



Events that Promote Engineering Students' Intrinsic Motivation to Learn

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Research based on Self Determination Theory (SDT) focuses on autonomy and competence as the most important psychological needs in fostering intrinsic motivation. Although relatedness, a third psychological need central to SDT, plays a role in motivation, its importance is often considered tertiary. This study seeks to describe what events changed students' motivational orientations toward learning in a second-year engineering course that was redesigned to promote students' sense of autonomy and how the three psychological needs of SDT affected those events. After completing the redesigned course, students were interviewed to gain an understanding of their experience through the semester. Interviews were coded to capture students' motivational orientation changes during the course and the psychological needs they mentioned in relation to their experience. The analysis of students' descriptions overwhelmingly pointed to relatedness as key to their motivational orientation in the course. Contrary to expectations based on the SDT literature, the analysis revealed a lesser importance of competence and autonomy. Students' statements were coded least frequently as pertaining to autonomy out of the three psychological needs of SDT, even though the course was specifically redesigned to support autonomy. Engineering educators should consider creating relatedness-supportive pedagogies and researchers should explore how the social context of large engineering courses may create a deep need for supporting relatedness.

Background and Motivation

Motivated students learn more and retain knowledge longer,¹ so how can instructors improve students' motivation to learn in their courses? Self Determination Theory (SDT) provides a theoretical framework of motivation that can be applied in a classroom context.² SDT asserts that a person's intrinsic motivation to learn can be fostered by meeting three psychological needs: autonomy, competence, and relatedness.² Autonomy refers to a sense that people control their own choices, and they can exercise their freedom of choice to proceed in whatever way they see as best. Competence refers to a sense that an individual has the knowledge and skills necessary to succeed. Relatedness refers to a sense of community, belongingness, and shared purpose in an individual's efforts. When all three of these needs are met in a particular context, an individual's motivational orientation in that context can move through a continuum of motivation toward internalizing that motivation until something intrinsic about the activity or context drives the individual.^{2,3} This same drive can theoretically be harnessed in an academic context to improve student learning.

We redesigned an electrical and computer engineering course for sophomore students to support students' autonomy and to facilitate improved student motivation. In our autonomy-supportive course redesign, students completed three autonomy-scaffolded design projects which replaced the midterm examinations in the traditional offerings of the course. Course lectures were taught according to each instructor's preferred teaching style. To build students' competence, discussion sessions led by teaching assistants (TAs) focused on collaborative solving of design problems. Further, the redesigned course included increased contact time outside of lecture and discussion with team-based meetings led by an instructor or TA to assist students with their projects and

homework. Following the precedent set by the SDT literature, our redesign focused on autonomy and competence as the most important psychological needs for improved student learning.^{4,5}

This study employs a thematic analysis of interviews with students to elucidate the student experience during this redesigned course. In particular, we focus on answering two research questions: 1) how do students' motivational orientations in a sophomore engineering course change in response to specific events in an autonomy-supportive classroom environment, and 2) how do students discuss motivational change with respect to the three psychological needs, autonomy, competence, and relatedness?

Context

To investigate the outcomes of redesigning a course to support students' autonomy, we chose Computer Engineering I as the context for our study. Computer Engineering I is a large course on digital logic and computer architecture course required for all second-year electrical and computer engineering (ECE) majors at a large public university. Each semester, the course enrolls over 200 students. Other universities across the United States offer similar courses.

Traditional offerings. In traditional offerings of Computer Engineering I, students attend two lectures taught by a professor and one discussion session out of eight taught by teaching assistants (TAs) each week. Several professors in the ECE department rotate through the role of primary instructor. Their teaching styles vary from entirely didactic lectures to lectures that include significant use of active learning techniques. TAs also rotate through the course and very few lead a discussion session for the same course over multiple semesters.

Course redesign. In this study, we analyze the outcomes of the redesign of Computer Engineering I that was offered in the fall of 2012. The Fall 2012 course provided students with autonomy through design projects and additional project-related contact time with instructors and TAs through *weekly consultation meetings*. During weekly consultation meetings, students met in teams of four to six students with an instructor or TA to discuss their written homework and design projects. This additional time with instructors and TAs was also intended to give students a safe space in which to gain competence with the autonomy provided with the design projects. Students completed three autonomy-scaffolded (that is, increased levels of autonomy for each successive project) design projects during the semester which replaced the midterm examinations of the traditional offerings of the course. The first project required students to design a multi-module combinational logic circuit. To provide students with autonomy, they could choose from a menu of options of partially specified projects such as calculators, number converters, message encoders, and password hackers. For the second project, students were required to demonstrate a sequential logic design. A few project options without specifications were suggested, but students were encouraged to generate their own project ideas based on their personal interests as they became more comfortable with their autonomy in the course. The third project provided the most autonomy, constraining only the context of the project: designing or modifying a computer architecture. This scaffolding of autonomy with progressively more autonomy throughout the semester allowed students to build competence with the course content and design process rather than overwhelming them with choices in the first week of the course.

Method

To better understand how this autonomy-supportive course design affected students' motivations to learn, we conducted post-course exit interviews. We analyzed the data from a constructivist perspective in which we treated each student's exposition as the constructed truth of their experience in the course.⁶ With our thematic approach,⁷ we sought commonalities among students' experiences in the Fall 2012 redesigned course and the events they highlighted as changing their motivational orientation toward learning the course material.

Data collection. Post-course exit interviews followed a semi-structured protocol focused on events that changed students' motivational orientations in the course and were designed to take between 45 and 60 minutes. An email solicitation requesting volunteers for interviews was sent to all 216 students who had completed the Fall 2012 redesigned course with the goal of sampling until saturation. No sample exclusion criteria were defined or applied. Seventeen students volunteered to be interviewed. No students who volunteered were rejected for an interview. All 17 interviews were audio recorded. Each student was compensated \$10 for volunteering their time.

Data analysis. The interview audio recordings were transcribed and analyzed with a skeletal a priori coding scheme, to comport with our goal of understanding the student experience from the student perspective informed by SDT. Three authors, who were not involved in teaching the course or grading student work, coded the interviews to ensure that no bias based on student performance or participation in the course would be introduced into the analysis.⁶ First, we individually coded the interview transcripts with a skeletal a priori coding scheme focused on how students discussed their sense of autonomy, relatedness, and competence² and when students exhibited any of four motivational orientations around their learning (described in SDT).⁸ This coding scheme included events that students discussed in their expositions as critical in changing their motivations. After several iterations and negotiations of our individual codes, we compiled a codebook. The codebook saturated after 10 interviews, but all 17 interviews were coded for completeness, and no additional interviews were conducted.

Trustworthiness. We followed three standard procedures to address trustworthiness in our data analysis and interpretation. First, during the interview analysis, three authors compared and discussed codes for each interview until we agreed unanimously on all codes to reduce individual variation in perceptions about students' statements. Second, after theme development, we conducted peer debriefing where we asked two peers with knowledge of the course redesign project and of relevant qualitative methods who were uninvolved in the study to debrief with us on our themes from the interviews. Through this process, we uncovered any interpretive leaps we made during theme development and further refined our themes. Third, we carried out member checking by sharing a complete draft of the manuscript with the interviewed students and asking whether it accurately reflected their experiences in the course. All students approved the presentation of their quotations and interpretations as accurately portraying their experiences in the course. No students requested any changes to the manuscript.

Limitations. Our study was limited to interviews with self-selected students at a large, public university in the Midwest. Because we did not reject any students and did not take a

random sample of the students in the course, a self-selection bias may have existed within the interviewed students. Our sample was representative of the gender distribution in the course, but the sample may have consisted only of students who simply desired \$10, who could travel conveniently to campus for the interview, who had strong opinions (positive or negative) about the course, or other unforeseen factors that could affect the results of the study.

Results

Of the three psychological needs identified by Self-Determination Theory (SDT), students discussed relatedness most often in their statements related to motivation changing events. Autonomy appeared approximately one-sixth as often as relatedness, contrary to the expected hierarchy of the psychological needs (autonomy, competence, and then relatedness). To provide perspective on the overall code frequency, Figure 1 displays the relative frequencies of relatedness, competence, and autonomy codes.

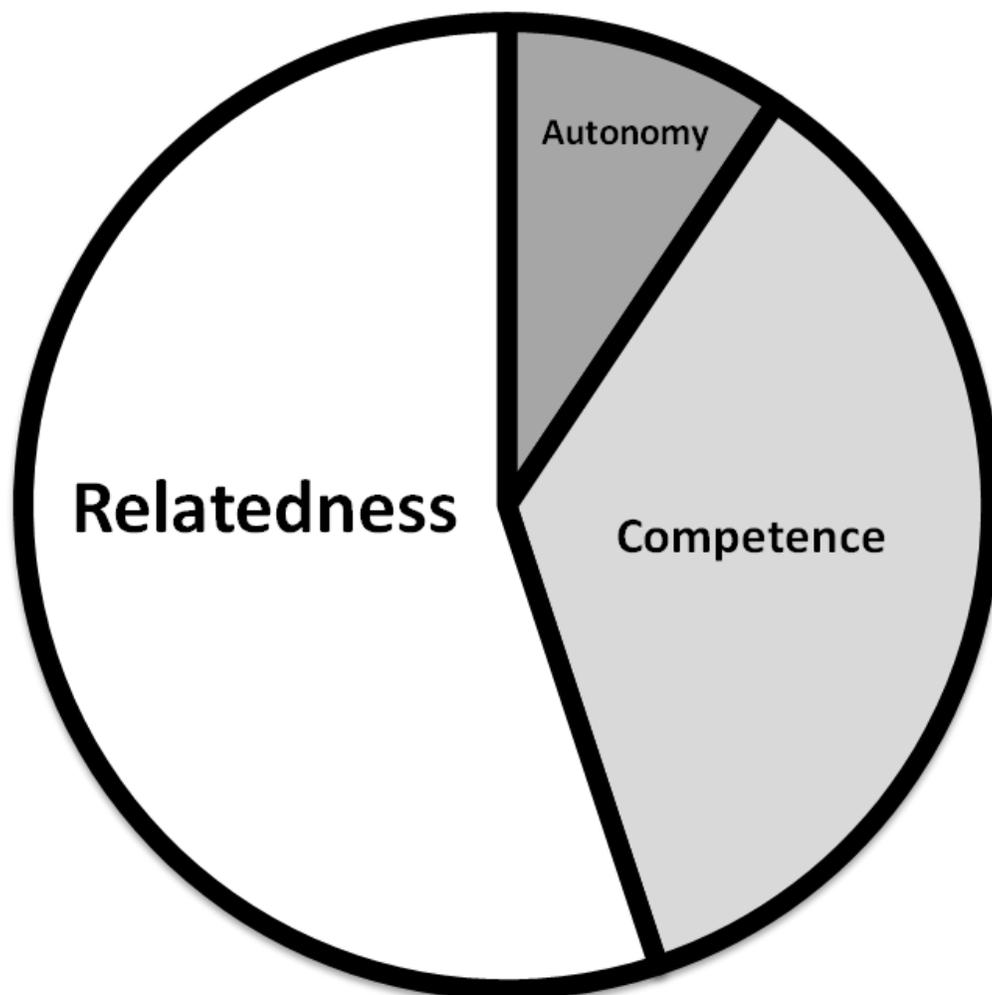


Figure 1. Graphical representation of autonomy, competence, and relatedness by frequency of code. Actual frequency counts of codes are as follows: 147 instances of relatedness, 95 instances of competence, and 25 instances of autonomy.

Three themes focused on motivation changing events emerged from the data: **projects versus exams**, **choice of teams**, and **course grading confusion**. To illustrate these themes and how relatedness affected students' motivational orientations, we present unaltered quotations from students' interviews. These quotations are presented in block text. Students were given number identifiers based on the order in which they participated in interviews.

Projects versus exams. Having the relatedness and extended duration of group projects instead of exams positively impacted students' sense of competence. Student 7 expressed how a sense of being part of something "bigger" as a member of a team resulted in better preparation for working in a real world environment.

I feel like the exams don't always necessarily test your knowledge or maybe the kind of knowledge that you would need in a work environment. I feel like working in a group and solving a bigger task is more beneficial in the long run than just being able to crank out twelve problems in an hour. - Student 7

Students 5 and 16 noted the difficulties with the time pressure of exams and expressed feeling as though they had learned more from the semester long projects than they would have from traditional exams.

I was actually surprised by how much I liked [the IM course conversion]. Especially the projects because I am not a great examiner. A lot of times I'll understand it, but on the exams I'll look at it and be like, "I think I know where I'm supposed to go with this" but I like to know I'm going in the right way before I start to doing stuff, and that hurts me on the exams. The projects themselves, as I was going through them it was really interesting being able to actually do the work and then see how it's working, modify it, and get help on the factual operation of what we were doing. Overall, I'm pretty sure I would have I liked this version much better than I would have liked the typical "write the stuff on the paper." - Student 5

Overall, if there was another project-based class like this, I would take it in a heartbeat and I'm sure it would fill up fast because people would go, "Oh, no exams, everyone wants that." And it's all based on the fact that the projects replace the exams in that the time you'd spend cramming, trying to learn something before a certain date, you spend over a couple weeks of time learning it at a slower pace, but you learn it in a more concrete way.... I do think it was a good exchange. - Student 16

Choice of teams. To provide autonomy, students were allowed to choose one person to work with on a team, their entire team if they created their own project, and whether or not they wanted to dissolve and reform teams after the first project. However, rather than note said autonomy, students focused on the sense of relatedness created in these chosen team situations.

Student 2 explained how choosing the entire team for a created project resulted in an increased sense of “trust” among team members.

Because we picked our own project, we got to pick our whole group. So we were already like a group of friends that, like, we kind of knew everybody would be into it and contribute. And we sort of had that trust going on. So, it worked out well. - Student 2

Student 13 chose *not* to choose any particular team member at the beginning of the course, but later chose specifically to “stick together” with the randomly assigned team because of the positive team environment they built over the semester.

I didn't know anyone in the class since all my friends had already taken it. So I just, I think you had the option of choosing one person to work with, but I didn't really know anyone, so I just didn't. I just had all these people put in the same group as me. So, that was kind of nice, just being introduced to new people and just having to work with new people.... We worked pretty well together so we just stayed together for all three projects, and there were six of us.... Everything worked out really well. That's why we decided to stick together because we worked well as a team. - Student 13

Course grading confusion. Because of the redesign of the course, students felt confused and intimidated by some of the structural elements of the pedagogy that were used to provide increased autonomy. Most notably, students found the course grading system to be a frightening new structure and desired a more solid understanding of the reasoning behind it. Student 8 discussed the grading system as “vague” and requested a “more concrete” system as something that would help alleviate concerns about the course redesign.

The first week we started our projects, I don't think the TA's were fully aware of the mark schemes or how to allot the points, so it was kind of vague, so the first week we were all trying to scramble and try to define what our project is. I feel that is part of [our] job, but we felt, “Where do we get our points from?” So it might have been better if the TA's knew from the professors that, “We want students to do this, this, this, if they exhibit this, this, this, then they get xyz points.” Some more concrete mark scheme or something. - Student 8

Student 15 expands on this concern with some specific examples of how the grading system, while designed to provide students with the autonomy to choose which assignments to complete, might have been detrimental to some students' sense of competence around the course material.

You didn't have to do all of [the assignments], which was kind of bizarre grading system in this whole class. *[laughs]* It was like some things you didn't have to do and some things you did.... Since you didn't have to do all [of the online quizzes], I saw that there were really hard ones this week so I was like, “Nmm, I'm just not going to do them. Because I don't have to do all of them, so these will be the ones I skip.” And then I didn't really learn that stuff. So, not that I want future people to have to have those all required, they should probably all count for something. Otherwise, there are things that I just didn't learn because some of the things looked a little too hard, and I was having a million other

assignments to do so that was lowest priority. Because you know it's not like your grade is ... 30% homework, 20% midterms, and 30% final, or whatever. You have like 5%, 5%, 5%, so nothing. You're like, "Well, I can scratch off a percent here. I don't need to do this because I don't need that percent." And it adds up because you just keep thinking they're all little pieces so they don't really matter. So, maybe having just a couple of things that you need to do to get your grade would probably be a lot better. - Student 15

Discussion

While prior research on student motivation for learning based on SDT has emphasized autonomy as the central need in promoting intrinsic motivation, our study surprisingly highlighted that relatedness was the central need in promoting students' intrinsic motivation in an electrical and computer engineering course, with competence also playing a large role. Because the importance of autonomy support for learning was established by studying how children learn,^{9,10,11} rather than how college students learn, we hypothesize that environmental differences may cause the variance in how students respond to the meeting of their autonomy, relatedness, and competence needs.

Given this difference in context and difference in findings, we argue that the centrality of autonomy support is not directly transferable to promoting engineering students' intrinsic motivation to learn at the college level. Rather, events that tap into students' senses of relatedness (such as learning through projects instead of exams and being able to choose teams to better build a community in the course) and competence (such as the extended durations of projects and more concrete course structures) may be more important than autonomy for students at the college level.

Conclusions

We conducted a study of an electrical and computer engineering course for second-year students; the course was designed to support intrinsic motivation by providing significant autonomy support. We found that relatedness was unexpectedly most salient to students, and their senses of relatedness and to a lesser extent competence defined their motivational changes in the course. This finding contradicts the generally accepted hierarchy of needs in SDT where autonomy and competence are thought to be more vital to motivation than relatedness.^{4,5,12,13,14} This contradictory observation highlights a gap in our understanding of the interdependence of the three needs.

More research is needed to elucidate how autonomy, competence, and relatedness interact in shaping an individual's motivational orientation situationally, contextually, and globally. We suggest two productive directions for future research: 1) qualitatively exploring the relative importance of the three psychological needs of SDT in a variety of learning contexts and 2) developing quantitative instruments that measure students' motivational orientations and felt needs in a course, particularly in contrast with the needs provided by their general learning context. This type of research can better inform teaching practice and its consideration of contextually-dependent principles versus more globally applicable ones.

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