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Board 235: Chemical Engineers in Chemistry Coursework: Longitudinal Impacts on Engineering Identity

Dr. Michael Geoffrey Brown, Iowa State University of Science and Technology

Michael Brown is an assistant professor of Student Affairs and Higher Education at Iowa State University. His research focuses on the development of educational technology to enhance student learning in introductory gateway courses in STEM fields.

Dr. Monica H. Lamm, Iowa State University of Science and Technology

Dr. Monica Lamm is an Associate Professor of Chemical and Biological Engineering at Iowa State University. She has broad interests in engineering education, including the use of retrieval practice and team-based learning to improve student course outcome

Mr. Md Imtiajul Alam, Iowa State University of Science and Technology

Imtiajul Alam is a Doctoral student in Human Computer Interaction at Iowa State University. His home department is the School of Education. Imtiajul's research area focuses on the gamification and implementation of Augmented reality in college-level STEM courses.

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Chemical Engineers in Chemistry Coursework: Longitudinal impacts of personalized feedback on Engineering Identity

Chemical engineers are expected to complete a sequence of general chemistry coursework before they enter their major program. As core pre-requisites, these courses serve as the foundational knowledge of chemical engineering work, but their role in contributing to the professional development of chemical engineers is perhaps not well understood. Drawing on research from a design-based implementation study funded by the NSF's Improving Undergraduate STEM Education program, we follow chemical engineers through three introductory courses to observe how and if their individual beliefs about engineering identity change over time when provided personalized feedback about their performance in chemistry courses. We present results from within courses to observe how students' beliefs might change during a semester as well as results that observe the sequential and cumulative impact of course-taking on students evolving beliefs about their competency as engineers using Godwin's scale [1]. We observe little impact of personalized feedback on students' engineering identity, although we do observe a slight increase in subjective beliefs about engineering identity over time, echoing prior work that suggests that engineering identity may emerge later in students' academic trajectories [2]

Related Literature

The Influence of Engineering Identity (EI)

Our work builds on prior research that attempts to map the emergence and influence of engineering related identity beliefs on students' persistence and success in undergraduate engineering programs [3-7]. Godwin's [1] proposed measure of engineering identity draws on three constructs reflected in similar research in physics, math, and science broadly: subjective interest in the subject, external feelings of recognition, and competency beliefs. That these concepts overlap with related frameworks for understanding students' motivation to succeed and perform in STEM education is perhaps unsurprising, but results in a complicated picture of how EI forms and what role it might play in students' trajectories. To disentangle expectancy value constructs of motivation and EI measures of competency beliefs, would require a simultaneous consideration of both- an approach absent in the current literature[8]. While a good deal of this work focuses on the factors that inform matriculation into engineering, especially for underrepresented and minoritized students [9], there is a need for research that explores the impact of engineering coursework on students' development of engineering identity [10].

Time and change may play a significant role in how EI impacts students' experiences. Multiple studies suggest that the presence of an engineering identity predicts the pursuit of an engineering major [2; 11]. Myers and colleagues identified that first-year students were significantly less likely to identify as engineers than their more advanced counterparts [2]. The extent to which caretaking in a major pathway impacts students' EI, especially courses that are aligned with and relevant to the sub-discipline of engineering education a student is interest in, is largely unknown. A fruitful space and a critical need exist for research that explores consideration of time, developmental change, exposure to curriculum, and related constructs like subjective interest and competency beliefs.

In a systematic review of the research, Morelock [12] identified constructive, detractive, and directional influences on students' development of EI. Constructive factors included the amount and types of engineering experiences student participated in and their acquisition of engineering related connections. Detractive factors included a lack of engineering related experiences, gender and racial marginalization, and anti-social relationship influences like pressure and isolation. Directional factors included early exposure to engineering, identity characteristics, and social and environmental conditions (like workplace configurations). In a similar fashion, interventions that allowed students to accrue engineering experiences were linked to higher levels of EI and activities that prompted meta-cognition like constructing a learning portfolio also fostered EI beliefs.

Personalized feedback from learner dashboards

Alongside interest in the development of engineering identity, post-secondary institutions and instructors have, over the last decade, pursued the use of trace data to develop models for personalized feedback at scale [13]. Often delivered through what are termed learner dashboards- web-enabled real time dashboards that visualize information about an individual's progress and performance in a course- these tools have the potential to bridge the gap between learner and instructor in large lecture courses [14]. While relationships and interactions with engineers and instructors are important for EI development, large courses prevent the kind of direct interaction and feedback that can foster persistence and performance [13]. Learner dashboards have the potential to spur reflection and meta-cognition about coursework strategies.

Personalized feedback through learner dashboards has shown some initial promise in spurring performance in experimental conditions [13], but empirical evidence regarding the impact of real time information feedback on students' motivational states, their competency beliefs, and their subjective beliefs about their professional identities is in short supply [15]. There is recent research that suggests that dashboards are most effective when they are closely aligned to course content are better at fostering reflection than generic dashboards [16]. In this study, we explore the longitudinal impact on engineering identity on constructive factors like exposure to engineering coursework, the development of competency beliefs over time, and the 'dosage' of personalized feedback that students received.

Methodology

Sample and Data Sources

The analysis we report in this discussion are part of a larger study of the impact of personalized feedback in sequential course-taking in chemistry among life science, engineering, and non-STEM majors. In this study, we control for whether student received personalized feedback through our ChemistryLab dashboard. Our sample (n=2819) is composed of students who took 1-3 courses in the Chemical Engineering sequence: Introductory General Chemistry I, General Chemistry II, Material and Energy Balances (Chemical Engineering). Our data collection ran from Fall 2020 to Fall 2022, includes 5 semesters and three potential cohorts of students who completed the sequence. In general, the majority of Chemical Engineers complete the sequence in order and on time (about 63% of the eligible students in our data). At the start and end of each semester, students received a brief survey that asked about their motivations for taking the course, their attitudes towards Chemistry, their engineering or science identity beliefs (based on their major), and their coursework strategies. We also collected data from the learning management system about students' behavioral engagement for participants that consented through the survey.

ChemLab Dashboard

The personalized dashboard provided individual students feedback on their coursework strategies through the following technologies:

- A weekly planner tool that identified what students needed to do to be successful in the course and provided suggestions for ordering tasks.
- Badges that indicated how students performed on assessments related to core concepts in the course

- A performance tracker that helped students identified what types of assignments they were performing well in and what assignment types might need more attention (e.g. Lab Notebook, Post-Lab Quiz)
- Prizes that unlocked based on student engagement with the system (e.g. audio or video that offered encouragement)

Due to data limitations, we know when students accessed the dashboard, but not what features they interacted with.

Design-based implementation research

As this was a design-based research study, we made slight adjustments to the administration of the dashboard each semester. After the first administration, we added an explanatory video that helped students understand the purpose and relevance of the dashboard. At the start of the second year, the dashboard designers added a feature that included an interactive guided tour of the features, and we included a version of this tutorial that was developed by the research team. We also provided students throughout the study period with personalized announcements through Canvas, reminding students about the existence of features and encouraging them to access the dashboard. The wording of these announcements altered slightly based on the content and purpose of each course.

Analytical Strategy

This poster reports the results of initial exploratory descriptive work on students' change over time in EI. We conduct t-tests to observe significant differences for the six questions on our instrument related to engineering identity (see Table 1 for items; see appendix A and B for descriptive results for item responses). We compare average change in engineering identity based on whether students were in the treatment or control group for personalized feedback through the LMS enabled dashboard.

Findings

Our initial findings present an intriguing- albeit inconsistent portrait of changes in students' subjective beliefs about engineering and their emerging engineering identities. First, students in introductory coursework who received personalized feedback had higher (albeit small) positive growth in their responses to measures of engineering identity related to interest, enjoyment, and fulfillment. We would expect that the dashboard should have little impact on students' perceptions of how others view them, and we observed that consistently with the treatment group. Conversely, in upper level courses, where students are more likely to have committed to engineering pathways and have developed effective coursework strategies, we see no significant relationship between changes in EI measures and receipt of personalized feedback. This stands in contrast to students in the control group, who in the introductory Chemical Engineering course, had uniformly higher positive EI beliefs by the end of the term. It may be that students who receive personalized feedback earlier, exit their early courses with higher levels of EI.

Table 1. T-Tests of Difference: Engineering Identity by access to ChemLab Dashboard

	General Chemistry I		General Chemistry II		Material and Energy Balances	
	Control (n=194)	Treat (n=1056)	Control (n=115)	Treat (n=223)	Control (n=59)	Treat (n=128)
Parents see me	-0.04 (0.69)	-0.01 (0.65)	0.05 (0.25)	-0.03 (0.65)	0.27 (<0.01)	0.03 (0.29)
Teachers see me	-0.01 (0.55)	-0.01 (0.61)	-0.03 (0.64)	0.01 (0.45)	0.29 (0.01)	0.09(0.12)
Peers see me	-0.05 (0.71)	-0.04 (0.87)	0.15 (0.05)	-0.03 (0.65)	0.12 (0.15)	-0.02 (0.60)
Interested in learning more	0.08 (0.15)	0.11 (<0.01)	0.03 (0.37)	0.01 (0.42)	0.25 (<0.01)	-0.06 (0.78)
Enjoy learning	0.07 (0.19)	0.07 (0.01)	0.07 (0.21)	0.03 (0.32)	0.29 (<0.01)	-0.10 (0.86)
Find fulfillment	0.03 (0.61)	0.09 (<0.01)	0.08 (0.17)	<0.01 (0.47)	0.37 (<0.01)	-0.10 (0.87)

Implications

Our initial results suggest some interesting future direction for research on the relationship between engineering identity, other subjective motivational beliefs, and personalized feedback delivered through a web enabled dashboard. While the personalized dashboard appears to impact students' EI beliefs early on, that relationship is no longer significant in subsequent periods. Whether this is a novelty effect of a new technology, or represents some significant subjective change in students that occurs earlier in the first term relative to their peers who did not have access to the dashboard is unknown. In future research, we will explore the co-evolution of EI, motivational beliefs, and dashboard usage to better unpack that question.

Additionally, although we observe initial changes in students EI over time when they access the dashboard, there appeared to be regression (albeit not statistically significant) in students' EI beliefs who received the dashboard treatment in their introductory ChemE class. Future research should consider the longitudinal and cumulative impact of dashboard use on students' motivational and course related beliefs over time.

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Works Cited

[1] Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2013, October). Understanding engineering identity through structural equation modeling. In *2013 IEEE Frontiers in Education Conference (FIE)* (pp. 50-56). IEEE.

[2] Meyers, K. L., Ohland, M. W., Pawley, A. L., Silliman, S. E., & Smith, K. A. (2012). Factors relating to engineering identity. Global Journal of Engineering Education, 14(1), 119-131.

[3] Fleming, L. N., Smith, K. C., Williams, D., & Bliss, L. (2013). Engineering identity of Black and Hispanic undergraduates: The impact of minority serving institutions. Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Atlanta, GA

[4] Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2013). Understanding engineering identity through structural equation modeling. Paper presented at the Frontiers in Education Conference

[5] Pierrakos, O., Beam, T., Watson, H., Thompson, E., & Anderson, R. (2010). Gender differences in freshman engineering students' identification with engineering. Paperpresented at the Frontiers in Education Conference (FIE), 2010 IEEE.

[6] Tonso, K. L. (2006). Student engineers and engineer identity: Campus engineer identities as figured world. Cultural Studies of Science Education, 1(2), 273-307.

[7] Pierrakos, O., Beam, T. K., Constantz, J., Johri, A., & Anderson, R. (2009). On the development of a professional identity: Engineering persisters vs engineering switchers. Paper presented at the Frontiers in Education Conference, 2009. FIE'09. 39th IEEE

[8] Patrick, A., & Borrego, M. (2016, June). A Review of the Literature Relevant to Engineering Identity. In *American Society for Engineering Education Annual Conference,*.

[9] Li, Q., Swaminathan, H., & Tang, J. (2009). Development of a classification system for engineering student characteristics affecting college enrollment and retention. *Journal of Engineering Education*, *98*(4), 361-376.

[10] Rodriguez, S. L., Lu, C., & Bartlett, M. (2018). Engineering Identity Development: A Review of Higher Education Literature. *International journal of education in mathematics, science and technology*, *6*(3), 254.

[11] Prybutok, A., Patrick, A., Borrego, M., Seepersad, C. C., & Kirisits, M. J. (2016). Cross- sectional Survey Study of Undergraduate Engineering Identity. Paper presented at the American Society for Engineering Education Annual Conference, New Orleans,LA.

[12] Morelock, J. R. (2017). A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement. *European journal of engineering education*, *42*(6), 1240-1262.

[13] Brown, M., Schiltz, J., Derry, H., & Holman, C. (2019). Implementing online personalized social comparison nudges in a web-enabled coaching system. *The Internet and Higher Education* 43. https://doi.org/10.1016/j.iheduc.2019.100691.

[14] Eickholt, J., Weible, J.L. and Teasley, S.D., "Student-facing Learning Analytics Dashboard: Profiles of Student Use," *2022 IEEE Frontiers in Education Conference (FIE)*, Uppsala, Sweden, 2022, pp. 1-9, doi: 10.1109/FIE56618.2022.9962531.

[15] Maier, U., & Klotz, C. (2022). Personalized feedback in digital learning environments: Classification framework and literature review. *Computers and Education: Artificial Intelligence*, 100080.

Appendix A: Pre-Test Items Descriptives

Course	Year	Term	Pre - IDENT_PARNT	Pre - IDENT_TEACH	Pre - IDENT_PEERS	Pre - IDENT_INTRST	Pre - IDENT_ENJOY	Pre - IDENT_FULFIL
Materials	2021	Fall	2.00 (0.99)	2.26 (1.04)	2.14 (0.97)	1.66 (0.87)	1.77 (0.95)	1.83 (0.99)
Materials	2022	Spring	2.05 (0.97)	2.36 (1.01)	2.42 (1.01)	1.78 (0.91)	2.05 (1.17)	2 (1.20)
GC I	2020	Fall	2.26 (1.10)	2.61 (1.09)	2.55 (1.14)	1.76 (0.86)	1.87 (0.93)	2.04 (0.99)
GC I	2021	Fall	2.32 (1.27)	2.73 (1.25)	2.59 (1.25)	1.88 (1.14)	2.02 (1.08)	2.13 (1.08)
GC I	2021	Spring	5.58 (1.18)	5.11 (1.18)	5.28 (1.25)	6.17 (0.89)	6.15 (0.90)	5.85 (1.11)
GC I	2022	Spring	2.38 (1.16)	2.66 (0.96)	2.42 (0.97)	1.90 (1.04)	2.52 (0.92)	2.57 (0.97)
GC II	2021	Fall	2.08 (1.25)	2.73 (1.35)	2.49 (1.19)	1.78 (1.09)	1.96 (1.11)	2.12 (1.21)
GC II	2021	Spring	2.06 (1.06)	2.34 (1.07)	2.16 (1.04)	1.82 (0.94)	1.89 (0.97)	2.06 (1.00)
GC II	2022	Spring	2.23 (1.31)	2.44 (1.14)	2.28 (0.99)	1.89 (0.96)	1.93 (0.96)	2 (0.98)

Appendix B. Post-Test Descriptives

Course	Year	Term	Post - IDENT_PARNT	Post - IDENT_TEACH	Post - IDENT_PEERS	Post - IDENT_INTRST	Post - IDENT_ENJOY	Post - IDENT_FULFIL
Materials	2021	Fall	2.09 (1.00)	2.38 (1.00)	2.14 (0.87)	1.67 (0.65)	1.80 (0.66)	1.86 (0.81)
Materials	2022	Spring	2.31 (1.05)	2.78 (1.13)	2.73 (0.99)	2.05 (1.26)	2 (1.15)	2.26 (1.48)
GC I	2020	Fall	2.21 (1.10)	2.54 (1.10)	2.43 (1.14)	1.96 (1.05)	2.02 (1.05)	2.18 (1.12)
GC I	2021	Fall	2.25 (1.27)	2.71 (1.23)	2.57 (1.27)	1.95 (1.11)	2.08 (1.07)	2.11 (1.05)
GC I	2021	Spring	5.77 (1.14)	5.34 (1.08)	5.52 (1.19)	5.99 (1.03)	5.97 (1.03)	5.78 (1.14)
GC I	2022	Spring	1.85 (0.91)	2.38 (1.02)	2.28 (1.05)	1.76 (0.83)	2.23 (0.99)	2.19 (0.98)
GC II	2021	Fall	2.17 (1.15)	2.50 (1.19)	2.33 (1.13)	1.85 (1.04)	1.98 (1.04)	2.12 (0.96)
GC II	2021	Spring	2.08 (1.09)	2.37 (1.09)	2.25 (1.10)	1.83 (0.95)	1.93 (1.01)	2.11 (1.08)
GC II	2022	Spring	2.12 (1.18)	2.49 (1.24)	2.29 (0.98)	1.88 (1.02)	2.01 (1.00)	2 (0.95)