



Moving from Quantitative to Qualitative Analysis to Capture the Development of Self-Directed Learning for a Cohort of Engineering Students

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Abstract

This mixed-methods study investigated college students' self-directed learning (SDL) skills, attitudes, and beliefs over time, beginning with the start of their first year and continuing to the beginning of their fourth year. Validated quantitative surveys were utilized to compare two cohorts of engineering students at different institutions over the first two years. While some differences in the quantitative survey data were measured between the institutions, there were small changes in SDL competencies. During the middle of the second year, focus groups with a subset of the cohort were introduced into the study with the large public university. Qualitative data were collected via seven focus group sessions and through open-ended questions from online surveys over time.

The qualitative data revealed several interesting new aspects to self-directed learner growth and led to a richer picture of the complexity involved in student SDL development. The results are organized around four themes that emerged from our analysis: conceptions of SDL, growth towards SDL, learning vs. grades, and identity as a student to a professional. We document the changes associated with SDL over time for our cohort, and witness developments occurring in various ways at different times among the students.

Background

As part of a NSF TUES grant, a team of researchers sought to understand and describe the development of self-directed learning (SDL) of engineering students over the first two years of college. A cohort of students from a small private college and a cohort from a large public university were to be studied using quantitative survey data and qualitative open-ended questions. Quantitative data on SDL competencies were gathered from validated surveys, such as the Academic Motivations Scale (AMS), Metacognitive Awareness Inventory (MAI), and Learning Orientation Grade Orientation (LOGO II).

The ultimate goal for investigating the development of self-directed learning is to foster lifelong learning for students' well being in the long run. Being aware of one's self and the choices one makes with regard to learning goals and processes are thought to be valuable beyond the work place. Understanding when and how one develops SDL might assist instructors tailor courses and their interactions with students.

As this paper will reveal, despite having a well thought-out research plan, the results were somewhat unexpected in their lack of substantive measured changes in SDL outcomes, and additional measures were taken to better understand student development of SDL. The most significant course of action on our part was to extend the study beyond the 2nd year, and to incorporate more qualitative measures, namely focus groups^{1,2,3}.

Quantitative Survey Results (Years 1 and 2)

While some significant differences in the quantitative survey data were measured between the two institutions, the resulting data showed surprisingly small changes in SDL competencies over the first two years of college⁴. Figure 1 displays the learning and grade orientations (LOGO) attitudes and behaviors at four different points in time over two years for the two different institutions. Additional quantitative surveys, such as the AMS and MAI also did not show significant differences over the two-year span for the large public university.

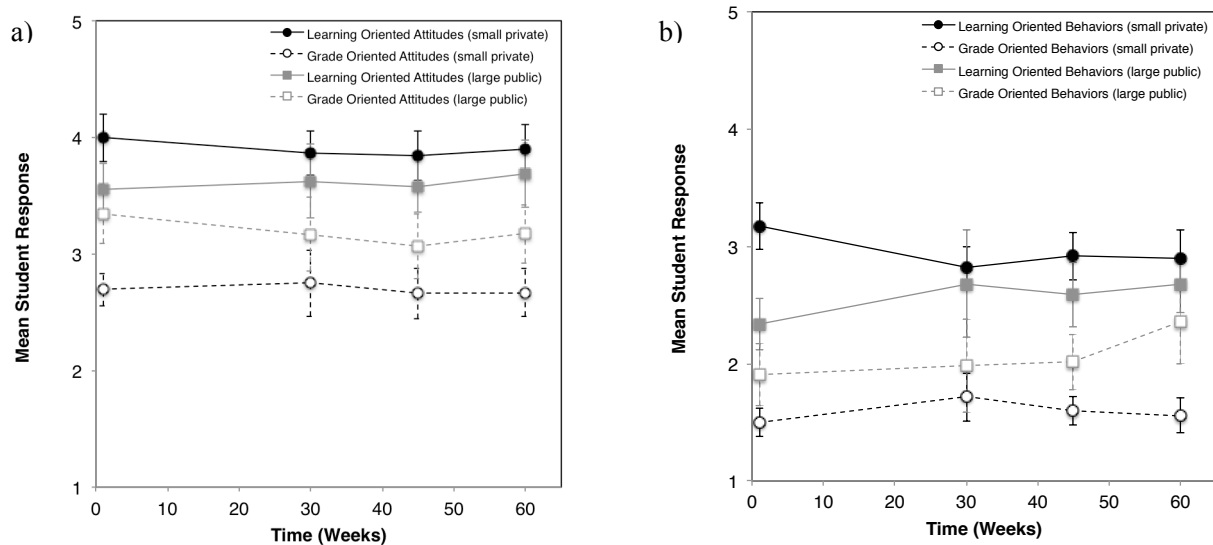


Figure 1. a) Learning Oriented and Grade Oriented *attitudes* and b) Learning Oriented and Grade Oriented *behaviors* over time for engineering students at two different institutions⁴. Error bars show 95% CI.

Employing Focus Groups for Additional Qualitative Data (Years 2-4)

Around mid-point of the 2nd year, we realized that the quantitative survey data might not be fully capturing the developments of the students. We decided to employ focus groups to probe more deeply the attitudes and beliefs of the students in a more interactive group setting. The goal of the focus groups was to provide an empirically grounded complement to the quantitative measures of SDL. Would results inform any substantive and useful comparison of the SDL preparation of students at a large public and smaller private engineering department? Were the surveys sufficient to capture a more fully informed picture of how students were developing as self-directed learners? Would we have a more complete understanding of how SDL is cultivated?

Qualitative investigation was extended into the fourth year for the large public university cohort. Analysis of the transcribed focus groups produced some insights and many questions, including how self-direction could be defined in multiple ways and measured across time as an unstable characteristic, given to transient and episodic experiences of self-awareness and doubt, reflection and quasi-reflection⁵. The ongoing processes of self-assessment and reflection provided repeated opportunities to reveal how students viewed self-direction, when they appeared to practice it, and what and who impeded its practice in relation to their academic, career, and life goals⁶.

Focus Group Research Design

Semi-structured interview questions and topics were developed, and the focus group moderator provided prompts to the students. Dialog was recorded and then transcribed. Due to the extra effort required to attend a focus group discussion (vs. filling out an online survey on one's own time), volunteers were requested, and lunch and a small stipend was provided for each focus group participant. The focus groups garnered the students most engaged with the project and willing to continue. There had been a steady decline of students participating in the study surveys over the first year (starting with 31), but a core set of approximately 12 students remained engaged throughout the course of the study.

The focus group data were collected in seven discrete meetings over a period of three academic years (Table 1), and included a total of 14 individual students (4 female and 10 males), each who participated in at least two focus groups. The participating students were attending full time, although some were also working, and one of the focus groups consisted entirely of community college transfer students. Focus groups met for approximately one hour.

Table I. Focus group dates and participants with gender breakdown

Group #	Date	Quarter, Year	# students	# Female	# Male
1	03-07-2013	Winter, 2 nd	9	2	7
2	04-09-2013	Spring, 2 nd	5	2	3
3	04-11-2013		4	1	3
4	04-16-2013		4	1	3
5	05-09-2014	Spring, 3 rd	7	3	4
6	11-21-2014	Fall, 4 th	4	1	3
7	12-05-2014		4	2	2

Emergent Themes from the Qualitative Analysis (Years 1-4)

Written responses from online open-ended survey questions and transcripts of the focus group dialogs provided a wealth of data. Figure 2 displays the timeline of when different measurements were taken over a span of almost four years. (The cohort is currently in the middle of their senior year.)

We were able to identify four (4) major themes for further analysis: definitions of SDL, growth towards SDL, grades vs. learning, and identity from student to professional. Each of these themes is discussed below and excerpts from the online survey responses and focus group transcripts are provided to demonstrate the changes over time.

Definition of Self-Directed Learning (SDL)

While we had working definitions of self-directed learning⁷, we purposefully did not give our definition to students. We sought to investigate their conception of what “self-directed learning” was, and we also realized that our own conceptions of SDL were evolving throughout the course of this study.



Figure 2. Timeline of when LOGO II, open-ended online survey questions, and focus groups were administered over almost 4 years in time for a cohort of engineering students.

Students were asked to define what self-directed learning was through online surveys (SurveyMonkey and Moodle) each year for their first 3 years, and asked indirectly through the focus groups. Table 2 displays a progression of what many students thought was SDL. At the start of their freshmen year, students equated SDL with being a good student who gets good grades. Their definitions focused on the teacher delivering knowledge and learning. Self-motivation and even brute force determination to study were associated with SDL. Such responses can be related to the pre-college experiences for most of the students, where instruction is structured, their roles as learners might be passive, and motivation might be external. Their definitions of SDL at the start of college are quite uniform and short for the entire cohort.

In years 2 and 3, students associate responsibility for learning with themselves, rather than solely with the instructors. Some students begin to view SDL in terms of their own interests and learning. The range of responses becomes wider as different individuals state different ideas of what self-directed learning is and how SDL might be demonstrated. We see that students create their own meaning, and their conceptions often overlap with our working definition of SDL but might not be as encompassing. SDL begins to show up as choices that students might have, in terms of not only *what* to learn but also *how*.

Defining SDL became an ongoing process as the research unfolded and as the students progressed in the curriculum. They began defining the instantiation of SDL practices by the ways they interpreted varying instructional models. For example, when students assumed instruction would include traditional, formalized lecture followed by tasks that allowed for practice of skills, and then the expectation was not met, students responded with a sense of abandonment, as if they had been unable to proceed with learning by self-direction⁸. They responded as if they had no direction, shifting their locus of control entirely back on the instructor, assuming no responsibility for their own learning and an apparent unwillingness to examine their positions.

Table 2. Students' definitions of self-directed learning across time

Date, method	Open-ended responses to the definition of Self-Directed Learning
F, 1 st yr Oct. 2011 Survey	<p><i>It is a test of self-discipline and you get as much out as you put in</i></p> <p><i>I would define that as going to class, learning, then go home and re teach it to yourself as well as going beyond.</i></p>
S, 2 nd yr May 2012 Survey	<p><i>The idea of self-directed learning is to encourage broader thinking and deeper inquiry in approaching a problem. It has its moments to be sure, but its very nature makes is oftentimes cumbersome and sometimes inefficient if given the various other demands many students must deal with.</i></p> <p><i>Learning based entirely on ones own drive to learn... personal desire to learn more about a topic.</i></p> <p><i>... learning based on your own wants and desires rather than some outside force making you learn. This could probably just be summarized as intrinsic motivation.</i></p> <p><i>... learning unconditionally about what you're interested in. This would just be for yourself, not for any other purpose in the moment in which you're learning about what you're interested in.</i></p>
S, 3 rd yr May 2014 focus group	<p><i>..it's like OK, here's a project you have to do on [given topic]. That's it. And so, pick what you want to study, how you want to study it, get it done in this approximate time frame and demonstrate that you've learned something.</i></p> <p><i>I kind of feel like self directed learning is kind of like you're being given a piece of paper, and you have to make it into a paper airplane and get it to the target. You're the one throwing the airplane and making it, but the teachers or coaches, as they call themselves sometimes, are kind of like the wind that directs the plane in the right direction.</i></p> <p><i>giving students a prompt and then you have to decide where they're going to get their information, and how much information they're going to get.</i></p>
S, 3 rd yr May 2013 Survey	<p><i>I am the one to decide to learn about something, and direct my inquiry</i></p> <p><i>Learning for yourself and to feel the joy of discovering something new that does not have to be for a job or career.</i></p> <p><i>...the responsibility falls to the student to learn what they deem necessary or relevant regarding the subject. This could include consultation of the professor for help in understanding the information that is found, but the motivation itself comes from a more intrinsic source, whether that be a sense of curiosity or responsibility.</i></p>
F, 4 th yr Nov 21 2014 focus group	<p><i>For my senior project, I picked something that I'm really interested in, but I don't know a lot about. I'm doing a project on molecular modeling. ... The problem that I'm having is that no one currently in our department knows pretty much anything about computer modeling. We have an alumni who's at UC San Diego, so he's been helping me figure out how to model, and how to do all this, but pretty much everything I've learned has been self-directed.</i></p> <p><i>Actually wanting to do the work rather than trying to get a grade</i></p>
F, 4 th yr Dec 5 2014 focus group	<p><i>the perfect amount of structure ..., as well as a solid balance and room for you to branch out into your own interests and branch out into your own projects...</i></p> <p><i>...a lot of self-directed learning, but it's also structured too, which is nice. It's structured...like due dates when things need to get done, but how you go about accomplishing that is completely up to you. So there's structure and no structure...a nice balance.</i></p>

By the beginning of their 4th year, SDL is a more normal learning mode for some students. They see themselves directing their choice of senior project and advisor, as well as what they are doing. Being self-motivated and doing the work is still apparent in their conceptions of SDL.

Students recognize that they need structure, such as due dates and milestones, (self or supervisor-imposed) are needed for them to stay on track and on the right path. There also appears to be comfort in working on an independent project.

Signs of Growth towards Self-Directed Learners

While we started with the premise that indicators of SDL included: self-regulation, help seeking strategies, internal motivation, managing time and effort, setting own learning goals, etc., we began to isolate self-awareness and reflective capacity as being the important feature as the study progressed. For changes to occur in an individual, an awareness of *what* and *why*, in context of their experiences seemed to be an important feature. Table 3 chronologically captures some of the student responses from the open-ended survey questions and the focus groups that demonstrate their ability to reflect and other SDL behaviors. Some of the prompts asked to provide and explain a time in which they demonstrated self-directed learning, or to describe their development towards SDL.

Table 3. Student responses over time related to self-directed learning behaviors

Date, method	Open-ended responses related to being self-directed (e.g., reflecting, goal setting, internal motivation)
W, 1 st yr Feb. 2012 Survey	<i>College is optional. All of this freedom forces us to be self directed unlike high school where everything is set up for us.</i> <i>Students have to be more self directed in college because the teachers are less interested in directing their students as in high school.</i> <i>The freedom and self direction of college is a double edged sword. The amount of freedom is liberating and teaches us how to survive on our own; however this also means that we must be completely self motivated to complete our own work when non one is here to prod us.</i>
F, 2 nd yr Sept 2012 Survey	<i>I have discovered the importance of learning. I never tried going out of my way to learn about things that could be potentially interesting before I tried it. ...I found that if I had enough motivation to learn something or get something done, I could really do it. Now I try to look more at what I can use what I'm learning in the future instead of grudgingly trying to get through each class.</i> <i>As I entered college, I perceived myself as a strong self-directed learner, however as I reflect back on it I fell like I hadn't fully realized what self-directed is, not would I fully know now, but I have learned more.</i>
F, 2 nd yr Nov. 2012 Survey	<i>Answering these questions are the only times I really think about it.</i> <i>Partially this study, because it makes me think.</i>
S, 2 nd yr April 2013 focus group	<i>Like when I go on academic probation ... like what is wrong ... why am I doing this ... and it's like ... it forces you to analyze, re-analyze, and over analyze, and see what's going on, and then it helps you to make better decisions, spend your free time better, like dedicate more time to school ... find that balance ... I definitely think that most of my learning takes place in what I do in my own decisions and what I do in my free time and mistakes that I make.</i> <i>It's just like coming into college and having been pushed more by parents and teachers and stuff and having to shift more to self-guided sort of motivation was sort of difficult for me and it hasn't gotten that much easier, but I'm starting to get the hang of it.</i>

<p>S, 2nd yr April 2013 focus group</p>	<p><i>I think it's a lot healthier to work on something you have a passion for, rather than what someone else is telling you to do. And I think it's much more rewarding in really all ways to do something like that.</i></p> <p><i>I feel like I've had a lot of these thoughts just floating around in my head. And then actually having to talk about them, really plants them into place and cements them as in oh, I can actually think really deeply about myself now.</i></p>
<p>S, 3rd yr May 2013 Survey</p>	<p><i>I had to find many resources to gain a better understanding on this topic. I used text books from the library, internet websites, youtube videos, and journal articles to find the information I needed.</i></p> <p><i>I had to contact people from another department in order to find out more about...</i></p>
<p>S, 3rd yr May 2014 focus group</p>	<p><i>... it really helped when it came to the self directed stuff. I knew, I kinda knew how much depth I wanted to go into a topic.</i></p> <p><i>That's one of the biggest life lessons that we've learned is that it's OK to fail. ... We needed like the knowledge that if we failed, it wouldn't be the end of the world. ... But since we knew that like as long as we were giving it an honest effort that would like... that's all that really mattered. So we decided we wanted to do something new and exciting, and yep, that's how that happened. We've learned so much new stuff, because other stuff we can just learn in a textbook, but doing the new lab work stuff, that's where we learn new stuff.</i></p>
<p>F, 4th yr Dec 2014 focus group</p>	<p><i>I feel confident that if I'm given an assignment where I need to learn something, then I could do it. I can teach myself what I need to know.</i></p> <p><i>I think we've slowly reached a maturity level where we understand what we want to learn, and we understand what we need to learn, and where we want to go in life, and paths we need to take in order to get there</i></p>

Students first view their actions in response to what instructors assign or what societal norms there are. Assessment of how well they are doing is in the eyes of the instructor or external judges, rather than being able to self-assess. The freshmen equate SDL with “freedom” and completing work. One must be self-motivated (internal or external) to do the work when required, and thus the self-direction is about “choice” of doing the work or not (i.e., procrastinating). In later years, students begin to demonstrate SDL in terms of questioning the worth or value of certain assignments and deciding for themselves if or how much effort to put in. Students also begin to see themselves as “in control” of their learning and development. Choice now includes topics for assignments or projects, teammates, and even project goals. Ability to reflect develops alongside autonomy and ownership, and sometimes the surveys or focus groups themselves act as an “interventions” that enable students to reflect on their development towards self-directed learning.

While many factors play a role in the development of SDL, time not surprisingly seems to be a factor. Entering freshmen carry with them expectations from their K-12 experiences and that repeated exposure to more open-ended and less structured activities allows growth towards SDL.

By the junior year, students display many more indicators of SDL, such as seeking out desired information from other professors, establishing project topics and taking ownership, and an acceptance of “failure” as part of the learning process. The shift towards comfort with ambiguity and “failure” is noticeable. Over time some students begin to choose their topics based upon their personal interests, rather than based upon their need to perform with high grades.

In addition, third year students are very purposeful in their choices of how they spend their time including time in extra-curricula activities. Students make constant, calculated decisions about which courses to take, what instructor or advisor to select, and how much time to spend on courses in context of their own goals (both short term and long term). For many, getting the highest grades possible is typically not the most significant driver or measure of success. Although grades still play a significant role, getting relevant experiences such as internships and experiencing college life are important for students. Especially prominent by the senior year, students are well aware of what they want to get out of college. Students are somewhat aware of their life needs and career goals by seeing themselves beyond college. The students are indeed taking responsibility for their own learning, and a shift from external to internal motivation is detected, even though such a shift is not being picked up by the quantitative measures.

Grades vs. Learning

Students' relations to grades were some of the most interesting aspects of this study. Given their K-12 experiences and the significance of grades in getting accepted into college, freshmen often view grades as an external motivator. Gaining knowledge and building expertise – learning oriented achievement goals – seem to be missing from their responses. Students also revealed how much of a stressor grades can be, and how upsetting it is to receive a grade that did not reflect how much time they spent studying for a particular course.

Students lamented the way that open-ended work offered opportunities for professional growth but did not always positively impact their grades. Over time, more and more students begin to report how their learning becomes more important to them (Table 4). Students begin to be able to differentiate between a grade in a course and what they learned or may have gotten out of a course.

When students began to assume responsibility for their learning and made learning central to their enterprise, they worried less about due dates, homework, and missing assignments. They had learned in one class their sophomore year, about the inverse relationship between learning and a concern with grades. Focus on learning meant that they would be doing just that, and grades would take care of themselves. While some students wrote explicitly about how meaningful that lesson was for them, others persisted in a belief that their learning was compromised by external factors such as time, social constraints, motivation, and the differences between high school and college.

Some students reported that by senior year, their GPAs were not moved much by a single grade, so opting to focus on learning had a bigger pay-off than focusing on getting a higher grade. Other students found satisfaction in the completion of challenging projects, where the return on investment was in learning rather than in the grade. These reports followed students' summer work experiences where they successfully met industry demands to complete projects independently and in a timely manner. Students' concluded that learning from the internship took precedence over grades because it reflected authentic work experiences, where performance was not only expected, but valued.

Learning also took on broader significance such as social meaning and independent thinking. One student described studying with a student others had avoided during their first years of teamwork, and learned how much she had come to appreciate about his knowledge and skills. Their individual stances on grade orientation shifted to more learning-centered orientations with time and experience.

Table 4. Student responses over time related to Grades and Learning

Date, method	Open-ended responses related to grades and learning
<p>S, 2nd yr April 2013 focus group</p>	<p><i>It's always nice to get a good grade, but when you have something completed, and you feel like you've learned it, then that's really motivating to me</i></p> <p><i>I wish I could say that I got as much motivation out of completing something than as getting a good grade cuz that would be the intrinsic motivation... but when schools are looking at your application for graduate school, the first thing they look at is your GPA... Sure you might be better off intrinsically, but extrinsically, you're worse off. So it's kind of a weird ... Sometimes it's almost like a tug of war with a pulley in the middle where sometimes they're both pulling in the same direction, and sometimes they're kind of pulling against each other. It's kind of weird. I wish I could say that I was completely intrinsically motivated but the reality of the world is that you can't be, which is unfortunate</i></p> <p><i>The way I looked at it was I'd rather spend more time on my [major] classes to make sure that get an <u>A</u> in that class than have to bother putting in the extra effort to try and get an <u>A</u> in this econ class I don't care about</i></p> <p><i>grades motivate me a lot. ... If I get an <u>A</u> in a class, I think, well, I've worked hard for this and it's something I can show like my parents and they can be proud of me</i></p> <p><i>...in high school and things before, I was like ... yeah, I can do this, these assignments, this work that I'm given, but, I mean, I don't care. I can do it, but it doesn't mean anything to me. And um, coming to college, it's gotten to the point where like it can mean something to me. ... it's definitely helped me a lot actually learning to appreciate and cherish what I'm taking in right now.</i></p> <p><i>when you don't have to worry about failing, you're so much more apt to want to learn and like just interested in what you're learning when you don't have to worry about grades.</i></p> <p><i>you do enough to get a good grade and you really don't need to do more than that ... depending on the class, I mean obviously if it's a major class where I feel I'm actually benefiting more from what's going on, then I can put more effort into that</i></p>
<p>S, 3rd yr May 2013 Survey</p>	<p><i>My motivation for learning has changed from being grades oriented to learning for knowledge's sake and learning more to help people.</i></p> <p><i>I was more concerned about grades than actually learning the material.... Now as a third year, I am more excited to learn... I will even look up information this is not required for the class. I actually want to know and deeply understand what I am learning about.</i></p>

<p>F, 4th yr Nov/Dec 2014 focus group</p>	<p><i>In a lot of our more difficult classes, especially last year in our junior series, which is considered by just about everyone to be our hardest classes, I was finding that I didn't have the motivation to get a good grade because I just wanted to learn the material because the material was interesting, and I thought it would be useful from a technical sense. So once I learned something, I didn't put in a lot of extra effort...like the extra push...for like the <u>A</u> or the <u>B</u>. I was happy with a <u>C</u>. I was glad to be learning, and my priorities were elsewhere. I didn't really care what grade I got because I was learning so much.</i></p> <p><i>But for me, I knew that my skill level, for what I wanted to achieve, for what I could explain to someone...this is what I learned....then that was more important than saying, I got this great grade, but I don't know what's going on.</i></p> <p><i>What about this do I actually want to keep in my head? What about it is important? Am I going to have to explain this to someone when they see it on my resume? Things like that become infinitely more important than a letter on a paper.</i></p> <p><i>It starts to feel really pretentious when you start looking only at those grades and those numbers, not really looking at the people behind them. ... I say pretentious because it's like it's become institutional, it's become kind of a tradition that you get judged on your GPA.</i></p> <p><i>...this year, I feel like grades are not as important anymore. Like I'm next quarter, I'm not gonna work [part-time job], and I've signed myself up for more units. I feel like I just wanna take as many classes as I can manage in the last year that I have in school. And if I get <u>Cs</u> in those classes because I have a lot on my plate, that's OK, as long as I learn a lot. ... I just want to take classes that are relevant to the field that I wanna get into when I graduate. I want to learn enough to impress whoever I get employed by.</i></p> <p><i>...my evolution from that thought of, I wanna good grade to I wanna learn, because to be completely honest, before I just wanted my paper so I could get out ... and I think that the largest aid in that evolution was the fact that I took classes, got <u>As</u> in those classes and didn't learn a thing. And then I took classes, got <u>Cs</u> in those classes and learned a ton. So, that's kind of the biggest factor for me in my transition from wanting a letter grade to learning</i></p>
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Some reported tensions stemming from the need to maintain appropriate grade point averages (GPAs) to avoid academic probation and make themselves eligible for future pursuits, such as graduate school. Thus, while students may not hold as much value to their grades vs. their own learning, they are aware that they must still maintain a certain GPA.

Interestingly, the quantitative survey to measure learning and grade orientations (LOGO II) did not vary much over time. Figure 3 shows the collective average for a subset of the 10 students who were most engaged in this study (i.e., those in the focus groups). Thus this “sub-cohort” was asked to take the LOGO survey a total of 5 times over nearly a 4-year span. It was somewhat surprising that attitudes and behaviors for learning and grades remained somewhat stable with time. Even when examining individual changes for a student (rather than the cohort averages), there were only minor fluctuations over time, and those slight changes were not even in any detectable or consistent pattern. Thus while students’ views on grades changed over time with the qualitative measures, the quantitative measure was unable to detect such changes.

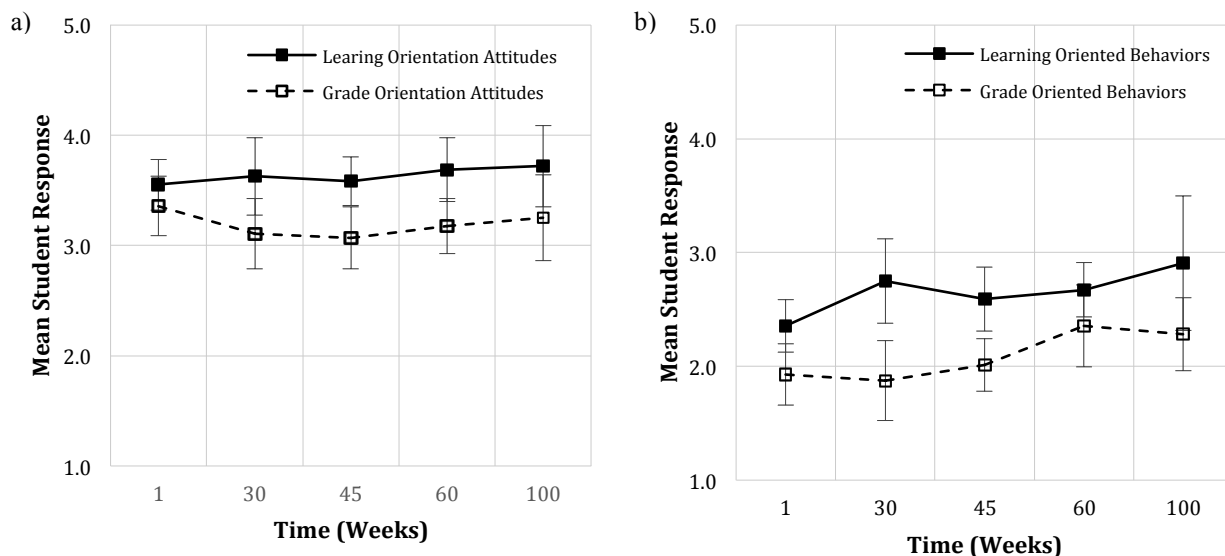


Figure 3. a) Learning Oriented and Grade Oriented *attitudes* and b) Learning Oriented and Grade Oriented *behaviors* over nearly 4 years for the smaller cohort of engineering students at the large public university. Error bars show 95% CI.

It may be that the students interpret the LOGO survey questions differently each time such that it results in similar results, or students stay consistent in how they answer the LOGO survey questions even while expressing different views through the qualitative measures. The fact that students demonstrating high levels of SDL in years 3 and 4 still recognize that grades are important to others may have contributed to the consistency of the LOGO results. However, the reasons for the importance of grades have shifted from internal validation to external requirements for their goals after college. In addition, the focus groups are situation-based (i.e., specific stories of different events) while the LOGO-II survey prompts are highly generalized contextual-level.

Identity as a Student to a Professional

Identity of the students emerged as another common theme from our study. How students identified themselves was related to their attitudes and behaviors. During the early years of college, students identified themselves as college students who follow a set curriculum of courses and are left on their own to manage their time⁹. Identity as a student and professional engineer is highly influenced by the institutional culture. The emphasis on practical knowledge, demonstrated skills, and getting internships bore out in the focus groups. We found that some factors, like internships and club activities, can have a profound effect on their SDL development by providing motivation to learn on their own¹⁰.

As students matured and began to make connections related to “professional identities” in contrast to their “student identities,” more characteristics of SDL became evident. Consequently, time appeared to be influential features in the development and display of SDL.

By senior year, students are realizing and providing their own definition of “success,” which could be considered a result of their own self-directed learning to be able to state their own personal goals rather than accepting society’s or someone else’s vision of “success.” Sometimes this realization can also be paralyzing, in that no one is telling them what to do next.

Seniors are also viewing life beyond college and adopt more of a professional identity; yet they also want to get the most out of taking courses that are available to them now. Grades have even less importance, and getting a job or getting into graduate school have become the prime motivators. Students are very much “self directing” their learning at this point – deciding what they want to learn (e.g., taking courses of their interest and not required) and how much time and effort to put into their required courses.

Table 5. Student responses over time related to identity as student and professional

Date, method	Open-ended responses related to identity as student and engineering professional
S, 1 st yr April 2012 Survey	<i>I feel that college changes people immensely, and seeing other people change, I have started to look at how I have changed since I arrives, and how I relate to my school work through these challenges.</i>
F, 2 nd yr Sept 2012 Survey	<i>I feel motivated to merely make my life what I want it to be and not fall to any trap or insect-like lifestyle.</i>
W, 2 nd yr March 2013 focus group	<i>I see it [school] as getting more skills so that I can go to job fairs or interviews and talk about my experiences and how I would be able to apply those skills to a real job.</i> <i>My high school teacher said electrical engineers make the most money, so I went into that. Engineers Without Borders helped me see things differently. ... I no longer see engineering as just a way to make money, but now I see it as a way to help people.</i>
S, 2 nd yr April 2013 focus group	<i>I'm more interested in finding internships, and things that are gonna prepare me for a career, rather than, obviously I'm gonna finish school, but I've got my eye on more after school</i> <i>I started out in construction management so I'd have a professional degree, and I was originally only going to finish my bachelor's degree and then go out and work in the work force.</i>
S, 3 rd yr May 2013 Survey	<i>Having a lot of open ended assignments has allowed me to try and figure out what my own interests are and give meaning to the information I do find rather than feeling like I need to learn the materials solely because the teacher says I should.</i>
S, 3 rd yr May 2014 focus group	<i>there's so much pressure to be like successful to get an internship, but I feel like everyone's version of success is different. ... I know that whatever I do in my future, I want to be happy with what I'm doing and passionate about what I'm doing and not just make a bunch of money and be miserable.</i> <i>I'm learning so much that I wanna be there instead of being like how fast can we get this done. I think like that's the biggest change I've seen in myself and all of my friends. All I hear is more about doing our best, instead of doing the project.</i>
F, 4 th yr Dec 2014 focus group	<i>I think the most important thing learning is...is figuring out what knowledge you want to put in your head, to reach the level of success or lifestyle that you want to live. ... In the end, it's like learn what you need to, to do the things you want.</i> <i>I had an internship this summer, and I was given a project ... I was totally successful with the project. So that was like the proof and the reassurance I needed to know that I am capable of solving problems in the workplace.</i>

<p><i>I think in this department, we talk a lot about life-long learning, and over the summer, I feel like the internship that I had over the summer was like having an office job, where I sat at a desk, from 8-5 everyday, and did paperwork, and stuff. It was a good learning experience, but it made me realize that for my career, I want to find something where I can continue to learn new things everyday, and every year have new projects to tackle, and I think that's part of the reason that I've stayed in college, that I just like learning. And I'm realizing that you can do that outside of college too, if you pick the right career.</i></p>
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Conclusions

The combination of quantitative and qualitative assessment over time to study the development of self-directed learning of a cohort of engineering students has produced several emergent themes and additional questions. Reflection appeared to be an important component of SDL that emerged across time. Three reflection frameworks appear useful to the analysis. They include Dewey¹¹: “they might serve as we improvise, revise, and create new ways of deriving meaning from experience – thinking to learn.”; VanManen¹² includes recognizing underlying and contradictory assumptions as well as various forms knowledge may take; and Schon¹³ expected that reflectivity included reframing problems. Each theorist contributed an angle on reflection that added both definition and dimension to the ubiquitous term.

Identifying self-directed learning and assessing SDL are not the same. As our collaborators’ findings revealed in their analysis of quantitative measures published in a separate paper¹, surveys from the well-tested field of motivation and learning do not adequately capture the subtleties and idiosyncratic features of SDL that appeared throughout the findings of the qualitative studies. In addition to learning what did not work to the satisfaction of the research team, expanded methods and more appropriate measures of SDL are needed.

We found that focus groups were beneficial to our study, but also required much more work. The focus groups revealed the dynamic of students reflecting with one another and forming their own individual academic and professional identities. Peer interaction within the focus group discussions provided much richer contexts to develop ideas in what students actually think (vs. concise survey responses). Students reveal their individual identities through their focus group discussions, and we got to know them as individuals (e.g., with families, part time jobs, hobbies/passions, worries, etc.). The richness of the focus group data revealed that the previous quantitative surveys do not give us a very complete picture. In discussions over time, details emerge, providing examples that reveal their maturity and changes in beliefs^{14,15,16}. For example, in the 3rd and 4th year focus groups, participants came wanting to share their experiences in specific courses, internships, and projects! The focus groups themselves seemed to provide the sort of atmosphere that asked them to engage the same sort of reflective capacity that accelerated development in self-direction requires.

In this paper, we concentrated on four themes that emerged for our data, but we cannot generalize our findings to all engineering students at different institutions. We believe patterns for SDL development would be common, and in the future, we hope to report on the role of instructors, course structure, and curriculum in order to inform the design and implementation of effective learning opportunities that encourage development of self-directed learning in college.

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