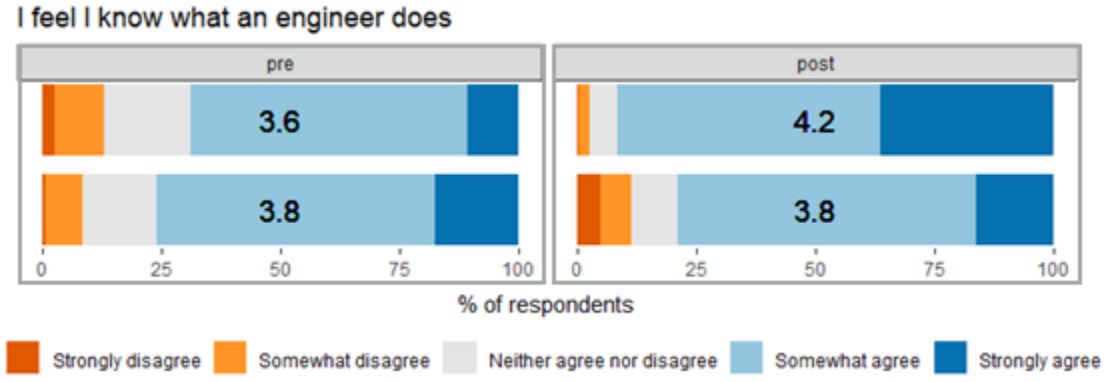

Figure 10: Fall 2020 assessment responses to the statement: "I feel that I know what an engineer does". The top row represents those students who were enrolled in the course, while the bottom row represents those students who were not enrolled in the course.

Next, we consider student responses to the statement: “In general, being an engineering student is an important part of my self-image.” As Figure 11 shows, in Fall 2019 there was no change from the pre- to post-survey among students in the course. In contrast, there was a slight increase for students not in the course, who on average reported on the post-survey that being an engineering student was slightly more important to their self-image compared to students in the course.

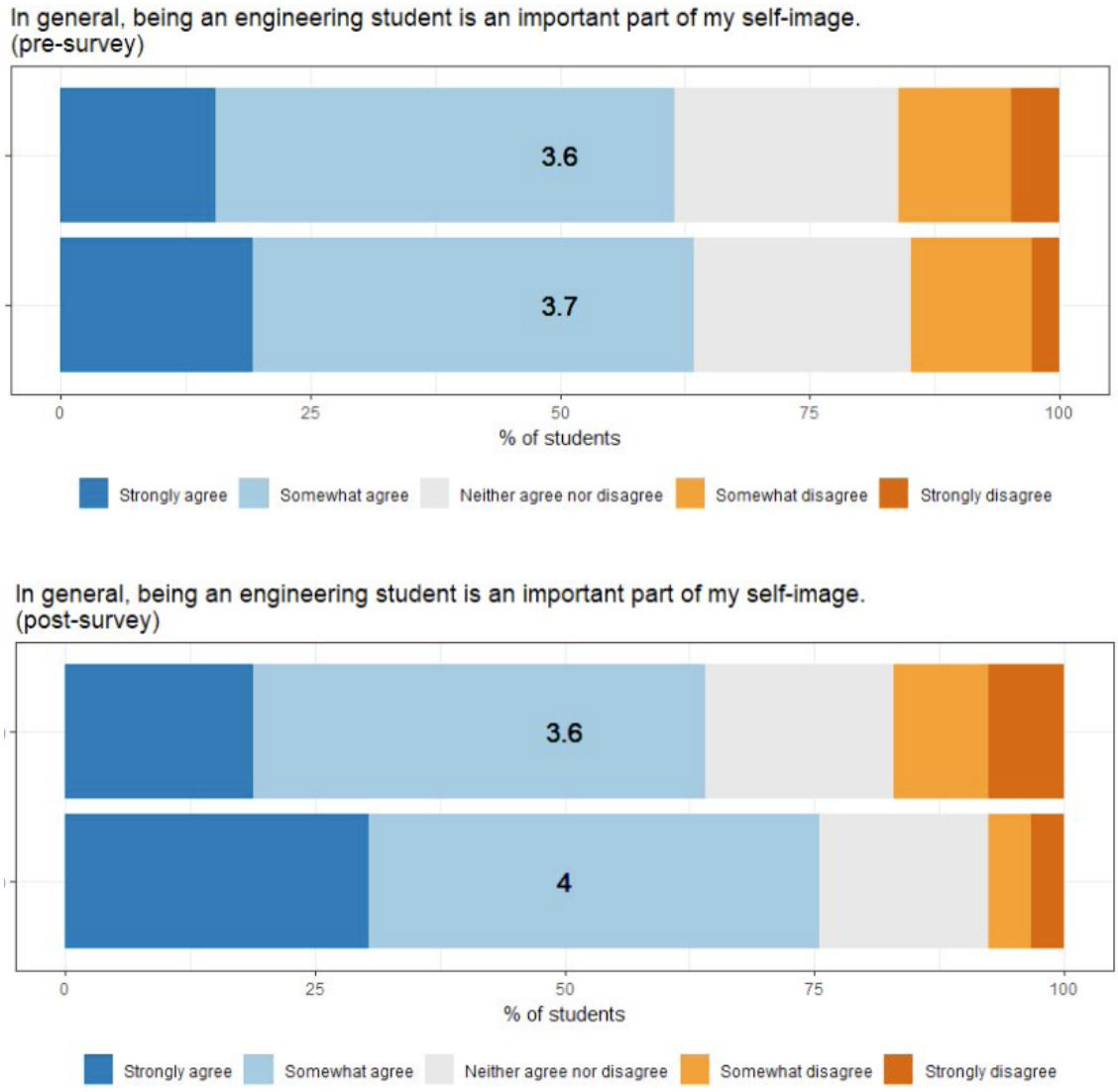

Figure 11: Fall 2019 assessment responses to the statement: “In general, being an engineering student is an important part of my self image”. The top row represents those students who were enrolled in the course, while the bottom row represents those students who were not enrolled in the course.

In contrast, in Fall 2020, we observe a larger increase in this dimension among students in the course than for any other group of students across the two years. In addition, the average response is slightly higher among students in the course than for any other group across the two years. This change suggests that during the Fall 2020 semester, students in the course may have engaged in more reflection on what being an engineering student means to them than in the previous semester in the course, and more than their peers not enrolled in the course in Fall 2020.

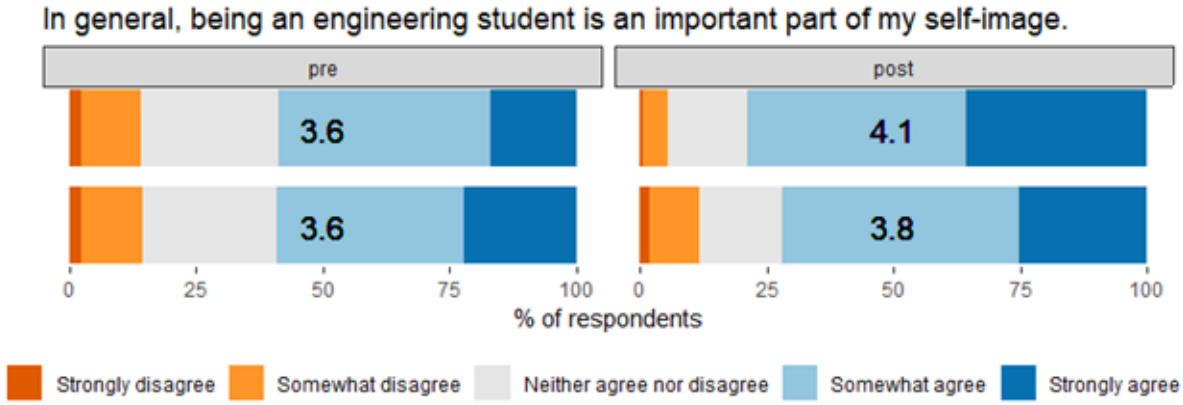

Figure 12: Fall 2020 assessment responses to the statement: "In general, being an engineering student is an important part of my self image". The top row represents those students who were enrolled in the course, while the bottom row represents those students who were not enrolled in the course.

Across these close-ended questions, we see that compared to students in the course in Fall 2019, during the Fall 2020 semester, students in the course gained more clarity over their future plans, more understanding over what an engineer does, and were more likely to say that being an engineer was an important part of their self-image. Further, in contrast to Fall 2019, in Fall 2020 we see students in the course on average report responses similar to their peers not enrolled in the course.

In-depth analysis of students' Personal Action Plans

To gain additional insight into how this introduction of choice, in a departure from a "one size fits all" approach, may have facilitated self-understanding, we turn to an analysis of students' Personal Action Plans from the Fall 2020 semester. This analysis allows for a more in-depth understanding of how student exploration in the course, and in particular the opportunity to design their own pathways through Exploration and Engagement Modules, shaped student self-understanding. These data include a sample of 48 student assignments, each of which is randomly drawn from one of the course's 48 discussion sections. In this analysis, we investigate students' explanations of the thought process behind their choices of Exploration and Engagement Modules. In these explanations students recount how they chose the modules and in

what ways completing the different types of modules influenced subsequent choices (e.g. Foundation Modules guiding Exploration Modules or Exploration Modules guiding Engagement ones).

As we mentioned in the Motivation section, first-year engineering students differ greatly in terms of their experiences entering the university and expectations with regard to engineering majors, co-curricular activities, and future career options. First-year students also bring into their college experience different skills, interests, and social identities, creating different learning needs and motivating different paths through the course, when opportunities to choose are afforded. In the analysis of students' explanations, this diversity is evident. While some students mention approaching the course modules from a feeling of certainty about the major and career they want to pursue coming into the course, with clear ideas of what they wanted to learn and explore, others express their uncertainty, and share feelings of being overwhelmed by the multitude of options in front of them.

Based on different levels of certainty about majors and career paths, the two groups of students choose different forms of exploration and engagement. Those students who mention having a clear idea of the major and career they want to pursue, seem to choose Exploration and Engagement Modules that are tightly related with these interests. These choices seem to allow them to gain in-depth understanding of the desired majors, many times confirming their interests in specific areas of engineering or helping them clarify what is not in alignment with their skills and interests: "*I realized that* [area of engineering] *probably isn't for me."*

For the students who mention having a vague idea of the area of engineering they want to follow or who are contemplating options in many different areas of engineering, the modules (and potentially other course activities designed to foster self-understanding) seem to offer opportunities for self-reflection and analysis of personal interests, skills, and values that ultimately help them make decisions about what to explore, inviting them to "*think about what was important to me*…"

Reflecting on their own interests, skills, and values seems to help some students in narrowing their options and envisioning very specific futures for themselves. In these cases, students offer explanations with language that communicates *realization* of what they want to engage in and *certainty* about specific careers they want to pursue.

It is important to notice that both groups of students, those who mention having a clear idea of the area of engineering they want to pursue, and those who declare being unsure or having just a vague notion of the major and career ahead of them, mentioned gains from the modules and the opportunities to choose their own path through the course. These gains are expressed in terms of achieving a deeper understanding of engineering and aligning choices to personal values and

interests. Both groups seem to gain a broad perspective of the different areas and dimensions of engineering, as well as an understanding of the different Immersed Program opportunities available in the college. This broad perspective appears to support students who feel certain about their interest by inspiring them to explore beyond their initial ideas and 'remain open-minded.' The students who mention feeling uncertain, find in the array of modules areas of engineering that appeal to their interests, skills and values, gaining clarity about where to orient their exploration (Figure 13).

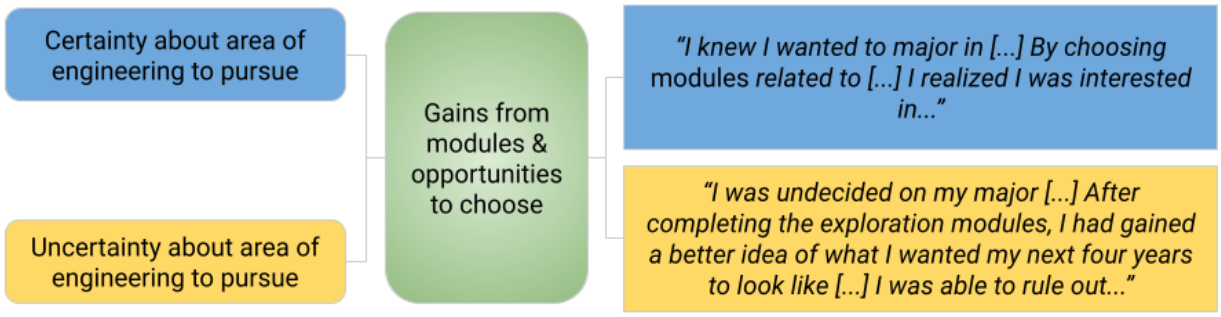

Figure 13. Examples of language used by students to communicate *realization* of what they want to engage in and *certainty* about specific careers they want to pursue.

Another important gain coming from the opportunity to choose a path through the course seems to be the decision to 'take action to achieve desired goals,' which was mentioned by many students in the sample of explanations. The analysis suggests that given the possibility to explore and engage in activities directly aligned with personal interests, skills, and values, students feel more empowered to take new steps in their college experience, such as joining student organizations or seeking additional resources. This decision to take action seems to be possible for students, regardless of their original feeling of certainty or uncertainty about the area of engineering they wanted to pursue. In their explanations, many students mentioned how after completing Immersed Program Modules they decided to join a student organization, schedule appointments with academic advisors, and connect with upper-level students to receive advice on which classes to take, or which kinds of internships to seek.

What inspires exploration and Engagement choices

The analysis of students' explanations about their path through the course indicates that student choices are inspired by personal features, as well as social experiences. The students bring into their college experience an array of passions, skills and interests, and social identities that motivate different choices of exploration and engagement in the course. For instance, some students mentioned how their passions for the arts and music inspired their choices of specific modules. Other students shared how behind their choices there is a desire to connect with others

that share similar social identities. Many students referenced specific skills that motivated their exploration and engagement in the course.

The diversity of personal features that students bring to their college experience, and that inspires student choices, seems to fit perfectly well with a course design that allows students to choose different paths and adjust their learning experiences in alignment with their personal characteristics.

Beyond personal features, the choices made by the students in the course are also inspired by social interactions where they follow the example or advice from a near-peer mentor, instructor, academic advisor, alumnus, friend or family member. Many students mentioned that a key factor in their decisions was something specific they had learned through Foundation or Exploration Modules. Finally, the analysis of students' explanations suggested that students' choices are also inspired by a desire to develop skills like leadership and communication. This aim is complemented with a desire to learn about how diverse people in engineering approach their work and career trajectories.

Implications of this research

Prior to Fall 2013, ENGR 110 utilized a twice-weekly, one-hour lecture format which sought to introduce students to the available engineering departments within the College of Engineering. Following an initiative led by the College of Engineering Undergraduate Advisory Board, and culminating in a series of recommendations from a subsequent College of Engineering senior design project, ENGR 110 was revised for the Fall 2013 semester to focus not only on the available academic departments within the College of Engineering, but also on the exploration of potential career opportunities within engineering at large, and the available co-curricular opportunities within the College, and the University of Michigan at-large, that could supplement the students' classroom experiences and assist the growth in their self-understanding as a means of supporting their personal and professional decision-making. Starting in the Fall of 2014, the course began providing two options for student exploration of the available engineering departments and disciplines offered within the College: department faculty-led presentations and department-specific conversations that were led by near-peer, upper-level undergraduate engineering students, the latter of which were included as part of newly introduced weekly discussion sessions led by these same near-peer, upper-level undergraduate engineering students.

Prior to our participation in the Foundational Course Initiative, conversations between the ENGR 110 instructional team and students during course office hours sessions provided anecdotal, but consistent evidence that students were clearly divided as to which sources of information, faculty-led presentations or student-led conversations, provided them with the most actionable information on which to base their further exploration of the available engineering departments

within the College. This anecdotal evidence was clear: students enrolled in ENGR 110 had unique needs and questions, as well as varied and preferred ways of obtaining the information needed to address these needs and questions. This understanding inspired our decision to seek the further modification of our course structure via the Foundational Course Initiative.

Through our participation in the Foundational Course Initiative, ENGR 110 sought to create a choice-based course that fosters student autonomy, motivation, and overall course satisfaction, as students explore the breadth of opportunities available to engineers in both their education at the University of Michigan and their future careers. We believe that the results presented here support the stated hypotheses that: (1) if given the option, students will pursue different paths to explore their interests, and (2) by creating their own paths, students will deepen their self-understanding about their strengths and interests with respect to engineering, empowering them to make more informed decisions about their personal and educational pathways within the University of Michigan and the College of Engineering.

The revision of ENGR 110 represents the second time that a foundational, first-year course within the College of Engineering has been revised to include student choice. Previously, student choice was introduced within ENGR 100, a required first-year, project-based engineering design course, by providing students with the ability to select from a menu of introductory team-based project experiences, which were developed by faculty representing the breadth of engineering disciplines offered within the College of Engineering. Pre- and post-semester surveys were performed and the new choice-based format for ENGR 100 was found to support the concept that allowing students to engage in learning that supports their personal interests may increase student motivation in engineering [9]. We believe that the results discussed here pertaining to ENGR 110, plus the positive outcomes previously observed as a result of the introduction of choice into ENGR 100, suggests that empowering students with choice in first-year engineering courses may be beneficial across a variety of course types.

Future research could investigate how incorporating elements of choice within various types of course structures impacts student experiences and student learning, particularly with respect to self-understanding. This future research could also explore how different pedagogical decisions within the online learning modules, like pre- and post-reflection assignments, contribute to developing student self-understanding.

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Appendix

A1. Academic Department and Immersed Program Acronyms Used In This Work

Acronym	Full Name
AERO	Aerospace Engineering
BME	Biomedical Engineering
CHEM	Chemical Engineering
CEE	Civil and Environmental Engineering
CLASP	Climate and Space Sciences and Engineering
EECS	Electrical Engineering and Computer Science
IOE	Industrial and Operations Engineering
MSE	Materials Science and Engineering
ME	Mechanical Engineering
NAME	Naval Architecture and Marine Engineering
NERS	Nuclear Engineering and Radiological Sciences
ARTS	Arts and Engineering
ABRD	Engineering Abroad
LEAD	Leadership Development
SOCL	Social Impact
ORGS	Student Organizations and Teams
RAT	Research and Teaching
WRK	Work Experience