

Article

Content and Cohorts in Engineering Education: Leveraging Self-Determination Theory in Authentic Learning Experiences for Undergraduates

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Abstract

Motivation and retention in engineering education are critical elements of a national strategy for many reasons, and thus merit exploration in traditional venues as well as extracurricular settings. We use Self-Determination Theory (SDT) to understand students' motivation in an authentic undergraduate learning experience geared toward retention in the semiconductor industry, an example of an industry of national importance around the world. Twelve students participated in two cohorts of training in cleanroom techniques and equipment. We conducted semi-structured interviews with participants to probe their perceptions of authenticity, motivation, and engagement in the program. We used thematic analysis to identify emergent themes from interview transcripts and deductively coded for concepts of interest. Participants' perceptions of authenticity often reconstructed the dimensions of the designed authentic learning experience. Students linked their perceptions of authenticity directly to the SDT constructs of autonomy, competence, and relatedness. Interestingly, students reported a salience for relatedness in authentic experiences, generated principally through cohort instruction. In the connections between students' perceptions of authentic learning experiences and motivational drivers, relatedness, an often-overlooked factor in engineering curricula, emerged as particularly relevant to enhance student motivation.

Keywords: undergraduate engineering students; authentic learning experience; Self-Determination Theory; semiconductor advanced manufacturing



Academic Editors: Lykke Brogaard Bertel, Dorte Moeskaer Larsen, Connie Svabo and Martin Niss

Received: 1 April 2026

Revised: 20 July 2026

Accepted: 26 July 2026

Published: 5 August 2026

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1. Introduction

1.1. Authentic Learning Experiences

Authentic learning experiences are relevant to the participants (herein, undergraduate students) and are situated within a relevant social context (Stein et al., 2004). Engagement with authentic learning experiences as an undergraduate student can be pivotal to developing students' engineering identities and decisions to transition to engineering careers (Strobel et al., 2013; Zou & Chan, 2016). Additionally, authentic learning experiences may be experiential such that they occur outside of a traditional classroom, an often-overlooked setting for education research (Borch & Svabo, 2025). Such experiences have three components: context authenticity, when the environment represents the world outside the classroom; task authenticity, when activities resemble real-world operations; and impact

authenticity, when students create products used outside of the learning environment (Strobel et al., 2013). Common examples of authentic learning experiences include case studies, inquiry-based projects, fieldwork, and lab work (Galindo, 2024).

Authentic learning experiences confer a variety of benefits to students' affective outcomes, such as intent to persist in engineering, self-efficacy, and interest in the domain (X.-Y. Chen et al., 2023; Hughes et al., 2021; Mraz-Craig et al., 2018). Further, the inclusion of an authentic, real-world context in project-based learning has been linked to increased engagement among undergraduate students (Chang et al., 2024). These benefits also apply to authentic research experiences. For example, undergraduates in a summer electrical engineering research program were more likely than their matched peers to pursue advanced degrees in engineering (Morley et al., 1998).

Crucially, educational experiences can seem authentic for students even when they are not directly applicable to real-world situations, and cognitive realism—the task's design and method of engagement—may be adequate to convey authenticity in a learning experience (Herrington et al., 2003; Roach et al., 2018). Such benefits have been demonstrated in fields adjacent to the semiconductor education described here. For instance, in undergraduate electrical and computer engineering, robotics offers a promising avenue to promote cognitive realism and foster motivation and authentic learning elements (Khanlari, 2016).

In summary, a strong theoretical basis underpins and supports our investigation that engagement in an authentic research experience increases participants' interest in the field of study. Consequently, the Gateway program, the setting for this study, deliberately incorporated elements of context authenticity, task authenticity, impact authenticity, and cognitive realism in its design. However, the extent to which undergraduates recognize these design components of authenticity is unknown. Furthermore, mismatches between curriculum designers' and undergraduate participants' views of authenticity may affect the potential impact on motivation- and retention-related student outcomes.

1.2. Leveraging the Psychology of Motivation: Self-Determination Theory

Psychological theories and concepts of motivation can inform how students benefit from authentic learning experiences, especially those outside the formal curriculum. Broadly, motivation is positively associated with academic achievement (Cromley et al., 2016) and retention in science, technology, engineering, and mathematics (STEM) majors (Pedraza & Chen, 2022). It is therefore desirable to explicitly link course content and structure with motivational drivers.

Self-Determination Theory (SDT) posits that satisfaction of three basic psychological needs—autonomy, competence, and relatedness—fosters growth and intrinsic motivation for a particular task or activity (Ryan & Deci, 2000; Urhahne & Wijnia, 2023). Autonomy is defined as a sense of freedom, ownership, and volition (Deci & Ryan, 2000; Urhahne & Wijnia, 2023). Competence refers to the drive to grow and succeed during the pursuit of goals (Deci & Ryan, 2000; Urhahne & Wijnia, 2023). Relatedness is the desire to have close emotional connections with others and feel a sense of belonging (Deci & Ryan, 2000; Urhahne & Wijnia, 2023). When all three needs are satisfied, individuals experience higher autonomous motivation, which has been linked to increased engagement and deep learning strategies, particularly among students with mastery goals (i.e., goals related to knowledge acquisition and skill development; Rothes et al., 2022).

SDT has been widely used in engineering education scholarship to theoretically ground the understanding of how and why educational interventions translate to long-term success. Many studies have examined the link between SDT's three psychological needs and student outcomes. Project-based and active learning have been associated with support of student autonomy (Stefanou et al., 2012). Students in a required first-year electrical

engineering ethics course who reported high autonomy and competence, maintained motivation throughout the term (Bombaerts & Vaessen, 2022). In an introductory computer engineering course, autonomy support was critical for students' intrinsic motivation to learn; moreover, the development of relationships with other students via team projects and out-of-class interactions improved relatedness (Trenshaw et al., 2016). Autonomy of one's own learning and intrinsic interest in engineering support academic well-being in project-based learning (J. Chen et al., 2023). Competence is positively associated with intrinsic motivation and resilience among undergraduates (Sanchez-De Miguel et al., 2023). The importance of relatedness, particularly with instructors, has bolstered the tendency of engineering undergraduates to seek academic resources, an important skill to succeed in more challenging courses (Oh et al., 2024). Further, peer and faculty interactions—manifestations of relatedness—have significant and positive associations with a sense of academic belonging in engineering (Polmear et al., 2024). Project-based learning modules in undergraduate engineering education serve as a natural setting for students to develop teamwork skills (Abas, 2026).

SDT has been proposed as a guide for redesigning courses to be more effective for engineering undergraduates (Vanasupa et al., 2009). An intervention to promote the recruitment and retention of women in engineering became more effective at reaching its goals when it incorporated elements to support autonomy, competence, and relatedness (Dell et al., 2018). The effectiveness of SDT extends beyond engineering to other STEM disciplines. In applied calculus, competence and autonomous motivation are important for students' academic achievement (C. Wang et al., 2022). Additionally, in undergraduate chemistry and biology courses, autonomous motivation, where the locus of causality is internal, is associated with better grades (Botnaru et al., 2021).

Figure 1 illustrates how we operationalize SDT for this study. While increased motivation is likely to have downstream effects on engagement and retention (dashed arrow), here, we focus on the connections that precede and contribute to motivation. We explore links between the program architecture and its designed authenticity, students' perceived authenticity, and motivation (solid arrows). Notably, the Gateway curriculum was designed to convey the knowledge needed to work independently in a cleanroom (i.e., autonomy) with an understanding of techniques and relevant equipment (i.e., competence). Participants were admitted in a cohort model to maximize the program's reach, but explicit supports for relatedness were not intentionally incorporated into the program.

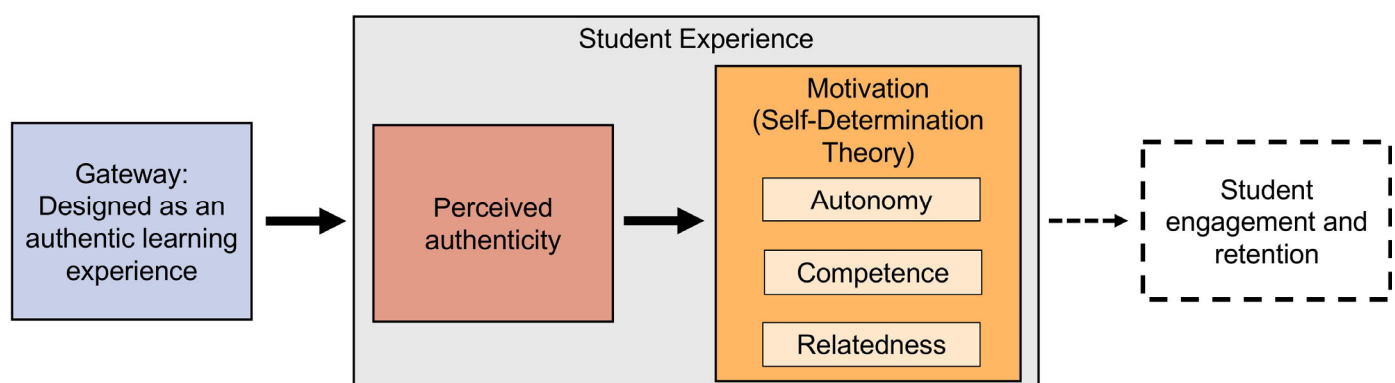


Figure 1. Participation in authentic learning experiences impacts motivation in two-steps. First, when students perceive it as authentic, and then via the three constructs of Self-Determination Theory. We focus on the connections indicated by solid arrows between the authentic learning experience and the student experience. Downstream effects on engagement and retention (dashed arrow) are not captured in this study.

1.3. Study Context

Semiconductors are critical for the global economy. The United States (US) projects a shortage of workers in the semiconductor industry and associated sectors, with forecasted needs including computer scientists, engineers, and technicians (Markel et al., 2025; Semiconductor Industry Association, 2023). In 2022, the United States government passed the CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act to support research and development in the semiconductor industry and associated sectors, such as nanotechnology, clean energy, quantum computing, and artificial intelligence, and to grow and develop the associated workforce (*CHIPS and Science Act, HR4346, 117th Congress 2021–2022*, 2022). As a result, many new initiatives are encouraging individuals across education and experience levels to pursue these careers (Semiconductor Industry Association, 2023; The White House, 2022).

Historically, academic–industry partnerships have effectively developed and implemented programs to improve competencies in targeted engineering fields and retrain the existing workforce (Diehl et al., 1998); these programs can also contribute to employability skill development among undergraduates (Vlachopoulos & Pachni Tsitiridou, 2026). However, a paucity of data on the effectiveness of these programs has limited the examination of university-based authentic learning experiences for improving motivation and intent to persist in this industry among aspiring engineers. This research examines the role of one such program in impacting students' motivation and engagement, “Cleanroom Gateway” (hereafter Gateway), a two-week¹ training program that introduces undergraduate students² to the semiconductor industry in a university cleanroom experience. The program sought to increase career readiness through hands-on exposure to cleanroom techniques and equipment and contribute to industry awareness through active engagement with university faculty and staff in an authentic, experiential learning environment. At scale, an authentic training program like Gateway could address domestic labor needs by increasing persistence in the appropriate engineering fields (and subsequent industry). Thus, it is urgent to generate a clear understanding of effective program design by understanding what drives students' motivation and engagement.

The Gateway program was hosted in a cleanroom, a workspace designed to “control contamination levels, temperature, pressure, and humidity to meet certain environmental conditions” (ACH Engineering Inc., 2023) necessary for the specialized manufacturing processes characteristic of semiconductor development and associated applications. Gateway participants learn both preparatory and procedural tasks, such as the safety protocols and donning of protective gear (known as “bunny suits”) required for entry. Once inside, they engage in continuous safety training while learning about the instrumentation and technology.

In this study, Gateway participants enrolled in a small cohort and the program activities guided them through the fabrication of a neural probe, a sensor used for neurological research. The cleanroom faculty and staff actively mentored students, and all participants engaged in peer mentoring. Gateway is a relatively novel experience because in a typical undergraduate curriculum, students rarely have the opportunity to work in fully operational cleanrooms and are instead exposed to virtual reality activities (F. Wang et al., 2024) or other contrived simulations.

Gateway offered an authentic experience because participants performed the same tasks as professional engineers working in cleanrooms (Magana et al., 2016). The impact of this designed authenticity may depend on the extent of overlap with participants' perceptions of authenticity. We used SDT as our framework to characterize motivational drivers in terms of autonomy, competence, and relatedness (Deci & Ryan, 2000). A better understanding of the potential mechanisms of motivation in Gateway can help identify

effective elements of program design. Specifically, we sought to answer the following research questions:

1. Which programmatic elements do undergraduates perceive as authentic?
2. How does Gateway support students' autonomy, competence, and relatedness (as outlined by SDT) to support intrinsic motivation?

Students explicitly linked their definitions of authentic learning experiences (research question 1) and the three psychological needs outlined by SDT (research question 2). We present these connections alongside the findings related to our two research questions.

2. Materials and Methods

2.1. Program Recruitment and Description

In the spring of 2024, program staff recruited undergraduate engineering and STEM applicants, identified via department email lists at a private research university. Incentives included an \$8000 stipend for the summer, and the course did not interfere with the standard academic curriculum. Of 38 applicants, 14 were selected based on grades, transcript alignment with the program's technical scope, and a statement of interest. Twelve of the selected applicants participated in the program. Participants were assigned to one of two cohorts ($n = 7$ and $n = 5$, respectively) conducted in sequential sessions. Each session comprised two weeks of intense project-based training with a prescribed curriculum (Rocio Vazquez et al., 2022), followed by seven weeks in a less structured research internship. Completion of this training was formally recognized with a set of micro-credentials issued by IEEE (Institute of Electrical and Electronics Engineers), a global non-profit organization of academic and industrial engineers. While the cohorts did not overlap temporally, the student internships did. Here, we focus on the two-week training experience.

2.2. Research Subject Recruitment

All Gateway participants ($n = 12$) were invited to participate in this research study. At the end of the program's first week, participants responded to a program assessment survey, after which they were sent a request to participate in a semi-structured interview. Students who participated in an interview were compensated with \$25 Amazon gift cards. Eighty-three percent ($n = 10$) of Gateway participants were interviewed.

2.3. Demographic Survey and Participants

The program survey collected quantitative data with demographic questions. All interviewed students were engineering majors, with seven in electrical and computer engineering. Half the participants identified as men (50%); similarly, half were Asian (50%). Most participants identified as continuing generation (90%) or started their undergraduate program at the same four-year institution they were currently attending (70%). To preserve anonymity, we do not report other gender, race/ethnicity, college generation, and transfer student status. The average age was 19.5 ($SD = 0.97$) years, and the matriculation distribution was 40% (rising) sophomores, 40% juniors, and 20% seniors.

2.4. Interview Protocol and Method

Previous studies based on qualitative interviews have explored SDT in engineering education, such as in a second-year engineering course (Trenshaw et al., 2016) and during innovation projects (Fila & Purzer, 2017). Aligned with this scholarship, two authors (ST and EJT) developed and followed a protocol with questions in four general areas: (1) overall impressions, (2) perceived and personal goals, (3) specific components, and (4) student engagement. Interviewers augmented the script (Appendix A) with clarifying questions as needed. Some questions assessed motivation-related outcomes, such as "Did

you find the educational experience enjoyable?”, while others appraised the learning environment, such as “Do you feel comfortable asking your classmates for help?” Interviews were conducted online for 90 min during the program’s second or third week, prior to the end of the first week of the research internship. Interviews were transcribed verbatim with a transcription service.

2.5. Interview Analysis

We used thematic analysis (Terry et al., 2017) to qualitatively code the interview transcripts, with a combination of inductive coding methods to identify relevant recurring themes pertaining to authenticity and deductive coding based on SDT (e.g., autonomy, competence, relatedness; Auerbach & Silverstein, 2003). Four members of the research team (CAB, ST, LB, EJT) read two randomly selected transcripts and took analytic notes of relevant themes; examples included: “Authenticity is doing things that the people who work in that industry do,” “Teaching others as a way to demonstrate/practice mastery,” and “Having a community/cohort helped with motivation.” The four researchers jointly converged on common themes across the transcripts based on these notes.

A smaller coding team (CAB, ST, LB) then reviewed five randomly selected interview transcripts and developed a coding rubric (Appendix B) to capture the identified themes. This smaller coding team subsequently coded all interviews to consensus, with disagreements resolved via discussion. Each excerpt was considered to have reached consensus when all three members of the coding team agreed that it reflected a specific theme. We used the software Dedoose to conduct transcript coding and qualitative analysis.

Due to limited sample size and the qualitative nature of this study, we do not report frequencies and instead focus on the variety of ideas represented in the transcripts. We include illustrative student quotes, which we anonymized and lightly edited for clarity. In many cases, multiple students articulated similar ideas. We provide select quotations throughout the Results and Discussion section for concision. Additional quotations are reported in Appendix C.

3. Results and Discussion

This integrated Results and Discussion section allows us to give context to student quotes as they are presented. A brief general discussion section follows. Students overwhelmingly noted and valued program aspects that they deemed authentic. In their responses, we identified specific elements that supported their autonomy, competence, and relatedness, as well as linkages between these elements and their definitions of authenticity. Moreover, they reported authenticity as a mechanism to overcome demotivation.

3.1. Perceived Authenticity

We asked participants to define dimensions that make an educational experience authentic and provide illustrative examples from Gateway. Participants described the similarity to real-world jobs; the opportunity to develop useful, transferable skills; and interactions with peers and instructors as elements of Gateway that made the program authentic (Table 1).

Table 1. Student perceptions of authenticity.

Students perceived the Gateway program as authentic because. . .	• It was similar to real-world jobs (i.e., engineering work). • They had the opportunity to develop useful and transferable skills. • They interacted with peers and instructors.
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3.1.1. Similarity to Engineering Work

Participants described Gateway as authentic because of the similarity to professional engineering. For example, students noted the physical location in the cleanroom.

Student B: “You feel like you’re an actual employee there and you’re in the same building and the same floor using the same utilities, the same spaces. You have your badge and everything, you have to log in, you have to not go to certain floors that are confidential, that kind of thing. So that’s what makes it feel authentic, in my opinion.”

Additionally, students asserted that they were performing tasks identical to those of engineering professionals.

Student J: “I would say the process that we learned, like photolithography for example, is the exact same steps that are used for cutting edge chips manufacturing. That’s what excites me about it, because it’s pretty much learning the exact steps of how it’s made for real-world application. And I think that’s the most exciting part of it, because we are actually getting this hands-on experience.”

In effect, the setting of a fully functional cleanroom and the similarity of tasks to those of professional engineers enhanced students’ perceptions of authenticity in the program. Students’ reports demonstrate that they perceived the work they were performing in Gateway as “real,” authentic work.

3.1.2. Development of Useful, Transferable Skills

Participants described Gateway as authentic because they developed skills they could transfer to future engineering positions.

Student C: “On the very first day, he [the instructor] was just like, ‘These are the lists of industry professionals that we have in this program sponsoring this. These are the lists of industry companies that are wanting people in this profession, and these are the things that we are doing for them currently that they’re using.’”

Participants created neural probes as they learned the techniques and equipment. The obvious real-world application bolstered their appraisal that they were participating in an authentic experience.

Student C: “If I’m doing things that I can see, oh, people who aren’t even in this program are doing, then okay, then I’ll probably do something authentic. Within the cleanroom, I felt like it was immediately shown that it was authentic because we were building a person’s PhD project [the neural probe]. This is something somebody did for a PhD, and it has been used in medical trials and stuff like that, the neural probes. And at that point I was just like, ‘Oh, okay, cool. We’re actually doing something that has had use.’ Not necessarily because we could use it, but it has been used.”

3.1.3. Interactions with Peers and Instructors

Participants expressed a perception of authenticity beyond technical aspects to incorporate the interactions they had with their peers and instructors in the program.

Student E: “Another aspect of authenticity is whether the people I’m around are enjoyable to be around. I mean, it could be just by chance because these people, I think they’re all great, but I don’t think there was an issue with that. That was pretty straightforward. Literally, the first day, I think we were all eating lunch together. We were talking.”

Additionally, participants expressed that the instructors' professional positions and experience contributed to the sense of authenticity.

Student B: "And yeah, also the people. I guess another really cool thing is the two instructors. . . I'm not exactly sure the position of the other one, but one of them is the associate director of the cleanroom lab, and so they really know what they're doing. They've known what they're doing for a really long time. They're constantly learning more and understanding more machines and how things work. So being able to interact with them, people at the top of that field, makes it authentic."

3.1.4. Interpretation: Perceived Authenticity

Components of program design were intended to provide the facets of authentic learning experiences associated with persistence in engineering, engagement, and engineering identity (Chang et al., 2024; X.-Y. Chen et al., 2023; Hughes et al., 2021; Morley et al., 1998; Mraz-Craig et al., 2018). Gateway deliberately provided context authenticity, with its cleanroom setting; task authenticity, via training techniques and equipment relevant to engineering careers; and impact authenticity, with the project to fabricate a neural probe useful beyond the learning environment (Strobel et al., 2013).

Typical experiential program architects would consider the physical environment—e.g., the bunny suits, sophisticated equipment—to adequately provide context and task authenticity; and the construction of neural probes—with relevance beyond the classroom—to provide impact authenticity. These results suggest that a single student operating alone in a cleanroom would not recognize sufficient authenticity. Only one of the seven characteristics of context authenticity includes "social interactions," and it is only lightly emphasized as a component of authenticity in the operational definition proposed by Strobel et al. (2013). However, participants described interactions with peers and instructors as a key component of perceived authenticity. In other words, we find an inconsistency in the minimal role of social interactions presented in typical definitions of authenticity in learning environments, and the strong role they played in undergraduates' perceptions of authenticity. Evidently, learning experiences should incorporate meaningful interactions with peers and instructors to be perceived as authentic by students.

3.2. Exploring Motivation Using Self-Determination Theory

As noted above, Self-Determination Theory posits that three psychological needs—autonomy, competence, and relatedness—must be met for meaningful engagement in an educational experience. Students' descriptions of the Gateway program supported this framework, and elements of the program supported combinations of these three constructs.

3.2.1. Gateway Elements That Supported Autonomy

Autonomy refers to the ability to do tasks independently, self-direct, critique one's own work, and evaluate performance (Deci & Ryan, 2000; Urhahne & Wijnia, 2023). During the interviews, participants were asked about their assessments of success, and many responded that they sought to complete a task independently.

Student I: "I think [I will know that I am successful when I am], understanding what I'm doing, being able to [. . .] get to the point where I can do it by myself and not have to rely on other people"

In addition to a sense of independence, autonomy is characterized by an intrinsic interest in a topic or pursuit. Students expressed intrinsic motivation for learning new skills and concepts, which encouraged them throughout the program.

Student C: “I just really enjoy answering my own questions if I ever have questions. I do enjoy asking people, but sometimes I want to interpret it [on] my own so that I can get a better understanding. And asking people is part of that learning on my own. But yeah, that skill of just learning by myself at home after the work has been done is just a thing that I have been doing throughout my life, which is I guess just a useful skill for anybody to do. Just do it yourself and learn more. And if you have more questions, then you have more questions to ask for the person who’s in charge the next day. So just if you enjoy learning, then it’s a great way to just keep learning.”

When students described experiencing autonomy, they expressed enthusiasm, which is not a direct component of autonomy as described by SDT; however, students made these connections.

Student A: “It [an enjoyable educational experience] gives you enough to work with to know what direction you need to go in. But then it gives you enough room to independently think about how to do it. And I do think this cleanroom opportunity is kind of like that.”

3.2.2. Gateway Elements That Supported Competence

Competence refers to students’ perceptions of their knowledge or skill attainment and confidence in a particular topic or task (Deci & Ryan, 2000; Urhahne & Wijnia, 2023). When discussing Gateway, many students highlighted their growing confidence to complete tasks, or self-efficacy, in the cleanroom.

Student F: “It [how much I am learning] is just a matter of how well I’m understanding what’s going on in the cleanroom. I think which machines I can operate is probably the main metric. It feels like days where we learn how to operate a new machine feels like we learned something, whereas days where we just use the old ones to do something is not as [much learning].”

Participants noted demonstration of their competence when assisting peers.

Student B: “So a lot of times if you don’t know something and you know someone else did it, you go ask them and then they go show you, or the other way around, and I teach someone how to do something. And that’s very rewarding. That makes you feel like you know what’s going on, you know what you’re doing. So, I guess that’s one of the bigger things, just teaching your other students. That’s a way to see how well you’re doing and see how much you’re improving.”

Some participants described connections to the curriculum as relevant to their intrinsic motivation.

Student C: “The enjoyable [part] is learning all of this stuff. That was the intellectually stimulating part. All these new concepts. I had to learn thermodynamics. All of this math that I just learned in the previous semesters are being put into use now, and it’s kind of eye opening, just like, ‘Whoa. The things that I learned are actually being used.’”

Participants expressed enjoyment of a newfound opportunity to develop and demonstrate competence in the cleanroom and electrical engineering more broadly.

Student B: “It is engaging because it’s extremely hands-on, and they’re making you do these things, they’re making you learn these things. And so we had two weeks of that [cleanroom] training program, and then now I’m in my first week of the actual internship, and I can do things that I wasn’t able to do before. So that’s also rewarding, and I can see myself using all of this information in the

future, because sometimes I'm hanging out with friends who are older than me, so they just graduated college, and I feel like sometimes I can talk to them about things [related to the field], that's more their level, and I wouldn't have been able to do that earlier, two weeks ago."

However, while students generally reported that completing tasks contributed to a sense of competence, some reported a lack of confidence and subsequently questioned their sense of belonging. This was particularly pertinent in specific technical tasks, such as operating certain machines or encountering error messages.

Student B: "And in this setting, I think it's a little bit different [from a traditional classroom], because we're not being tested on anything, we're not being graded, but we are working with extremely sensitive, and extremely expensive equipment, and so I think I definitely got a lot of anxiety from just saying, 'Am I doing this right?' And doubting myself a lot and having to double-check with them. Or one time, I pressed this button before I pressed the other button, and the machine stopped, and that's just. . . Your heart stops for a second, because it's just such incredible technology, and it's a very big privilege to be there, so I guess another thing that contributes to anxiety is just saying, 'Oh, do you deserve to be there? Are you worthy of being there?' And I feel like, for me, the answer is no, because I feel like I haven't put in enough time and effort into the subject to be able to work with such machines, and to work on such technologies, but we need people in the industry anyways, and that's what the program is trying to achieve."

This experience momentarily threatened the participant's sense of competence, but repeated practice and recognizing the programmatic goals ameliorated long-lasting impacts.

3.2.3. Gateway Elements That Supported Relatedness

In SDT, relatedness refers to the sense of being affectively bonded to others, such as peers and instructors in the Gateway context (Deci & Ryan, 2000; Urhahne & Wijnia, 2023). Notably, students commented on the sense of community within their cohort.

Student C: "Also, I do enjoy the fact of having people who I can get along with during the program so that let's say I'm pursuing work, but I'm also having fun with my friends or just meeting people in this program who I can become friends with in [the] context [of] this program."

Participants linked the collaborative nature of the program to their enjoyment.

Student I: "I would say this program is enjoyable. I think part of it, what makes it enjoyable, is we get to collaborate with the other people in it and learn from each other. We're doing hands-on work, and we're kind of doing something different every day."

The sense of relatedness fostered by the program manifested in positive instructor-student and peer-peer interactions. One student described how the instructors' conduct supported relatedness.

Student E: "I think a lot of that, it's not that they [the instructors] specifically did something to make us feel safe, but just inherently, they just feel approachable. I think it's a little hard to describe. It's just they're always willing to respond to the question. They don't seem annoyed."

Specifically, participants stated that the instructors fostered an atmosphere wherein students were encouraged to ask for support.

Student C: “If there’s nobody to ask, [...] I’ll just ask [the] professor and I feel relatively comfortable asking them. They’re very approachable. They took the time to explain everything, and they’re still very, very approachable in that sense.”

Participants connected their descriptions of relatedness and belonging. The bonds formed within cohorts and connections with the instructors reinforced students’ sense of belonging both within the program and in engineering more broadly.

Student D: “And then within this program as well. We are all like [University name redacted] students and we do have a lot of shared experiences from that standpoint as well. So I feel like that was a way to draw on community. But there’s so many other ways that I feel like we could have all come along and felt to create that community within our cohort. And I think that drawing on either our own shared experiences or just helping each other out will definitely help that inclusivity standpoint.”

3.2.4. Intersections of Autonomy, Competence, and Relatedness

Autonomy, competence, and relatedness are constructs central to SDT. Interestingly, many excerpts were co-coded as satisfying two of the three psychological needs. However, it was notable that no excerpts were coded as both autonomy and relatedness (Figure 2). Importantly, autonomy and competence were stated programmatic objectives, whereas relatedness was primarily generated as a byproduct of the cohort instructional model.

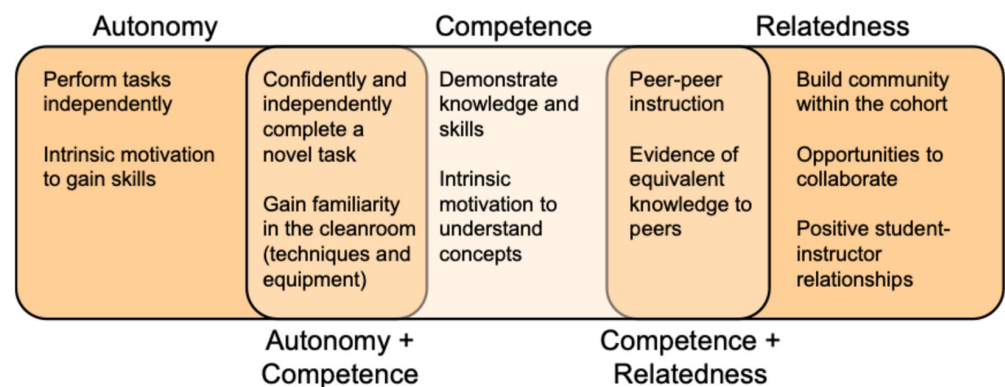


Figure 2. Distinct elements of the Gateway program supported participants’ autonomy, competence, and relatedness. Some elements supported both autonomy and competence, or both competence and relatedness. No excerpts were coded as both autonomy and relatedness.

Excerpts coded as both autonomy and competence included a sense of stimulation or challenge. For example, this student described the confidence to independently execute a newly assigned task.

Student J: “I think for me the main measure [of success] is when I get a new task, for example from [the instructor], I know confidently what I need to do to successfully complete the task, and that I don’t hesitate to go use some equipment or the tools. And so far, for example the tasks that we got today, I really knew how to follow those steps and how to do it. So, to me that’s a good sign that I built enough skill and that I have enough knowledge to successfully complete it.”

As the program generated familiarity with the cleanroom, students’ autonomy and competence grew.

Student G: “I remember my first day in the cleanroom, I’m like, ‘I don’t know what anything does,’ but [now] I could generally walk around the [area] and be like, ‘Okay, this is what this is.’ I could give a very cursory tour of the cleanroom,

and I could go up to a device. I don't think we've learned how to use the chemical. . . I forgot, the PCVD³ (*sic*), so the chemical deposition tool, but I feel like I could go up to it and read the manual really quickly or the binder that they have there, and it'd be like, 'Okay, I can figure out how to use this thing on my own.' I probably shouldn't. I should probably have an instructor train me, but I feel like I could."

Peer-peer interactions, such as in the development of an ability to explain protocols to their colleagues, fostered a sense of both autonomy and competence.

Student E: "I guess I think I felt more successful when I was able to pretty much quickly pick up on how to use a machine. And then when I ran into a problem with that machine, I knew how to fix that. And then also, another way I knew was how clearly I was able to explain it to my peers because sometimes we learn the machines staggered, so if I really understood the machine, I'd be able to explain every step properly, explain why we do that step. And I think if I could do that clearly and they did it well, then that makes me feel like that was successful."

Many excerpts were co-coded as competence and relatedness. For example, this student reports that sharing a common knowledge base with peers contributed to confidence and a sense of belonging.

Student G: "Maybe there are more people that are more well-versed, but it doesn't seem like anyone from the cohort has had previous experience. So, I think I would say, yeah, sure. If I'm at the same baseline level of knowledge as everyone else, I think, sure, I could say that I belong in this program."

Competence and relatedness resulted from peer-peer interactions, specifically opportunities for peer instruction.

Student C: "All we were doing [during the 2-week training] was learning and all that the professor was doing was literally just teaching us and telling us what to do. But a lot of the time, there is, let's say, one professor, one lab lead, and they can't split their attention between seven people all that well, because there are seven people. That's a lot of people to take care of. So what we would do instead is that we would have, let's say, people who got it first would then explain it to the group as the professor had to do something else to prepare for the next step. And I think that was the key to making me feel like I was competent within this group, and that's what helped me get through it."

3.2.5. Interpretation: Motivation via Self-Determination Theory

Although students reported some combinations of autonomy, competence, and relatedness (Figure 2), we coded no excerpts as both autonomy and relatedness. This is reasonable because autonomy emphasizes skills and confidence for independent task execution, whereas relatedness describes connections with others. Instruction that empowers independence is unlikely to simultaneously nurture connections. However, autonomy may be the least salient for undergraduate engineering students, with motivation more strongly related to relatedness instead (Trenshaw et al., 2016). The seeming importance of relatedness for students may be in response to general cultural cues, in that the ability to contribute to a team is increasingly regarded as central to today's workforce (Deming, 2017; Hirudayaraj et al., 2021). Traditionally, this has been an area of lower focus in engineering education, which has concentrated on the delivery of technical knowledge (Hirudayaraj et al., 2021; Trenshaw et al., 2016). It is therefore incumbent on engineering educators to identify ways to provide experiences that generate relatedness among peers and with instructors, so that technical education confers knowledge retention and encourages re-

tention in engineering. Notably, peer–peer instruction could represent another form of autonomy—autonomy from the instructor. While this was outside of our conceptualization of autonomy based on its definition provided in SDT, broadening the conceptualization of autonomy to include these multiple contexts may lead to additional connections between autonomy and relatedness, particularly in cohort models of learning.

3.3. Intersection of Authenticity and Self-Determination Theory

Throughout the interviews, participants spontaneously connected dimensions of perceived authenticity (Table 1) and the SDT psychological needs. The program was designed to be authentic in that it offered impact authenticity, task authenticity, and context authenticity (Strobel et al., 2013). Students recognized those components and clearly articulated the connection between perceived authenticity and the three constructs of SDT. Figure 3 shows our operational mapping of design authenticity to perceived authenticity and how it connects to SDT.

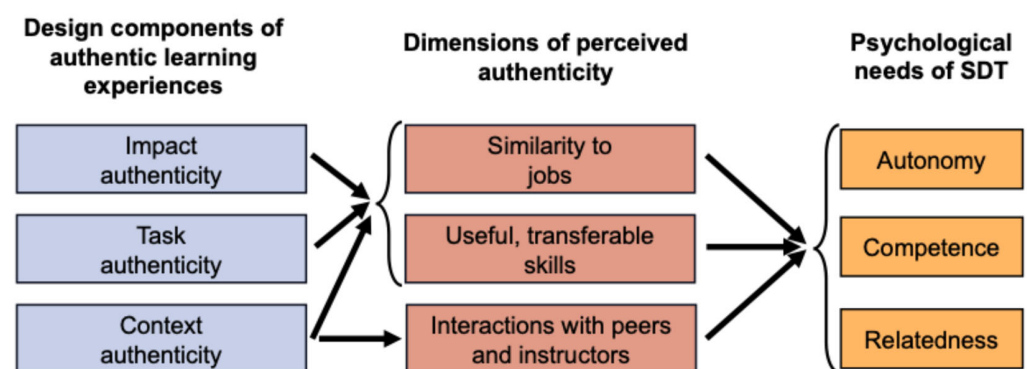


Figure 3. Mapping the design components of authentic learning experiences to perceived authenticity and subsequently to the components of SDT. Design components mapped onto the dimensions of perceived authenticity. During interviews, participants made connections between the dimensions of perceived authenticity and all three psychological needs described by SDT.

3.3.1. Similarity to Real-World Jobs Intersects with Self-Determination Theory

Perceived similarity to real-world jobs intersected with autonomy. Specifically, one student emphasized the task similarity to those of “real” engineers in cleanrooms. The use of “I” and taking initiative in learning emphasizes autonomy.

Student E: “In terms of the actual lab work, I think authentic means [...] working on something that actual researchers would be working on. It doesn’t feel like they’re lowering the bar. I want to feel like, ‘Okay, I’m actually putting an effort to learn this. I’m actually learning what the real people do.’ I think that would make me feel it’s authentic, to get the real practical exposure to it and not a dumbed-down version.”

The task at hand, neural probe fabrication, presented students with an opportunity to demonstrate competence.

Student C: “Yeah. I mean, manufacturing the neural probes, that was a three to four days process. And by the end of it, I was finally able to extract the neural probe from the wafer, and I was like, ‘Whoa, I did that.’ And everybody got to do that. So that was very successful. I felt that was like, wow, that felt really rewarding. I felt successful in that moment. Just the culmination of four days of work coming into this moment, succeeding and getting things out was really nice.”

When describing the learning environment, this student repeatedly used “we,” which indicates that being in the cleanroom setting among peers impacted their perception of authenticity and inspired relatedness.

Student F: “We’re actually in the clean room, and that’s a level of, I guess, seriousness, we’re seriously doing this. It’s like, we’re actually there, and we’re actually learning relevant techniques.”

3.3.2. Useful, Transferable Skills Intersect with Self-Determination Theory

The second dimension of authenticity was the development of useful, transferable skills. This overlapped with autonomy when participants discussed the various tasks they could complete independently by the end of the training program, and how those technical skills would benefit them in future professional roles.

Student H: “I’d say this experience was valuable in a career skillset sense. I did gain skills, the smaller ones, handling samples carefully or using different machines like the spin coat, the PECVD, all of the other machines that [were] also helpful. I am pretty sure I’ll be using those skills later on. If I do go to medical school or if I do go to industry, those would be helpful.”

Development of useful, transferable skills overlapped with competence as students demonstrated their new and growing capabilities, as this student describes. Moreover, the excerpt depicts self-regulated learning skills acquired during the program and a plan to transfer them to other undergraduate learning environments.

Student G: “I feel like I tend to be very satisfied with what I learned, like, ‘Oh, this is how you do. . . We deposited metal or we put some photoresist and then deposited metal and that’s it. That’s how you do things,’ which is generally how you do things, but it made me intrigued. I was reading stuff or looking up stuff, reading stuff online, just vague articles and it was like they were putting the metal before the photoresist. I’m like, ‘What’s the purpose of that? What do you do that for?’ And I could go in the next day and ask, ‘Oh, are there cases where we deposit metal first before putting that photoresist on there? What does that do? How many layers high can certain things get? And why would we need that many layers?’ It was just stuff like that. It made me try to understand things on a deeper level rather than just be satisfied with where I’m at and I feel like I would want to apply that more just even during my normal school year.”

Participants anticipated building professional networks through Gateway, which they identified as a useful takeaway from the program. They expressed hope that newly developed connections with others, an artifact of relatedness, would provide career benefits.

Student B: “In this industry, it’s a very, very tight-knit group of people who understand what’s going on, or are really interested in it. And I feel like having learned all these things, and having met these people is very valuable for me career-wise, but also it inspires me to do things that they’re doing. Even if I don’t actually end up going the same path as them, I feel like it’s cool to be able to meet these people, and connect with these people, so that I can ask them for advice later on in life, or maybe use them as an example in my career.”

3.3.3. Interactions with Peers and Instructors Intersects with Self-Determination Theory

The third dimension of authenticity was the interactions with peers and instructors. For example, this participant describes how recognition that everyone in the cohort would be challenged at some point enabled self-assessment and metacognition. This is emblematic

of autonomy because it demonstrates a willingness to take charge of one's own learning, but with explicit mentions of everyone in the cohort.

Student D: "I would say that authentic experiences in the classroom setting are all, it goes back to maybe going through challenges [...] just understanding that everyone learns differently. So even though I might've [been] challenged with one thing, somebody might've just completely understood it. And I feel like that just goes back to recognizing our different backgrounds as students. [...] And I would say in the clean room, it's probably best to embrace that through understanding that we all have these different backgrounds and just working together through that, through all the equipment."

The interactions with peers and instructors supported students' competence by establishing a trusted network to rely upon when faced with a challenge. This, in turn, enhanced the understanding of cleanroom techniques, as this student describes.

Student G: "I think there was one time I accidentally spun coat and exposed the wrong side of the silicon wafer, and I was looking at it under the microscope and I'm like, 'What the heck am I looking at?' And then I usually just talk to either the staff or even one of the cohort and they're just like, 'Oh, yeah, I did that too. It's just the wrong side. Do it again.'"

The link between developing connections with others in the cohort and relatedness is perhaps the most straightforward, but participants' emphasis on these connections in their definition of authenticity was noteworthy. As Student E said, "Another aspect of authenticity is whether the people I'm around are enjoyable to be around. [...] Literally, the first day, I think we were all eating lunch together."

3.3.4. Interpretation: Authenticity and Self-Determination Theory

Without specific probing, participants described links between dimensions of perceived authenticity and the SDT constructs that support motivation (Deci & Ryan, 2000; Ryan & Deci, 2000; Urhahne & Wijnia, 2023). These linkages highlight the close connection between perceived authenticity and motivation to engage in an educational experience such as Gateway. Gateway was designed to support autonomy and competence through clearly articulated protocols and hands-on practice of sophisticated techniques.

However, the third SDT construct of relatedness was not explicitly designed into the program. Cohorts naturally provide economies of scale unavailable in one-on-one instruction (Doolen & Biddlecombe, 2014). Cleanroom training is led by highly seasoned staff competent in the use of sophisticated equipment. Moreover, in the university context, this training imposes an opportunity cost in that the cleanroom is unavailable for funded research, fee-for-service operations, or other revenue-generating activities during a training session. Thus, it is simply not feasible to conduct this training on an individual basis.

It appears that the cohort structure, developed for economic reasons, brings additional value. Indeed, it has been previously noted that cohorts are associated with improved attitudes about engineering (Doolen & Biddlecombe, 2014). Here we describe a potential mechanism in that cohorts allow for a direct approach to satisfying the SDT psychological need of relatedness. As such, increased messaging about the importance of working on a team in professional settings or intentional team-building activities in a cohort-based program could further increase participants' perceptions of relatedness.

3.4. The Power of Perceived Authenticity to Overcome Demotivation

Occasionally, students mentioned demotivation, but they could overcome this potential barrier by relying on the authenticity as they perceived it. For instance, one student experienced a momentary lack of direction:

Student C: “But demotivating wise was mostly whenever anxiety kicked in and uncertainty kicked in, I was like, ‘What am I really doing? What are we doing today?’ That portion makes me feel like, ‘Why am I here at work today? Did I really do anything productive?’”

But this same student pointed out that this could happen at any job, so the perceived authenticity helped overcome temporary frustration.

Student C: “When those moments happen because they happen no matter at any job. So, I’m just like, those are the moments where I feel a little demotivated like I don’t know what’s going on.”

Participants expressed that they felt frustrated at the lack of time to practice their skills and internalize the material, as the training portion of the program was limited to two weeks.

Student A: “I guess maybe the only thing [that was frustrating] would be time constraints. So, we only had two weeks, which is a very short amount of time. [. . .] [At] one point we were introduced to coating the silicon wafer with photoresist. And I wasn’t able to get a clean one. [. . .] What I wanted to do was keep on trying to figure out what was wrong, what was wrong in my process to get it better, be more exact. Because really the silicon or the semiconductor manufacturing process is very exact. So, I wanted to be more exact in how I am trying to work in the clean room. And there just was not enough time for. So, I guess that would be the only frustrating part that I felt.”

This student’s desire to continue practicing and perfecting the process is indicative of their buy-in to the importance of this task with real-world implications. Providing students additional opportunities to develop expertise with the protocols may boost perceived authenticity by emphasizing the importance of consistency and accuracy in results. In addition to a desire for increased practice, students described repetitive tasks, such as taking measurements and following protocols, as demotivating.

Student H: “I guess in terms of motivation, the project itself is a big thing, because during training, we were making prints on top of wafers, and that was fun. We were making neural probes and that was fun. But as I’ve said, we might just be doing a lot of measurements and I feel like that’s going to be boring and that’s a little unmotivating. So I think the type of task we’re given is a big thing [in determining my level of motivation].”

This participant further articulated the role of task objective in motivation.

Student H: “The difference [in how the task impacts my motivation] would be in how I understand the end goal of the task. For example, with the neural probe, I knew that with each individual process I was going to get a neural probe, there was a result that I was working towards versus just taking measurements. I don’t understand that they’re using those measurements to calculate the rate, but that’s it.”

Emphasizing the importance and relevance of tasks perceived as tedious, such as measurement, may improve a sense of perceived authenticity because these tasks are a necessary element of professional cleanroom practice. In other words, perceived authenticity can partially relieve demotivation associated with repetitive tasks.

Finally, students noted that the physical discomfort associated with the personal protective equipment and bunny suit was initially demotivating, but that concern seems to have dissipated during the program.

Student B: “Demotivating, just. . . Maybe it’s sort of physically uncomfortable, but I get used to it. I’m getting used to it. Physically uncomfortable, but I get used to it. I’m getting used to it more and more every day.”

Interpretation: Authenticity to Overcome Demotivation

Importantly, perceived authenticity relieved demotivation sparked by tedious tasks or insufficient time to practice newly acquired skills, so the incorporation of perceived authenticity in program design could play a key role in participant satisfaction and motivation. This has critical implications for virtual programs that do not naturally engender relatedness. Virtual training programs may provide significant economic benefits to deliver content at scale, but relatedness may develop differently in a virtual cohort.

4. General Discussion

Here, we describe an effort toward greater engagement and retention in a technical sector of international importance: the semiconductor industry. We offer four key contributions to scholarship on engineering education. Empirically, we demonstrate how an extracurricular experience can be deliberately formulated to align with each dimension of perceived authenticity. Theoretically, we report three key findings: First, we show that undergraduates’ perceptions of authenticity emphasize different dimensions than those typically described in the literature as representing authentic learning experiences and, specifically, students experience the social interactions that felt genuine and relatable as one of the primary components of their perceptions of authenticity. Second, we reveal a mapping between perceived authenticity and SDT psychological needs (Figure 3), providing a previously unrecognized link between experiential education and motivational drivers. Finally, we suggest that relatedness—where less attention is typically directed in engineering education (Hirudayaraj et al., 2021; Trenshaw et al., 2016)—may be the most salient to encourage motivation in engineering undergraduates. While we do not directly conduct a comparative analysis of the relative impact of autonomy, competence, and relatedness, we find that relatedness is critical to students’ perception of authenticity.

Limitations and Future Research

The limitations of this study open several new avenues for further exploration. First, the program was structured to include a stipend for all participants. Thus, the intrinsic motivation described here was plausibly affected by the extrinsic motivation afforded by direct financial incentive. However, this financial support to undergraduates creates access to more students, regardless of financial stability (Bangera & Brownell, 2014; Jensen et al., 2021). Additionally, students described the stipend as a source of extrinsic motivation for choosing to apply to the program, which aligns with prior work (Economy et al., 2014). Although participants did not describe the stipend as a source of extrinsic motivation for engaging in the program once it began, in principle, it could affect students’ perceptions. Likewise, linkages between the subsequent internship and future employment opportunities could potentially generate confounding effects (Ryan & Deci, 2020). While the stipend could increase the sense of “work environment” (context) authenticity, a differential impact on one of the SDT elements is not predicted; moreover, the stipend does not affect the idea that the design components and the perceived authenticity may differ. Nonetheless, further study of SDT elements under varying incentive structures would advance our understanding of these programs.

Second, students were selected in a competitive process, and thus endogenous factors may affect the generalizability of the findings. For example, high-achieving students may collaborate differently from their lower-achieving counterparts (Kanevsky et al., 2022;

Lee et al., 2017), and thus they may be more sensitive to relatedness. In addition, the students were all enrolled at the same institution, and therefore, other environmental factors may affect the extension of these findings to other contexts. Finally, specialized learners (i.e., those who are not matriculated engineering students) who participate in the same program may not experience the same motivational drivers.

The architecture of this study did not provide for a statistically meaningful sample, nor for a counterfactual group to serve as a control. Importantly, this study does not constitute an evaluation nor an assessment of the experiential program. Instead, Gateway serves as a setting for the psychology of motivation that we explore. Despite the small sample size, this study introduces the new realization that activity design and the perceived experience may not align in the context of engineering education.

We recommend that future studies explore the relationship between authenticity and SDT to understand how our proposed mapping applies across engineering programs and student populations. Additionally, we identified relatedness as an important but often underexamined component of SDT in designed learning experiences for engineering undergraduates. Future studies could directly compare the relationships of autonomy, competence, and relatedness on motivation and engagement. The qualitative findings reported here could be expanded into a quantitative investigation into motivational factors, as well as to longer-term impacts of authentic learning experiences on participant retention in related engineering fields as the program scaled to support extensive data collection.

5. Conclusions

To our knowledge, this is the first attempt to compare designed and perceived authenticity, and moreover, map the dimensions of participants' perceived authenticity to the psychological needs articulated by SDT within the context of an extracurricular authentic learning experience. Importantly, relatedness, an often-overlooked factor in engineering curricula, may be particularly relevant to enhance motivation. Consequently, igniting perceived authenticity—and in particular, elements that enhance relatedness—in engineering education may be vital to improving student motivation and ultimately retention in undergraduate programs and their transitions into engineering careers.

Author Contributions: Conceptualization: C.A.B., S.T., K.S.M., A.P.B., E.J.T.; Methodology: C.A.B., L.B., S.T., A.P.B., E.J.T. (S.T. and E.J.T. developed and followed the interview protocol; C.A.B., L.B., S.T., E.J.T. developed the initial codebook; C.A.B., L.B., S.T. coded all interviews); Validation: C.A.B., L.B., S.T., E.J.T.; Formal Analysis: C.A.B., L.B., S.T., E.J.T.; Investigation: C.A.B., L.B., S.T., E.J.T.; Resources: E.J.T.; Data Curation: C.A.B., L.B., S.T., E.J.T.; Writing—original draft preparation: C.A.B., K.S.M., E.J.T.; Writing—review and editing: C.A.B., L.B., S.T., K.S.M., A.P.B., E.J.T.; Visualization: C.A.B., K.S.M., A.P.B., E.J.T.; Supervision: A.P.B., E.J.T.; Project Administration: C.A.B., L.B., S.T., A.P.B., E.J.T.; Funding Acquisition: A.P.B., E.J.T. All authors have read and agreed to the published version of the manuscript.

Funding: This work was primarily supported by the Microelectronics Commons Program, a DoW initiative, under award number N00164-23-9-G056 (to APB). The University of Washington College of Arts and Sciences (to EJT) also provided funding.

Institutional Review Board Statement: This study was determined to be exempt from review by the University of Washington Institutional Review Board (ID 000206204).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The data presented in this article are not readily available as per the IRB because the interview transcripts include identifying information of the participants. Requests to access the datasets should be directed to the corresponding author.

Acknowledgments: Thank you to Lida Dimitropoulou, Jennifer Fong, Sandeep Gupta, Demis John, and Shangmou Xu.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design or execution of the study.

Distribution Statement A: Approved for public release. Distribution is unlimited.

Abbreviations

The following abbreviations are used in this manuscript:

SDT	Self-Determination Theory
STEM	Science, Technology, Engineering, and Mathematics
CHIPS	Creating Helpful Incentives to Produce Semiconductors
IEEE	Institute of Electrical and Electronics Engineers
PECVD	Plasma-Enhanced Chemical Vapor Deposition
DoW	Department of War
IRB	Institutional Review Board

Appendix A. Interview Questions

First, I would like to get to know you a little bit and learn about your high-level impressions of the program.

1. Why did you decide to participate in this particular program? In other words, there are always options for summer experiences—why did you choose this program?
2. What is the first word that comes to mind when you think about this program? This might be an impression or an emotion. Why did this word come to mind for you? Are there specific aspects of this program (or professor) that lead you to think of this word?
3. I am going to go through a list of words people might use to describe a program (or a class). Please share your experience of the program in relation to some of the words I will mention. What makes...
 - a. An educational experience enjoyable? Is this program enjoyable? Why or why not?
 - b. An experience valuable? Is this experience valuable? Why or why not?
 - c. An educational experience frustrating? Is this experience frustrating? Why or why not?
 - d. An educational experience anxiety-inducing? Does this program make you feel anxious? Why or why not?

Now, I would like to move on to some specific questions about goals of the program, some of these may feel like they are in reference to the professor/instructor of the experience.

4. This experience consists of a training program and an internship after that. My understanding is that the training program is divided into two parts: daily lecture and daily clean room experience. Could you walk us through a typical day in the two-week training experience and a typical day in your internship experience?
5. What do you think about the lecture? Do they help your learning?
6. What do you think the instructor's goals for this program are? In other words, what do you think the instructor(s) wants the class as a whole to achieve by the end of the program? How do you know? What are some things the instructor does to try to have the class achieve these goals?

7. What are your goals in this program? (Or what do you want to get out of this program?) Do you feel that the instructor is supportive of those goals? Why or why not? How do you know?
8. The clean room experience sounds like it could be a very authentic experience and one that not all engineering students will get to experience as undergrads. What makes an experience authentic?
 - a. Have you had any other authentic experiences at college? Job experiences? What made these experiences feel authentic? How do you know? Did this training program help you gain an authentic engineering experience? In what ways?
 - b. In what ways does the instructor message the authentic aspects of this program?
 - c. In what ways might this program help you: secure a job, gain admission to graduate school, obtain another internship, or complete your major?

Now, I would like to ask some questions about specific components of this program.

9. Are there specific aspects of this program that help you stay motivated/lead you to feel unmotivated?
10. Do you feel that this class is relevant to your life outside of class? Why or why not? What are some examples?
11. Are there things that the instructor does to make the relevance clear? What? And what kind of relevance do they message?
12. How do you assess how well you're doing in the program? For instance, can you describe a time you felt successful in this program? At this point in the program, do you have a sense of how well you're doing in this program or how you will do at the end?
13. If you feel like you need support or feedback to be successful in this program, who would you go to or what would you do?
14. Do you think you will continue on in your major or continue the next course in the major? Why or why not? Are there specific aspects of this class that have led to your decision?

Now, I am curious to know about how you or other students engage in this course.

15. Do you think students feel comfortable asking questions in this class? Why or why not? Can you think of an example about a specific time when you asked for help from the professor? Was this during class or outside of class?
16. Some people think that STEM, and engineering in particular, can be quite competitive. What is your experience in terms of competition among students?
 - a. Is there anything the professor does to encourage or discourage this behavior among students?
 - b. How does the level of competition in this program compare to other STEM and engineering classes you may have taken?
17. Do you think students generally feel comfortable interacting with other students in this program? Do you feel comfortable asking your classmates for help? Is there anything the professor does to encourage or discourage this behavior among students?
18. In your opinion, what makes an educational experience welcoming and inclusive?
19. Do you feel like you belong in this program? Why or why not?
20. Can you think of any examples of when you felt validated or invalidated by an experience you had in this class, specifically as it relates to your identity (e.g., race/ethnicity, class, gender)?

21. Now I invite you to think broadly regarding all aspects of this program. What advice would you give to a friend or relative interested in taking this class in terms of how to approach this program? Is there anything specific you would say about the instructor of this program?
22. Is there anything else that you would like to add or clarify based on what we talked about today?

Appendix B. Interview Coding Rubric

Table A1. Interview coding rubric. Overarching categories, nested codes, and full descriptions for coding the interview transcripts.

Code	Description
Category: SDT	Self-Determination Theory of motivation posits that students' three basic psychological needs must be met for them to meaningfully engage
Autonomy	Ways that the program supports (or hinders) students' ability to do tasks independently, self-direct and critique their work, or assess success
Competence	Ways that the program supports (or hinders) students' perceptions of their knowledge or skill attainment and confidence in a particular topic or task
Relatedness	Ways that the program supports (or hinders) students' sense of being affectively bonded to others, including peers and instructors
Category: Motivation	This category includes sources of motivation for students' participation in the Gateway program and its activities
Demotivating	Descriptions of elements that students found demotivating within the program or reasons they felt demotivated in the program
Category: Authenticity	This category includes students' definitions and descriptions of the authentic nature of the Gateway program
Similarity to real world jobs	Definition of authenticity that highlights that people in the electrical engineering industry are performing similar tasks
Transferable skills	Definition of authenticity that highlights that the skills and knowledge they are acquiring are transferable to different fields or settings
Interactions with peers and instructors	Definition of authenticity that highlights developing meaningful relationships or connections with coworkers and peers in a small-group, cohort-based learning environment

Appendix C. Additional Example Student Quotes

3.1.1. Similarity to engineering work

Student F: "We're actually in the cleanroom, and that's a level of, I guess, seriousness, we're seriously doing this. It's like, we're actually there, and we're actually learning relevant techniques."

3.1.2. Development of useful, transferable skills

Student H: "What makes an experience authentic? I guess just learning the specific skills that would traditionally be used in an actual cleanroom experience. So that could be learning the proper etiquette in terms of gowning, learning what you should do and what you shouldn't do in an actual cleanroom. And then of course, circling back to how to carefully deal with the samples, how to operate the machines. I mean, haven't seen an actual [industry] cleanroom working environment, but I'm pretty sure that the training I had aligns with that."

3.2.1. Gateway elements that supported autonomy

Student A: "If I mess up, do I know what to do to maybe clean up or do it over or fix my mistake? If I keep on making the same mistake, then it's obvious that

I didn't learn anything. It's just, am I doing better than I was comparatively to before? And also, do I feel more confident using [the] machine? Do I feel confident knowing how it works? And if I were to be given a task, would I be able to do it?"

3.2.3. Gateway elements that supported relatedness

Student D: "Within the group, I would say that we have a very good community. We started with seven undergrads, so I've become very close with the six of them. I feel like in our little group, I'm more than happy to reach out if I have any questions or help. And within our own little group, I do feel valued."

Student G: "I feel like they [the instructors] were very open and [...] very patient with if you did something wrong so I didn't feel judged whatsoever if I asked something wrong. I think the only preference of asking was just like, I don't want to take too much of their [the instructors'] time so if my question is sort of stupid or if it's just a process thing that I know the other cohort has done, I would ask another student, or if it's something more detailed, I would try to ask the instructor if they had a pocket of time."

Student E: "I don't think there's much anxiety in this program. I don't have an issue with it, honestly. Yeah. Because I think it also helps that my cohort, we're all really good together. It's actually a pretty nice group of people to hang around."

Notes

- ¹ Subsequent to the pilot described herein, Gateway has been redesigned as a one-week experience (prior to internship), and the stipend levels have changed. The curriculum is publicly available (<https://dreamsgold.org/resources/> (accessed on 3 November 2025)).
- ² The Gateway program is offered to undergraduates and specialized learners (e.g., adult learners), participants outside the traditional undergraduate population who are potential candidates for positions at the entry- or technician-level. The present work is limited to undergraduate Gateway participants.
- ³ PECVD is plasma-enhanced chemical vapor deposition, a typical cleanroom material processing technique.

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