

Work In Progress: Authentic Learning Experiences (ALE) and the Development of Engineering Identity in the First Year

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Abstract

There are a number of different curricular approaches to entering into chemical engineering at universities across the country. Some programs use a common first year for all engineering majors, other programs allow students to enter directly into chemical engineering. The reasons which may drive these approaches are complex, involving the university at large, the structure of scholarships and financial aid in the state, among other factors. Programs with a common first year allow students time to explore different engineering fields prior to selecting one to focus their studies on, during a time that the student is learning important, basic skills. There are also programs which have a primarily common first year, but with introduction courses available. This work focuses on the effect of these, and similar authentic learning experiences, embedded in an otherwise common first year program, on the development of students' engineering identity and persistence in a selected major. A previously developed and validated survey tool focused on engineering identity was administered to first- and second-year engineering students. This was combined with various measures of student persistence, such as graduation rates. We believe that an authentic learning experience prior to the selection of major can greatly impact a student's engineering identity and persistence. By including multiple programs in this work, we hope to determine what key features may be needed from such an experience. This information may provide a roadmap to programs, which can use the information to design other authentic learning experiences inside the first year of study.

Introduction

There are a number of different curricular approaches for first-year students planning on majoring in chemical engineering at universities across the country. Some institutions use a common first year program for all engineering majors while other schools allow students to enter directly into chemical engineering. The reasons which may drive these approaches are complex, involving the university at large, the structure of scholarships and financial aid in the state, among other factors. Programs with a common first year allow students time to explore different engineering disciplines prior to selecting one to focus their studies on, during a time that the student is learning important, basic skills. There are also programs which have a primarily common first year experience, but with introductory courses specific to different engineering majors available. Both approaches have strengths and weaknesses with respect to student preparation and the student learning experience; however, there have been limited studies examining the impact of either approach. This work aims to address this important research question by examining how a department-specific, first year introductory course embedded in an otherwise common first year program aids in the development of students' engineering identity and persistence in a selected major. The work-in-progress leverages a previously developed and validated instrument focused on engineering identity, which was administered to first- and second-year chemical engineering students. In the future, this will also be combined with measures of student persistence, such as graduation rates, and informal comments from the student.

We hypothesize that an authentic learning experience (ALE) specific to a single discipline (e.g., chemical engineering) prior to the selection of major can greatly impact a students' engineering identity and persistence in their chosen major. Here, we loosely define an authentic learning experience as a chance for students to learn and apply some of the basic tools of the discipline, interact with the faculty from that discipline, and gain exposure to topics and applications relevant to the field. In this study, the learning experience consists of a three-credit hour course, taught in-person and supplemented with online course materials. An overview of the course is included in Table 1 below, which lists topics in the course, concepts which are introduced by way of showing students about the coursework later in the curriculum, and topics which are specific to the career of the instructor and the university. Of the three credit hours, approximately one hour is focused on basic programming skills. The course includes two exams, a programming project, and a final exam.

Table 1: Topics which are touched upon, to various extents, in the Introductory Course

Topics & skills which are focused on in the introduction course	Topics which are introduced during the introduction course	Topics which are specific to the university and instructor
Unit Conversions in the AES System	Fluid Dynamics – laminar & turbulent flow, friction factors	Advising for Future Chemical Engineers
Mass, Molar, and Volume Basis	Reaction Kinetics – Effect of concentration on reaction speed	Suicide Prevention Advocacy
Non-Reactive Mass Balances	Thermodynamics – Ideal Gas Law & Other Equations of State	Renewable Energy Sector
Reactive Mass Balances	Engineering Ethics	Defense Industry
Process Flow Diagrams		
Basic Programming		

Previous work has shown that of the various identity constructs– interest in the subject area, recognition (i.e., the beliefs that they are seen as a good student in the subject area by their peers, parents, and faculty), and performance / competence beliefs (i.e., beliefs in the ability to perform well and understand concepts) [1] – the strongest direct path to the construction of an engineering identity is recognition [2]; however, performance / competence beliefs also must precede recognition. Recognition constructs are measured using questions like “My instructors see me as a Chemical Engineer,” and “I see myself as a Chemical Engineer.” Performance / competence beliefs are measured using questions like “I believe I can understand concepts taught in Chemical Engineering Courses” and “I could never become really good at engineering even if I were to work hard because I don’t have natural ability.”

Methods

We sent an initial, informal survey to all students registered in the major to gather their impressions and comments regarding the Introduction Course. We also compared graduation rates in the major before and after the initial implementation of the Introduction Course.

The formal surveying work was conducted under an approved protocol (IRB 2023-0793). Borrowing from the previous work of Godwin [1], we surveyed students at the beginning and again at the end of the first-year introduction course, and again in the middle of the following semester when they were enrolled in a second-year chemical engineering course. The survey questions and the responses, which followed a Likert scale, for each cohort are given in Appendix A. These separate survey points allow us to comment on changes over the curriculum. The survey was administered during the fall 2023 and 2024 semesters to second year students in Materials & Energy Balances (MEB) course and during the spring 2024 semester to first year students enrolled in the introductory course. As such, the study has not tracked one cohort, with the data reported here representing two cohorts. During analysis, the data were screened to remove questions which were left blank. We used ANOVA analysis across the three survey points to search for significant differences between responses across the three survey offerings (start of intro course, end of intro course, and midway through MEB) for each of the survey questions. We used Python 3 to perform both the screening and the analysis to evaluate for significance.

Results & Discussion

Initial data gathered by an informal survey indicate that the introductory course is well received by students in the major. The survey asked all students registered in the major, “Do you think the first-year introductory course offers value to students?” 93% of respondents (n=56) indicated they thought the course does offer value to students. The survey also asked for any comments which they thought would be relevant to the introduction course; selected responses are below.

- I feel like chemical engineering isn't really what people expect going in. I, along with many friends I've talked to, thought it was very chemistry based. While chemistry knowledge is required, I find classes to be more math and physics based. I think the [first year introductory course] is very important in students' decisions so we can find this out before committing a whole semester or more to a major that isn't what we expected.
- I believe that [the first-year introductory course] is very valuable for students. In my opinion/experience, chemical engineering is unique in that our underlying concept (the mass balance) is not taught to any extent in high school. This is different from the other engineering whose underlying concepts are covered in high school classes or [general engineering coursework]. This gives [the first-year introductory course] value as it allows students to decide if chemical engineering is right for them earlier than others, allowing them time to switch out if it's not their speed.
- If I had started in [the second year MEB course], I don't think there is any way I would've continued in this major. [The first-year introductory course] was pivotal in my confidence in the major. I found [the first-year introductory course] simple but enjoyed the problem-solving aspect of the course. I tried to keep that feeling alive while working on the more challenging problems in [the second year MEB course].

- For me, [the first-year introductory course] helped confirm my decision of majoring in chemical engineering, which I had very little insight into before taking the course.
- I really enjoyed [the first-year introductory course]. I think it is a great way to get an idea of what future classes will be like at lower risk. If I had gone directly into [the second year MEB course] I would have really, really struggled.
- It was really helpful to have a more broad introduction to chemical engineering material before getting to [the second year MEB course]. At least in my case and many others I have talked to, students often are not really aware of what chemical engineers actually do and so having a class that introduces us to this in our first year is really helpful. I also feel like the intensity of [the second year MEB course] could be overwhelming if this is the first time students are introduced to Chemical Engineering material. It was also a nice transition into the department because it pushed for student involvement in the department in the first year which makes the freshmen actually feel like part of the department.
- [The first-year introductory course] provides a great opportunity for students to have a chance to look at what lies ahead in chemical engineering. It is a class that gave me a wake-up call for adjusting my study and work habits as a student. Without this class it is likely I would have quit the major much later when I encountered the harder classes. This would have put me behind and added an extra year for me. I was also able to establish connections to the other students looking to pursue chemical engineering. It was the first time I was truly able to interact with people that shared similar goals to me.
- I had some friends who took [the first-year introductory course] and realized chemical engineering was not for them, and they are still on track to graduate on time because they made the decision to change majors early

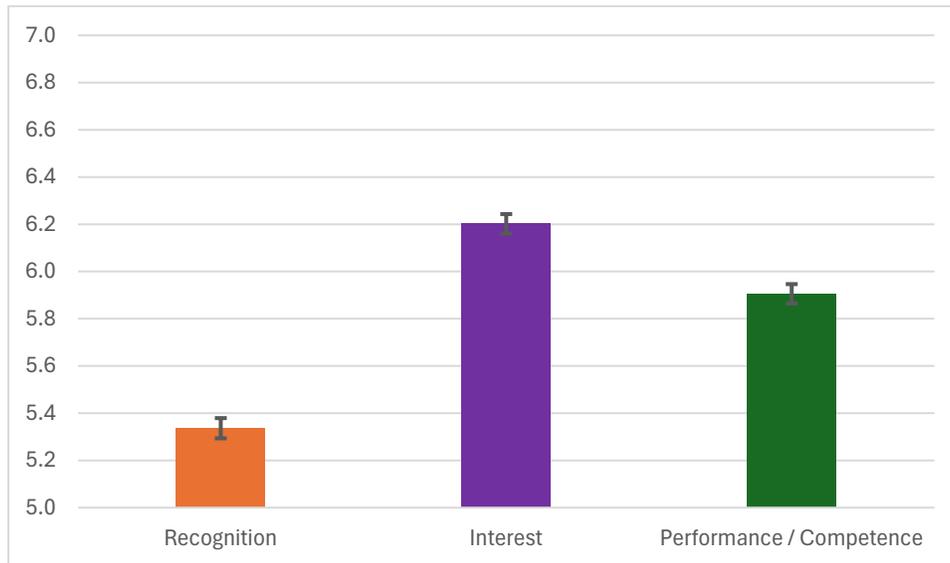


Figure 1: Pooled average and variance data representing the major constructs of identity; the pooled data represent 163 surveys submitted across the three survey points. Responses were given on a 1-7 Likert scale. The Recognition aspect is evaluated using Questions 4.1-4.6. The Interest aspect is evaluated using Questions 4.7-4.10, and the Performance / Competence aspect is evaluated using Questions 4.11-4.15. Full questions included in Appendix A.

The sections of the formal survey which represent identify formation do not show significant differences between the survey points. Much of the survey data, including the fall 2024 data from the MEB course, are still being analyzed to determine if subgroups are showing significant differences, so only initial results can be reported here. As there are no significant differences between the three survey points related to identity, the data have been combined, and the pooled average and variance are shown in Figure 1. Rather than being remarkable because of differences between survey points, these results are interesting because they show high levels of identity formation. Figure 1 shows that the average identity formation of the survey respondents is universally very high, averaging above 5 for all aspects, on a scale of 1-7. These data are surprising and indicate that while the degree of identity formation is not being significantly impacted over the course of the survey points, identity is unexpectedly high during all points of development included in the survey.

Another section of the survey asked students about their confidence in their abilities to perform various skills. The results are shown in Figures 2 and 3 below. The skills queried in the survey include some which are learning objectives in the first-year introduction course, and some skills which none of the students are expected to be familiar with. The question prompts are given in full detail in Appendix A. The analysis indicates that the differences between the survey points are statistically significant with the p-values are given in the legends of the two figures.

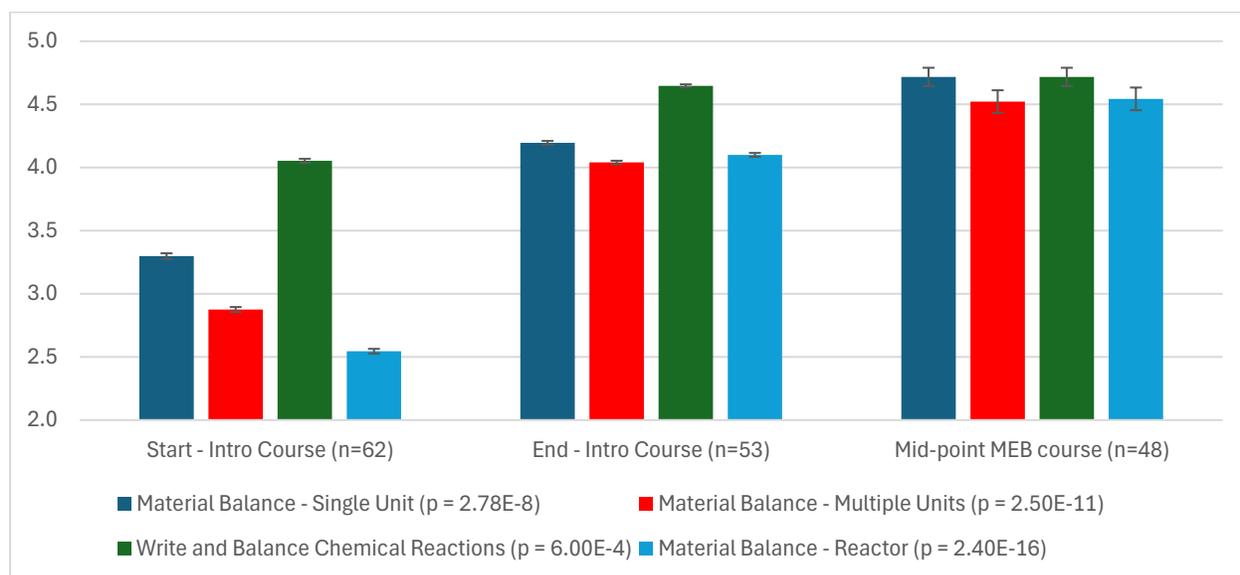


Figure 2: Survey results for skills which are familiar to students, shown at different survey points. Each question has the form “At this point in the semester, how confident are you in your ability to:” and ask for a response on a 1-5 Likert scale.

These results shown in Figure 2 all involve skills which are either prerequisite to the first-year introduction course (i.e., write and balance chemical reactions) or are taught in the course. There is an increasing trend in confidence in each of these over time, as expected. The prerequisite skill has the highest reported confidence at each survey point and also shows the smallest increase over the study period. The increase in confidence is the smallest of the skills shown, at

16% of the initial value reported at the start of the first-year introductory course. The other skills included in the figure have increases ranging from 43-78% of the initial value reported.

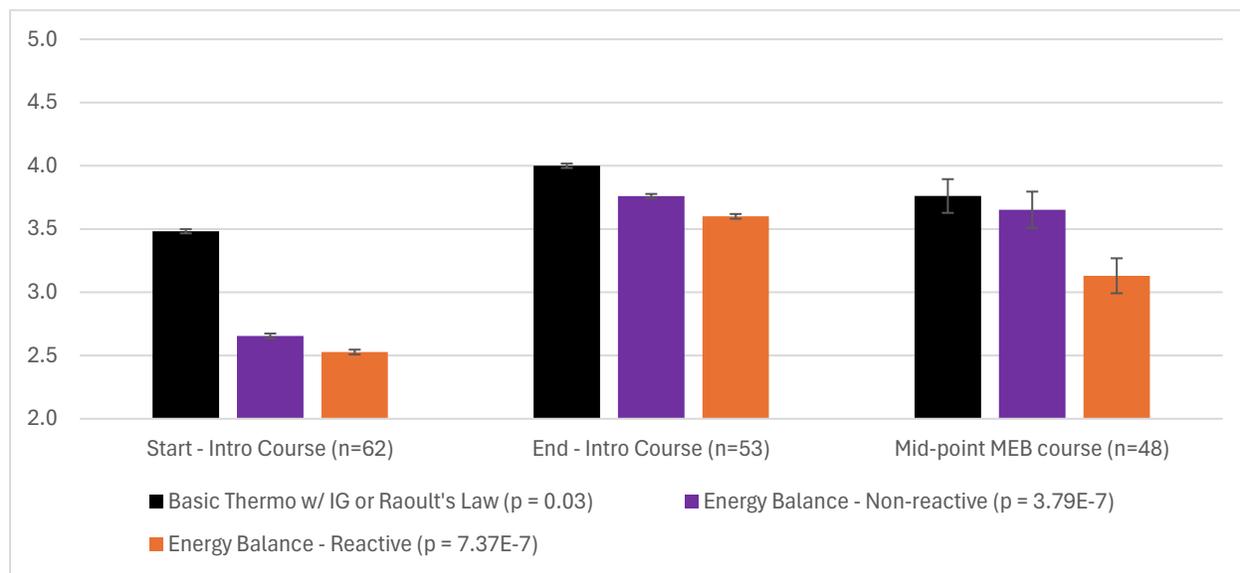


Figure 3: Survey results for skills which are not included in the first-year intro class. Each question has the form “At this point in the semester, how confident are you in your ability to:” and ask for a response on a 1-5 Likert scale.

The results reported in Figure 3 represent skills which are not included in the introduction course skills and which none of the students are expected to be familiar with. These questions probe the ‘baseline confidence’ in learning new skills. In contrast to the responses regarding skills that are familiar to the students, these results show a peak at the end of the first year. The question regarding thermodynamic calculations has the highest result at each survey point. This may simply reflect the wording of the question, which uses the term ‘basic.’ This may have increased the confidence students portrayed. The figure shows an erosion of confidence in things which are new or unfamiliar to the students. This erosion from the end of the first-year introduction course ranges from 3-13 % of the peak confidence reported.

Conclusions

The survey results show that the first-year introductory course is well received by students in the major, who shared anecdotal evidence of its value. The formal survey results show very high levels of engineering identity across the three identity constructs (recognition, interest, and performance / competence), which did not change significantly across the surveys, which were performed during the spring of the first year and in the fall of the second year. We also found that respondents demonstrated significantly more ‘baseline confidence’ in their ability to learn a skill they had never been introduced to at the end of the first-year introduction course, but that this confidence eroded during the second year.

Future Plans

To determine if the introductory course in chemical engineering is having a unique effect on the identity construction of the cohort, we plan to send similar survey instruments to other majors at the university. This will bring in cohorts which do not include an authentic learning experience as defined in this work. We are also interested in determining what features of a learning experience are critical and needed to have an impact on the identity construction of students. We are planning to conduct similar studies at other universities to collect this data. Through these surveys, examining chemical engineering students' perceptions of identity in multiple contexts, and engineering students' perceptions from other disciplines, we aim to isolate the effect of introductory courses on engineering identity construction and also determine which aspects of these introductory courses are essential for identity construction. We will also be investigating the causes of the very high identity formation shown in these results, and if this sense of identity persists through to graduation.

References

- [1] Godwin, A. (2016, June), *The Development of a Measure of Engineering Identity* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26122
- [2] Verdin, D.; Godwin, A. Testing for Measurement Invariance in Engineering Identity Constructs for First-Generation College Students. *Purdue e-Pubs (Purdue University System)* **2017**. <https://doi.org/10.1109/fie.2017.8190616>.

Appendix A: Survey Questions

Please indicate your agreement with the following statements (1-7 Likert Scale)	
These questions are used to assess the Recognition aspect of identity formation	
Q4 1	I see myself as a chemical engineer.
Q4 2	My parents see me as a chemical engineer.
Q4 3	My peers see me as a chemical engineer.
Q4 4	My instructors see me as a chemical engineer.
Q4 5	My TAs see me as a chemical engineer.
Q4 6	My advisors see me as a chemical engineer.
These questions are used to assess the Interest aspect of identity formation.	
Q4 7	I am interested in learning more about chemical engineering.
Q4 8	I enjoy learning chemical engineering.
Q4 9	I find fulfillment in doing chemical engineering.
Q4 10	I want to pursue a career in chemical engineering.
These questions are used to assess the Performance / Competence aspect of identity formation.	
Q4 11	I expect to do well in this engineering course.
Q4 12	I am certain I can master the skills being taught in this engineering course.
Q4 13	I am confident I can do well on assignments in this engineering course.
Q4 14	I believe I can understand concepts taught in this engineering course.
Q4 15	I am planning on majoring in chemical engineering.
Please indicate your agreement with the following statements (1-7 Likert Scale)	

Q5 1	Even if I were to spend a lot of time working on difficult engineering problems, I cannot develop my intelligence in engineering further.
Q5 2	I won't get better at engineering if I try harder.
Q5 3	I could never excel in engineering because I do not have what it takes to be an engineering person.
Q5 4	I could never become really good at engineering even if I were to work hard.
Q5 5	I can become even better at solving engineering problems through hard work.
Q5 6	I am capable of really understanding engineering if I work hard.
Q5 7	I can change my intelligence in engineering quite a lot by working hard.
Please indicate your agreement with the following statements: I feel really successful when... (1-7 Likert scale)	
Q6 1	I know more than other people.
Q6 2	Others get things wrong and I don't.
Q6 3	I'm the smartest.
Q6 4	I beat others.
Q6 5	I do better than my friends.
Q6 6	Others can't do as well as me.
Q6 7	What I learn really makes sense.
Q6 8	I solve a problem by working hard.
Q6 9	Something I learn makes me want to find out more.
Q6 10	Something I learn makes me think about things.
Q6 11	I get a new idea about how things work.
Q6 12	I do my very best.
Q6 13	I learn something interesting.
How prepared to you feel to perform calculations to: (1-5 Likert Scale)	
Q2 1	Convert Units
Q2 2	Compute Mass or Mole Fractions
Q2 3	Convert mass to volume using density
Q2 4	Determine the pressure in a vessel
Q2 5	Determine the change in the height of a manometer
At this point in the semester, how confident are you in your ability to: (1-5 Likert Scale)	
Q3 1	Perform a material balance around a single unit
Q3 2	Perform a material balance around multiple units
Q3 3	Write and balance chemical reactions
Q3 4	Perform a material balance around a reactor
Q3 5	Perform basic thermodynamic calculations using the ideal gas law or Raoult's Law
Q3 6	Perform an energy balance around non-reactive species
Q3 7	Perform an energy balance around reactive species
I feel that completing CHE 1300 gave me a better understanding of: (1-5 Likert Scale)	
Q18 1	What is the role of a chemical engineer
Q18 2	What types of jobs a chemical engineer can do
Q18 3	Why I selected chemical engineering as a major
Q18 4	How chemical engineering is different from other engineering majors
I feel that the experience in CHE 1300:	
Q20 1	Prepared me to succeed in CHE 2110

Q20_2	Increased my confidence in learning new skills.
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