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Fostering Motivation as a Class Objective in a Large Engineering Class for Second-Year Students: A Narrative Approach*

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Self Determination Theory (SDT) states that intrinsic motivation (IM) in a particular context is supported by increasing an individual's sense of autonomy, relatedness, and competence with respect to that context. When instructors use IM-supportive methods, they promote learning of class content. This research seeks to describe through narratives how students' motivation changes in response to a pedagogy designed with fostering intrinsic motivation as a primary class objective. After being observed in the classroom of an IM-supportive class conversion, students were interviewed to document their narratives. Interview transcripts were coded to describe students' motivational orientation throughout the class. The majority of interviewed students demonstrated increases in intrinsic motivation for studying the class content. The interviews revealed that individual choice, interpersonal relationships, and constructive failure were critical in moving students toward intrinsic motivation. While the IM-supportive learning environment did not affect all students equally, the common themes of individual choice, interpersonal relationships, and constructive failure provide deeper insights into how to improve and assess students' motivational changes in technical engineering classes.

Keywords: Self Determination Theory; intrinsic motivation; sophomore slump; class design; narrative inquiry

1. Introduction

As the demand for more engineering graduates remains high, retaining students within engineering majors has been maintained as a national objective in the United States [1]. The urgency of this demand has led to radical innovations in first-year engineering classes and programs to make engineering more inviting and inclusive across the nation [1]. Unfortunately, the emphasis on improving first-year experiences may be exacerbating the ''sophomore slump'' that many students experience as they leave the welcoming environment of first-year programming and enter the ''math-science death march'' in the second and third years, before they can again engage in profound engineering experiences in their final year design or capstone classes.

In academic settings, the sophomore slump has been defined as a ''period of developmental confusion'' in which students disengage from learning activities because of ''struggles with achieving competence, desiring autonomy, establishing identity, and developing purpose'' [2–4]. In the context of engineering education, the sophomore slump is seldom discussed. Few programmatic or instructional efforts offer to remedy it, despite the still present high attrition rates during the second year [1, 5–7].

The Low-Cost Intrinsic Motivation Course Conversion [8–9] is a pedagogical technique that was designed to improve students' motivation to learn in core second- or third-year engineering classes while minimizing the time and training required from faculty to make these meaningful changes in their classes. Given the critical importance of improving students' affective outcomes in the second year, we explore how a class that underwent a Low-Cost Intrinsic Motivation Course Conversion affected students' motivational orientations during the semester. In particular, we focus on answering the questions (1) what aspects of the class created positive shifts in students' motivational orientations toward an intrinsic motivation orientation and (2) how can faculty assess this shift in motivation as a method for evaluation of class design?

2. Background

An individual's motivation arises from human needs for autonomy, relatedness, and competence [10–11]. In an academic context, students feel competent when they master a body of knowledge, enjoy autonomy when they control their learning, and achieve relatedness when they belong to a community. Motivation ranges on a continuum from extrinsic (receiving rewards such as grades, complying with rules) to intrinsic (satisfying personal interests, deriving from the inherent value of an activity) [11].

Intrinsic motivation (IM) improves cognitive

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development within local factors such as the academic subject, the characteristics of the students, and the institutional context [12–15]. Both surveys of and interviews with students revealed that the strongest motivators to enter engineering were intrinsic, both psychological ("I enjoy engineering") and behavioral ("I like to fix things") [12, 16]. Motivation was positively correlated with persistence and the intention to complete the engineering degree. In engineering courses, active learning classes generally improve students' conceptual understandings, academic achievement, intrinsic motivation, and attitudes about the college experience [17–21]. Despite the importance of intrinsic motivation in learning, it seldom has served as the focal point of pedagogical change in engineering and engineering students' motivations become more extrinsic over time as a result [22].

With their emphasis on *autonomy-supportive pedagogies* [18, 23], Ryan and Deci explain that autonomy-supportive teachers spend more time listening, articulate fewer directives, ask more questions about what the student wants, verbalize fewer solutions to problems, make more empathetic statements, and offer greater support for students' internalization of learning goals [24]. Further, different learning environments are more or less conducive to an instructor's use of autonomy-supportive actions. For example, when K-12 teachers are led to focus on meeting national or state standards, they use fewer autonomy-supportive actions [25]. To effectively promote students' intrinsic motivation to learn, autonomy-supportive behaviors must be coupled with equally effective, well-defined class structures that guide student learning and support their psychological needs [26].

While existing SDT instruments assess students' perceived support for SDT constructs during specific tasks or generally toward academics, no current instrument specifically evaluates these SDT constructs in the context of a single class. Instruments such as the Learning Climate Questionnaire [29] are based on SDT, but they lack the resolution to evaluate specific factors and constructs. Other instruments such as the MUSIC Model of Academic Motivation Inventory focus on the class level but include factors not in SDT [30]. Because of these limitations, our study focuses on a qualitative understanding of students' motivation.

Although SDT is a proven research and class design framework for elementary and secondary schools, it is relatively untested for the design of the college classroom or the engineering classroom with their radically different social environments [23]. Further, the design of technical classes has historically focused on cognitive rather than affective outcomes [27–28]. Our research questions will provide understanding both into how SDT applies to the college engineering classroom and whether a class designed to improve motivation can be successful.

3. Class design

The IM-supportive class was designed with the goals of supporting students' sense of autonomy, relatedness, and competence, as described by SDT. Complete details of the class design and its positive impacts on cognitive outcomes are discussed in other publications [8–9], but a brief description of the class is provided as context for this study.

3.1 Student demographics

Computer Engineering I is a large enrollment (on the order of 200 students per semester), second-year, digital logic and computer architecture class required for all electrical and computer engineering majors at a large public institution in the Midwest United States (Midwestern University). Each week students attend two lectures taught by a professor and one discussion section out of eight taught by teaching assistants (TAs).

As part of a quasi-experiment in the Fall semester of 2011, two of the discussion sections (37 students) were converted to be experimental IM sections and were taught with IM-supportive pedagogies where students were given the autonomy to choose their learning activities. Because this was the first offering of the IM-converted sections, we allowed students to leave or enter the sections at their discretion. In order to account for students' freedom to leave or enter sections, we measured students' preparation and motivation at the start of the semester. These measurements suggest no discernible difference in student populations between the two types of sections [9].

3.2 IM-supportive pedagogy and class structure

To minimize faculty time and effort, we made the discussion sections the locus of change for the pedagogy. The professors delivered lectures as they normally would. The changes to the pedagogy were driven instead by the TAs in charge of the two IM-converted discussion sections. Within these IM-converted discussion sections, students were organized into learning teams (to promote students' sense of relatedness) based upon the students' stated purpose for taking Computer Engineering I. Each learning team had four or five students. During the semester, these learning teams negotiated a series of three purpose-based learning contracts with the TA. In these learning contracts, students were given autonomy over three elements of the class: (1) what elective topics they would study (topic selection), (2) how they would learn mandatory and elective topics (practice selection), and (3) how they would demonstrate their mastery of those topics (mastery selection). The TAs supported students' sense of competence by giving the students time to adjust to the autonomy in the course. Autonomy was scaffolded such that students had fewer choices at the start of the semester and more autonomy as the semester progressed.

Based on the prior research in primary and secondary schools, we designed the sections to focus on promoting students' autonomy and scaffolding students into progressively greater autonomy. On the first learning contracts, students were allowed to select topics, mastery, and practice options only from pre-approved lists. Students were given progressively more autonomy such that on the final learning contract students were allowed to choose whatever topics they wanted to study and practice those topics in whatever way seemed best. This final learning contract gave the students autonomy that was comparable to the autonomy that students might have in a senior design class, shown in Fig. 1. Increased levels of choice and autonomy in the experimental IM sections are highlighted in bold. The hypothetical level of autonomy in a senior design class is included for reference. Because of campus regulations, all students were required to take the same final examination (resulting in low autonomy at the end of the term).

4. Methods

We collected three types of data on students' motivation: motivation surveys (previously discussed in detail [9]), classroom observations, and post-class exit interviews. We analyzed the data from a constructivist perspective in which we treated students' narratives about their motivation as the constructed truth of their experience in the class [31]. We chose to conceptualize our study in the tradition of narrative inquiry [32] because it provides rich descriptions of the specific details and micro-events that affected students' motivation, though they may struggle to articulate their motivations. Our narrative inquiry into the student experience focused on a paradigmatic analysis in which we sought commonalities among students' narratives in terms of what class events most influenced their motivational orientations [33]. In the results section, we present composites of students' narratives through the use of crafted vignettes, which combine students' statements from surveys, interviews, and the researchers' classroom observations and field notes. The use of multiple data sources allowed for triangulation of our interpretations to bolster their trustworthiness, credibility, and dependability.

We also present unaltered quotations from students' interviews and trajectories of students' experiences throughout the class. Vignettes and unaltered quotations are presented in block quotations. Unaltered student quotations in the vignettes are presented in italics. All research was performed with the approval of the local Institutional Review Board (IRB Protocol #12046).

4.1 Classroom observations and interviews

Classroom observations and interviews were conducted with a primarily narrative eliciting design aimed at understanding the student experience and motivation throughout the class from their perspective. This emphasis on describing the student experience is tempered by the goal of understanding students' motivation in the classroom through the lens of Self Determination Theory (SDT). Consequently, our observations of student behaviors and our excerpts from interviews emphasize affective statements related to students' perceptions of their felt autonomy, relatedness, and competence. The results of these observations and interviews are

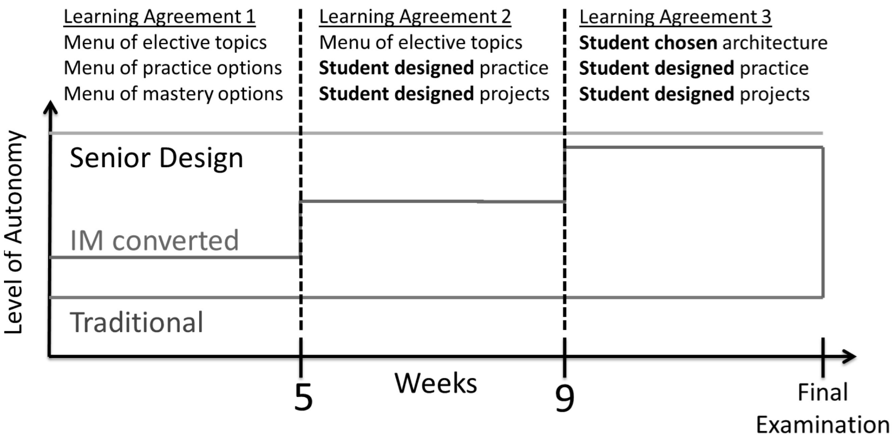

Fig. 1. Comparison of learning activities for the traditional and IM-converted sections.

reported by crafting vignettes that combine details from the observations with quotations from students' interviews. These vignettes are supplemented by additional quotations from the interviews as well as trajectories of students' motivational orientations derived from students' statements about their motivation during the semester. All names in the vignettes and quotations are pseudonyms for composite representations of students or TAs.

4.2 Classroom observation method

One author conducted observations of both the weekly IM-converted class sessions and students' presentations outside the classroom to capture life as it happened. The observation protocol was informed by *participant observation*, focusing on nine dimensions of observation: space, actors, activities, objects, acts, events, time, goals, and feelings [34–35]. Observations were recorded when unobtrusive on a tablet computer in Microsoft One Note with no a priori observation template. Observations began by recording space and object dimensions such as weather, room lighting, seating arrangements, and furniture. These observations were captured with sketches and handwritten notes. Students were the primary actors of interest and observations focused on recording their activities, acts, goals, and feelings and what time those observations occurred. Students' interactions with each other and their interactions as a team with the TA were a focus during observations. When possible, quotations from students were captured in the field notes, but no recordings devices were permitted in the classroom. Observations were constructed into a vertical time line of events to facilitate the construction of narratives. Immediately after observations, the observer expanded on field notes. When available, the observer debriefed with the TAs, asking them to expound on classroom interactions and add their perspective to the observations.

4.3 Interview method

We asked students to share their individual narratives through 45–60 minute exit interviews. Eight of the 37 students in the IM sections volunteered to be interviewed. Of the eight students, one was female and seven were male. They collectively represented six of the seven learning teams in the IM sections.

Building from a narrative tradition, interviews were structured to allow students to direct the focus and language of the interview [36]. To set the context of the interview, students were given an unmarked paper timeline of the semester. Students were given time to reflect on the previous semester and mark relevant events critical to their stories and motivation. After this period of reflection, the interviewer began the interview with a "grand tour" question to begin the students' narration [36]. As students told their stories, interviewers asked questions to better understand why certain events were critical to the narrative and what aspects of those events affected students' motivation throughout the semester. These follow-up questions were unstructured and prompted by the students' stories [36].

Interviews were recorded, transcribed, and then coded using a five step process [32–37]:

1. Three authors individually coded the interview transcripts with an open coding scheme to allow the student experience to emerge. The codes described students' motivational and affective statements with a particular emphasis on noting how students discussed their sense of autonomy, relatedness, and competence as well as what factors (extrinsic vs. intrinsic) mediated their motivation [10–11]. We also coded which events students discussed in their narratives as critical in shaping their motivations.
2. To improve trustworthiness, we discussed codes until we had a unanimous agreement on the inclusion and interpretation of each code. These codes were long and descriptive of the students' motivational orientations.
3. Thematic analysis of the codes revealed that students' motivations could be reduced to a set of four motivational codes. This reduced set of codes mapped to four of the motivational orientations described in SDT [38]: (1) no motivation or disengagement, which mapped to amotivation (AM); (2) motivation by grades or requirements, which mapped to external regulation (ER); (3) motivation by career or bettering oneself, which mapped to identified regulation (IR); and (4) motivation by learning, excitement, interest, or fun, which mapped to intrinsic motivation (IM).
4. We reduced our code set to the four motivational codes and looked for patterns across the interviews.
5. For each event students described, we quantized their motivation during that event by the frequency that their statements were coded as a particular motivation orientation. For example, if a student mentioned grades three times and their career seven times while discussing the second learning contract, we identified that student as motivated by a combination of external regulation (ER) and identified regulation (IR) and favoring IR. From these quantized motivational orientation points, we identified three distinct trajectories for student's journeys through the class.

Students' motivation during each event was quantized on a 13 point scale: (0) AM, (1) favoring AM and some ER, (2) even combination of AM and ER, (3) some AM and favoring ER, (4) ER, (5) favoring ER and some IR, (6) even combination of ER and IR, (7) some ER and favoring IR, (8) IR, (9) favoring IR and some IM, (10) even combination of IR and IM, (11) some IR and favoring IM, and (12) IM.

During the interviews, all students marked at least five events during the semester on their timelines: (1) prior to the first learning contract (Prior), (2) during the first learning contract (LC1), (3) during the second learning contract (LC2), (4) during the third learning contract (LC3), and (5) after the final examination (Final). Trajectories plot students' quantized motivation versus time sequence of common events. Trajectories from all eight students were clustered and averaged to create composite trajectories. Three composite trajectories are shown in Fig. 2 with a numerical identifier to facilitate discussion. These trajectories are further described in the results section.

Member checking was carried out 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 trajectories, vignettes, and presentation of their quotations as accurately portraying their experiences in the course. No students requested any changes to the manuscript.

5. Results

Coding of the interviews and creation of student motivation trajectories revealed three composite trajectories for students' motivational orientations. We present the three composite trajectories in Fig. 2: (1) students progressing from a combination of ER and IR to a combination of IR and IM, (2) students progressing from a combination of IR and IM to full IM, and (3) a student slightly progressing from a combination of AM and ER to ER.

After experiencing the IM-supportive class conversion, students in all three trajectories expressed shifts in their motivational orientations toward IM. We focus on the experience of the trajectory (1) students because they experienced the greatest changes in motivational orientation. Their motivation changes provide greater insight into how IM-supportive pedagogies can affect students' motivations in technical engineering classes than the relatively flat trajectories of their peers. While we focus on these students, we will also supply evidence and quotations from trajectories (2) and (3) to support and critique our interpretations.

5.1 Trajectory (1): Progressing from a combination of ER and IR to a combination of IR and IM

We describe the experience of students whose motivational orientations shifted from a combination of ER and IR to a combination of IR and IM. The vignettes and quotations are organized by the events that the students identified as important.

Vignette 5.1.1 Prior to the first learning contract and during the first learning contract

The classroom was hot and clammy with the occasional breeze from the window. With its whitewashed walls, dusty chalkboards, and hard blue plastic chairs with hinged half desktops, the room seemed designed to make Jaime uncomfortable. The ancient overhead projector sitting in the center of the classroom as the lone piece of instructional technology seemed ironic for a class titled Computer Engineering I. As Jaime's classmates wandered into the room, the TA stood at

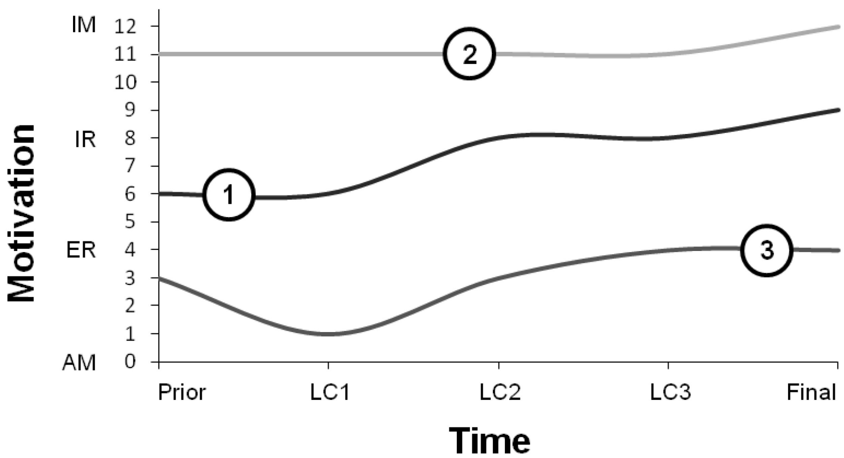

Fig. 2. Trajectories of student motivation throughout the class. Trajectories (1) and (2) are composites of multiple similar students. Prior refers to prior to Learning Contract 1. LC1, LC2, and LC3 refer to Learning Contracts 1, 2, and 3 respectively. Final refers to after the final examination.

a table at the front of the classroom flipping through a pile of papers.

The bell rang at 2 p.m., and the TA introduced himself. "Hey everyone, my name is Andy. I'm your TA this semester. We have an exciting opportunity for you in this section of the class, as it is one of the experimental sections of Computer Engineering I."

Experimental?! What are we, guinea pigs? Jaime's mind raced with questions.

The TA continued, "In this section, we will be giving you choices over how, why, what, and when you learn. You will be working in learning teams, and your team will get to shape the class to your personal goals and interests. For example, if you don't want to do the written problem sets, you can choose to replace them with a different activity that helps you better practice the class material."

Oh, crap, I'm never gonna do any work! When I get a group, I have to tell them the first thing we need to do is to do all the homework. If we don't do the homework . . . I won't learn anything if I don't. Jaime fretted.

"If you don't want to take the exams, tell us what you want to replace them with," the TA continued, "something that demonstrates your mastery of the material, like a project. If you decide you don't want to learn one topic, you can suggest replacing it with a different one."

Alex interrupted, "It seems that we will get lower grades simply because we're in the experimental section."

Sam continued, "Yeah, I really don't want to mess up my basics. This is a prerequisite for so many other classes, and I don't want to screw up my GPA."

"I can guarantee that we won't 'mess up your basics,' because the topics that are listed as essential are the basics. So as long as you make sure you learn the essentials, you should be fine and you won't need to worry about your grades." The TA responded.

"Can you at least tell us which are the easiest activities that will help us get an A?" Alex pleaded.

During interviews, students described their initial response to the class structure with a mixture of external regulation and identified regulation statements:

> . . . this is going to be something that can save our grades because we do care about grades {ER} and we think this is something new that we want to learn this way as long as we can accomplish everything {IR}.
>
> . . . I don't particularly like [the requirements of] academia {ER}. . . I'd like to go work and design things {IR} . . .

Students with these motivational orientations chose options that they thought would give them the highest chance for a good grade. One team chose to do a no-partial-credit group examination, reasoning that working as a team bettered their chances of good grades. Other teams chose to write examination problems, an option they admitted they chose because they thought that it "was the easiest thing [they] could do."

Vignette 5.1.2 Between the first and second learning contracts

Alex sat on the tile floor outside the professor's office trying to anxiously pass the time as other teammates petitioned their grades. Hearing the click of the office door, Alex quickly looked up from the cell phone.

"So what did the professor say?"

"Bad news, he agreed with the TA and isn't going to change our grades."

"Seriously?! What are we going to do then? Doesn't seem like we can change his mind."

"*Should we drop out of this section?*"

"Even if we change sections, we're still stuck with a D for the first mastery option."

"*We thought this option would be easy, but it turns out we all just got bad grades.*"

"I need to finish this class this semester though*, we shouldn't just give up*."

"We could try one of the project options. We'd probably *get more out of the [class]*."

"Yeah! It'd be great if we could design something that works well like my friend Pat's team did last time. It'd be more practical and interesting than writing exam questions."

Most students who chose these easy options experienced unexpected failure upon completing the first mastery component of the class. The team that chose to do the no-partial-credit group examination received a C grade (below average) on the examination. A team that wrote examination problems received a D grade (near failing). As described in the vignette, this team petitioned the professor to overturn their grades. Students described identified regulation or intrinsic motivation when discussing this event:

> . . . the end of the first learning contract, we got stuck because we got very low grades. . . {ER} we were very upset and we were thinking, 'Should we drop out of this section or not?' But then we kind of came out of that. *We shouldn't just give up*. . . {IM} (emphasis added)
>
> But after the first one when we were designing the questions, we decided to do a design thing more, to *get more out of the [class]* {IR} . . . The project aspect, trying to design something that really works well {IM}. To design things that work efficiently as much as a student [in the class] could probably do {IM}. (emphasis added)

Vignette 5.1.3 During the second and third learning contracts

Jaime returned to the basement computer lab of the engineering library where the rest of the learning team has been working diligently on their project, "Hey, did you realize it's already midnight?"

Alex replied with a hint of surprise, "We've been here for six hours? Doesn't seem like it."

"I think we should call it a night and meet back here tomorrow," said Sam.

Jaime nodded, "Yeah. I think we got some good work done and I could use some sleep. It was fun tonight. Same time tomorrow?"

The team began to pack their bags as they made plans for when to meet again.

"Sam, it's pouring rain outside. Did you need a ride home?" Alex asked.

"That would be great! Thanks!"

During this event, students described the importance of their teams and how they enjoyed working with them. Students focused on small actions such as getting rides home or eating dinner together as significant events in improving their relatedness and motivation. This sense of relatedness was often described in contrast to negative situations. Further, these statements of relatedness were often coupled with IM statements, emphasizing accomplishment and enjoyment.

> . . . we did a project as our learning assessment thing, which in retrospect I think we should have done for all three. . ..We had a good group. I think we stayed on task a lot. I think the first project was also very indicative of our ability to work. We split up work evenly, everyone got their work done and then we all got together and put our parts together. The only problem was when you're transferring . . . [CAD] files to one computer, it pulls files from other things, libraries that are specific to your computer so then . . . we all sat there and we're trying to figure out what was going on, so I think that was a good team building thing even though it kind of stunk.
>
> . . . on the day we were going to show the whole thing. . . we came together and each explained each individual part, how it works, how many gates and everything. Then . . . the TA, who's actually grades us, said, "Well, it's pretty good." So we feel good. Yeah, a great product. But we feel good, why? Because we actually made something. Instead of solving some problem [online] or score grades on the exams, we actually make something. . . *In our sophomore year we feel good, right, and we are pretty inspired by this.* (emphasis added)

For the third learning contract, these students were required to demonstrate their mastery and understanding of any computer architecture. Some students found this requirement too restrictive to match with their desired modes of learning, while the previous two learning contracts had dealt with more general concepts and allowed for more freedom of choice around the application of the projects.

> . . . we feel like, I think this experimental section was supposed to be what we *chose* to learn instead of what we *were told* to learn. . .number three they just told us, "This is what you are going to do." (emphasis added)
>
> So if learning contract three is something similar to two, or we make an advanced version of number two, we will feel way more motivated than making a new architecture.

When asked to reflect on their overall experience in the class, students' statements primarily indicated an orientation toward an intrinsic motivation to learn. They expressed desires to be "free to learn" and to learn and work on problems that were personally meaningful or exciting.

> I mean, if [the class] is a lot easier, we [will] . . . save a lot of time, we [will] go to bars, it would be fun, but I also think that after [we're] done with [the class] . . . the working process, the learning process is something we really appreciate. [We're] actually more excited about . . . [working] together to get it done instead of . . . just [getting] it done, so it's the process [we're] excited about.
>
> . . . I think instead of grading strictly based on what you accomplished, what you missed, you actually focus on "this is how we learned" . . . So really make it free, for us, [so] that we know . . . everything we did wrong is not gonna affect us that bad. We know . . . everything we accomplished is not gonna affect us that bad either. So *we wanna know we are free to learn. . .* (emphasis added)

5.2 Trajectory (2): Students progressing from a combination of IR and IM to IM

We describe the experience of students whose motivational orientations began as a combination of IR and IM and moved toward IM.

Vignette 5.2.1 Prior to the first learning contract and during the first learning contract

After announcing the design of the experimental section, the TA formed the learning teams and directed the teams to meet in different corners of the room. Pat's team haphazardly arranged their desks into a jagged oval and began chatting. The TA approached Pat's team first.

"So we can literally do whatever we want for this learning contract?" Pat blurted.

"As long as it helps you learn the basic material and demonstrates that you understand combinational logic circuits," the TA responded.

"Then we definitely need to do a project. I want to make something."

"Me too! What if we did a game like Simon™, Snake, or tic-tac-toe?"

"Or we could build something useful like a stop watch, logic equation solver circuit, or . . ."

"Ha! It would be like we did 'circuitception' where our circuit could design other circuits!"

"That'd be awesome!"

"Or how about we design a calculator with buttons and display?"

"What if we just designed our own architecture?"

"Definitely!"

During the interviews, these students emphasized the importance of experiencing relatedness to their teammates and having a shared communal purpose.

> It was still collaborative but everyone was doing their own part and it all came together at the end, which was cool. Seeing their ideas, their thoughts, what they learned, it was really exciting. One of the biggest things was the three of us were really excited to learn and that made it exciting.

Vignette 5.2.2 During the second learning contract

> "To be honest, I'm somewhat disappointed with what you guys delivered this learning contract," the TA explained. "After your first learning contract, I was so impressed and had high hopes for what you were going to do this time, but this project was at best a minor extension on your previous work."
>
> "I mean, you're right," Pat responded. "We slacked a little this time and don't deserve an A for our work on this project."

After their initial success, the team relaxed in their efforts to learn and delivered poor work. In response to their failures and a lack of motivation on the second learning contract, the student and his teammates revealed a deeper level of intrinsic motivation to learn during their third learning contract.

Vignette 5.2.3 During the third learning contract

> "One last question, what are the advantages and disadvantages of your architecture's pipeline?" the TA asked.
>
> It was 10 p.m. on a Friday night as Pat began his reply. The smell of Papa Jimmy's Pizza and garlic butter still lingered in the air. Pat's teammates alternatively sat on lab tables or chairs as the team logo remained displayed on the projector. The team had found an open lab space with a projector around noon and had camped out there all day to make sure they had a place to give their final presentations. Pat answered by giving three advantages and disadvantages to the pipeline design as the rest of the team nodded and smiled.
>
> "Wow!" the TA paused, "That was some advanced material. Just out of curiosity, what resources did you use to learn that?"
>
> "Well, I started with books, something I thought I would never do. They helped a little, but then I started attending the lectures of [a senior level class]. They just happened to be covering that material when I needed it. I liked that they were discussing ×86 processors, because everything made so much more sense once I understood how architectures work and are built in real life."

These students came out of the class with a sense of accomplishment and enthusiasm for the class, not only saying that they would take a similar class again, but also wishing that all classes followed the same structure.

> . . . we were presenting the third project the TA really spoke highly of how much we learned. It was really. . . I can go learn things now. On top of that he was like, "This is real life. You guys are touching at stuff you would have to go to jobs to find out." *We . . . did it because we wanted to.* That was really rewarding, not just the grade." (emphasis added)

5.3 Trajectory (3): Student began as a combination of AM and ER and progressed only slightly

We describe the experience of one student whose motivational orientation began as a combination of AM and ER and changed only slightly.

Vignette 5.3.1 Prior to the first learning contract

> "So the instructions say to think about why you want to learn the class material. So what are your goals for taking Computer Engineering I?"
>
> "*Honestly, I have no idea. . .*"
>
> "Me neither, I don't get what we're supposed to do with this thing. I like that it sounds like we don't have to take tests or do the homework."
>
> *"Yeah, but what would be the easiest option?"*

Unlike the students who transitioned from EM/IR or IM/IR, this student received an excellent grade on the first learning contract, despite low levels of effort and low identification with the material.

> I'd say I did almost no work for the first learning contract and neither did anybody else in the group and from that standpoint it went pretty well.

With continued success, motivational orientation stayed the same.

> . . . during this time I was doing stuff for a [student organization], which took up a lot of my time, so, again the whole "try to do as little as possible" thing really entered in there. . . So from the end of the second learning contract, throughout the entire third learning contract I did absolutely no work towards [the class] and neither did anybody else in my group.

This student left the class with a similar perspective to the beginning, focusing on grades and the ease with which high grades could be obtained.

> If their goal is to get a good grade in the [class], then yeah just do what we did, but I mean if your goal is to actually learn about the material I wouldn't advise taking the experimental section, or at least not the format we had. . . I had friends who actually took the real [class] and they learned much more about the architecture than anybody in the experimental section did.

However, after reflecting on the class, the student recognized a missed opportunity by taking the easy way out and highlighted projects as possibly worthwhile experiences.

> I think it would have been cool to do a project. I think, I know one of the other groups tried to make a calculator I think, for one of the first two projects and it sounded like that would have been kind of fun.

6. Discussion

Students' narratives revealed three experiences that shifted their motivational orientations: (1) perceived support of autonomy, (2) relatedness with teammates or instructors, and (3) responses to success or failure.

6.1 Autonomy and relatedness support shift motivation

As expected from SDT, students described autonomy support as critical to their intrinsic motivations to learn. The centrality of autonomy was most poignantly revealed in how trajectory (1) and trajectory (2) students revealed different perceptions of the third learning contract. The trajectory (2) students perceived the third learning contract as fully supportive of their autonomy as was intended by the class design, but the trajectory (1) students perceived the third learning contract as being restrictive (''[learning contract three] was supposed to be what we *chose* to learn instead of what we *were told* to learn''). The classroom observations and prior research on the TA's teaching journals [39] reveal that one TA had labeled these trajectory (1) students as ''bad students'' because of their early attempts to get easy A grades. The TA had developed a lack of trust in these students and adopted controlling behaviors toward them. In contrast, the TA trusted the trajectory (2) students and adopted autonomy-supportive behaviors. This difference in the TA's trust highlights how controlling behaviors can undermine even the most autonomy-supportive class structures in promoting students' intrinsic motivations.

Students with trajectories (1) and (2) frequently discussed team interactions and described how the team developed stronger relationships through difficulties and struggles. In contrast, the trajectory (3) student (Kelly) rarely discussed relationships with teammates. Kelly's disconnect with classmates was further revealed through the assertion that no teammates did any work in the class. Observation records indicate Kelly's own teammates explored topics well beyond the scope of the class. Similarly, Kelly surmised that other students were jostling to get into the IM-converted sections to get better grades, but only one student asked to switch into the IM-converted sections. Remarkably, that student completed a complex and difficult project, extending well beyond the scope of the required material, further revealing Kelly's disconnect with classmates.

6.2 Responses to success and failure shift motivation

Students described successes and failures as central to their shifts in motivation. Most trajectory (1) and (2) students described moments of crisis when their lack of effort or motivation led to failures. These failures caused dramatic shifts toward intrinsic motivation and increased effort. In contrast, one trajectory (2) student and Kelly described constant success throughout the class. Neither described dramatic shifts in motivation or increased effort. These observations diverge from SDT in that shifts toward intrinsic motivation depended less on the fulfillment of psychological needs and more on specific events such as failure.

One possible avenue to interpret this divergence is to look at alternative theories such as Attribution Theory to explain the change. The three-dimensional model of attribution suggests that when a student's causal attributions of a success or failure are stable, internal to an individual, and controllable, such as a student's own decisions, that student will identify more with their behavior and be more motivated to change it in the face of failure [40]. In other words, students with a strong sense of autonomy who experience failure are more likely to change their motivation and behaviors. While the class's general autonomy supportiveness provided the environment for the shift to intrinsic motivation to occur, the students' productive failures created the impetus for the shift.

Alternatively, an interpretation focused on relatedness may be equally compelling. After experiencing failure, students described specific interactions with their teammates or the TAs that coincided with the shift in their motivation. For trajectory (1) students, the team resolution to persevere created a deeper sense of relatedness that led to change. For trajectory (2) students, the team responded to the disappointment of the TA. The stress of failure on these students' relationships may have been the impetus for the shift in motivation. The students who experienced continued success did not describe moments of deeper relatedness with teammates or TAs.

6.3 Exploring a new motivational construct: Trust

The prominence of both autonomy and relatedness in our students' narratives suggests future research into a construct of *trust* as the mechanism for shifts in students' intrinsic motivation. To give students autonomy, the instructor must trust the students with their own learning. For students to embrace that autonomy, students must experience and internalize that trust. This trust in turn fosters relatedness. Further, if students trust the instructors' guidance, failures become safe events for positive growth rather than fearful events with negative consequences.

From a faculty development perspective, a construct of trust may also be useful for engaging faculty in the process of incorporating principles of SDT in their classrooms. Faculty often fear offering students autonomy or find the concept of relatedness to be too ethereal to be useful [24–25]. Changing the dialogue to an exchange of trust may provide different language for engaging faculty in the change process of becoming more supportive of students' intrinsic motivations to learn.

7. Conclusions

We provide conclusions for each of our research questions.

7.1 Research question 1: What aspects of the class created positive shifts in students' motivational orientations toward an intrinsic motivation orientation?

As expected from SDT, when class structures met students' psychological needs such as autonomy and relatedness, they shifted students' toward intrinsic motivation. SDT is a productive framework for the design of classes in engineering, providing one means for combating sophomore slump at low cost. Contrary to SDT, however, critical incidents such as failure may be equally important for creating or catalyzing these shifts. Future research about a new *Trust* construct may be useful in fully understanding this dynamic.

7.2 Research question 2: How can faculty assess this shift in motivation as a method of evaluation for class design?

Our analysis revealed that measurement of students' perceived support of their autonomy and relatedness within a class can provide a basis for evaluating class designs. To facilitate this process of evaluation, a new instrument scoped for measuring student motivation in a class based on the psychological needs of SDT should be constructed.

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