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Work-in-Progress: Relevance, Responsibility, and Agency in Laboratory Experiments Predict Engineering Identity

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Introduction & research purpose

Engineering identity is double-sided, meaning in comprises both sense of belonging in a particular field and how others position one in relation to that field [1]. Recent research highlights the value authentic learning experiences can have in developing engineering students' identity in and commitment to their field. Such experiences provide a window into professional practices [2, 3]. In chemical engineering, laboratory experiments play a critical role in shaping students' understanding of the profession [3]. As such, laboratory courses that engage students in decision making can play a role in this process, and students benefit from multiple opportunities to practice using their agency in experiments [4]. In the current study, we investigate the role that having consequential agency has on students' perceptions and development. Laboratory experiments comprise four domains over which students may have agency: Domain 1 includes experimental design, Domain 2 includes experimental oversight and data collection, Domain 3 includes data analysis and interpretation, and Domain 4 includes the communication of results. We sought to answer the following research questions:

- To what extent does engineering identity explain variance in persistence intentions?
- To what extent do relevance, demographics, and having agency in the four domains explain variance in engineering identity?

Literature review

Most students' laboratory experiences are prescriptive, allowing them to make only limited choices, especially in introductory courses [5]. Such experiences limit students' agency, in turn, reducing learning opportunities [1, 4]. In our past work, we highlighted that agency is contextual [6, 7] and found a positive relationship between engineering identity and persistence intentions that aligns with other research in engineering education [8-10]. Context is important since self-efficacy is dependent on the topic; however, in the case of agency, contextualization is not to a field, but rather to the consequentiality of the decision. We found that the most significant domain was Domain 3, analyzing data and interpreting results, which contributed to students' identities as engineers more than other domains and, since the tasks are more relevant to the field of engineering, the students' identities develop more [11]. Other recent publications in chemical engineering education also discuss ways to provide more opportunities for students to experience agency, from using data science tutorials that make it possible for more students to participate in authentic laboratory research [12] to creating laboratory experiments where students have increased opportunities to make decisions about how to analyze data (Domain 3) [13]. For instance, using a guided-inquiry approach, Elkhatat and Al-Muhtaseb [13] created scaffolded remote lab activities that allowed students to generate open-ended solutions to a design problem. The students self-reported their sense of agency increased in Domain 1 (experimental design) and Domain 3 (analysis). Many approaches regarding agency emphasize using reflection [14] or inquiry in some format, such as guided inquiry, discovery, or problem-based learning that support conceptual learning and provide opportunities for students to conduct authentic experimental practices [15-17]. Less is known about how to promote students' sense of agency [14]. Some laboratory experiences engage students in all four domains, which is true in course-based research experiences [18]. Yet, few studies have explored how instructional practices/designs shape engineering identity and persistence, though research confirms career-relevant design experiences enhance both [19].

Methodology

Following IRB approval (UNM Main Campus IRB, #2206007465) and informed consent, chemical engineering undergraduates from two public research universities (n = 157 at MSU; n = 81 at UNM) completed surveys as part of post-lab assignments in their junior- and senior-level laboratory courses. The surveys measured agency in the four domains, along with perceptions of the relevance of the experiment, their identity in engineering, their intentions to persist in a career in engineering, as well as demographics and have been discussed previously [11]. The post-lab writing assignments were scored using standardized rubrics. Exploratory factor analysis confirmed the survey provided valid information about the desired constructs and, therefore, statistical analysis was completed, including regression modeling and inferential tests. We grouped students in privileged (Asian, Middle Eastern, white) and minoritized (Black, Indigenous, Hispanic/Latiné, Pacific Islander) racial and ethnic groups, based on representation in engineering compared to representation in the US population [20].

Results

Using regression, we first predicted students' persistence intentions. Across all regression models, engineering identity strongly and positively predicted persistence intentions (Table 1, $F(1, 112) = 23.33$, $p < 0.001$, $r^2 = 0.17$). No other variables explained significant variance in persistence intentions, including demographics. Next, we predicted variance in students' scores related to engineering identity, finding that across models, students who reported greater consequential agency over experimental design (Domain 1) and communicating (Domain 4), and who reported that the experiment was relevant to the work of chemical engineers, also reported a stronger identity (Table 2, $F(4, 180) = 5.86$, $p < 0.001$, $r^2 = 0.10$).

Table 1: Regression model of persistence intentions

	Unstandardized Coefficients		Standardized Coefficients	t	*p*
	B	Std. Error	Beta		
Constant	2.93	0.66		4.46	<0.001
Identity	0.55	0.11	0.42	4.83	<0.001

Table 2: Regression model of identity

	Unstandardized Coefficients		Standardized Coefficients	t	*p*
	B	Std. Error	Beta		
(Constant)	3.07	0.59		5.19	<0.001
Relevance	0.20	0.09	0.16	2.08	0.04
Agency in Domain 1	0.12	0.06	0.15	2.00	0.05

Agency in Domain 4	0.13	0.06	0.16	2.03	0.04
Race/ethnicity	0.28	0.18	0.11	1.54	0.12

We checked for demographic differences and found no differences by gender, but students from minoritized racial and ethnic groups tended to report higher agency (Figure 1). They reported significantly higher agency over monitoring the experiment (Domain 2), compared to their peers from privileged racial and ethnic groups, who rated this domain lowest, $t(191) = 2.152$, $p = 0.03$. First generation college students reported significantly higher sense of responsibility, compared to their continuing generation peers, $t(195) = 2.24$, $p = 0.03$ (Figure 2).

Conclusions and Implications

We found that allowing students to exercise greater agency in designing experiments and communicating results reinforces their identity in the field. Our results suggest several instructional implications. First, instructors can focus on empowering students' agency by supporting them to design experiments. However, students may propose designs that are unlikely to yield results or even present safety hazards. In light of this, instructors can ensure students receive feedback. For instance, students can do a gallery walk to learn from one another before revising their experimental designs and conduct a Job Safety Analysis (JSA) to reduce hazards. Even more straightforward, they could compare their design to a set of possible designs to identify weaknesses and strengths of their own and others' designs. Second, instructors can support students' agency in technical writing by focusing on shorter, industry- or research-authentic forms of writing, such as short technical reports, abstracts, memos, and technical presentations. Asking students to meet the standards set by a professional organization can enhance the sense of authenticity. Third, instructors can highlight and reinforce the relevance of laboratory experiments by making explicit connections to real-world applications in chemical engineering, supporting integration into the discipline. Encouraging students to reflect on how their laboratory experiences align with professional practices in chemical engineering can contribute to enhancing their identity in the field.

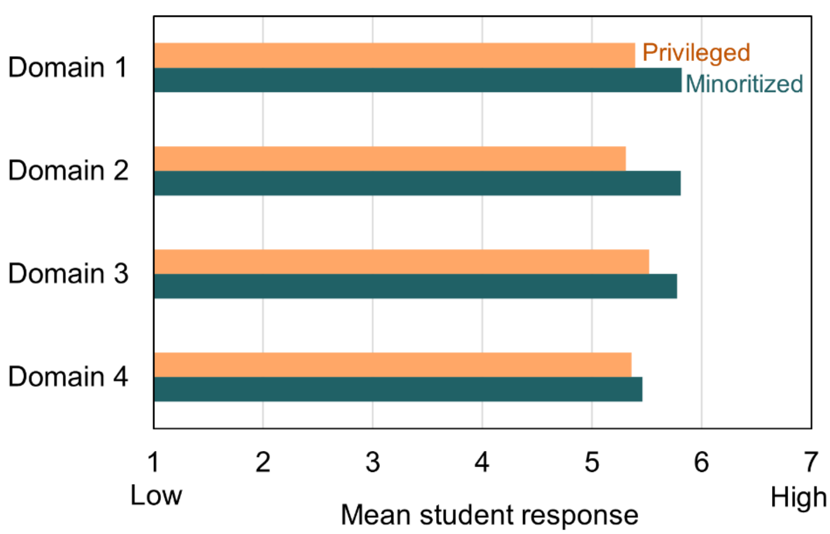

Figure 1: Mean consequential agency survey response scores where 1 is low and 7 is high, by domain, for students from minoritized (■) and privileged (■) racial and ethnic groups.

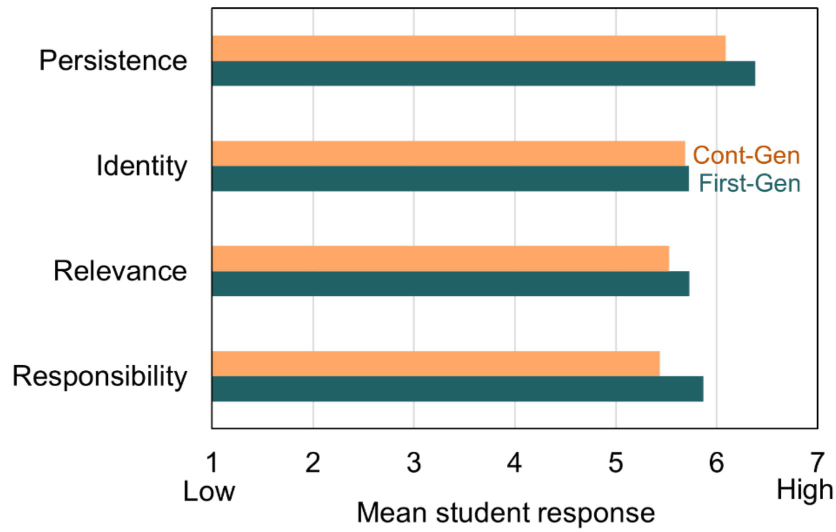

Figure 2: Mean survey response scores for first-generation (■) and continuing generation (■) students where 1 is low and 7 is high.

We also considered explanations for the differences between students from minoritized and privileged racial and ethnic groups. First, these survey results may suggest that minoritized students have systematically had access to lower agency laboratory experiments, leading them to expect fewer opportunities to enact their agency, resulting in perceptions that their agency is limited to less consequential domains. Second, this may reflect problematic peer relations, in which microaggressions play out in ways that limit certain students' opportunities to enact their agency. In our on-going work, we plan to investigate these differences further and also plan to link survey results to evidence of student learning on post-lab technical reports.

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