Investigating the ways in which Student Agency develops through Engagement with Knowledge

Nicole Pitterson
Engineering Education
Virginia Tech
Blacksburg, VA, USA
npitters@vt.edu

Jennifer Case[1]
Engineering Education
Virginia Tech
Blacksburg, VA. USA
jencase@vt.edu

Ashish Agrawal
Engineering Education
Virginia Tech
Blacksburg, VA, USA
ashishag@vt.edu

Indhira Hasbun
Engineering Education
Virginia Tech
Blacksburg, VA. USA
imhasbun@vt.edu

Abstract—**This Work in Progress paper reports on preliminary work in a new longitudinal project which tracks engineering students as they progress through four years of their undergraduate degree. It focuses specifically on students' engagement with disciplinary and professional knowledge, in domains of basic science, engineering science, and engineering design. The project centers on annual in-depth interviews that will be conducted with students recruited from the first year in a selected engineering program (Chemical Engineering) at two selected US bachelors' institutions: one a rural-based public land grant research university, and the other an urban public research university with a more diverse student intake. To highlight the distinctive features of the ways in which engineering graduates are formed, the project tracks in parallel a sample of students from a closely related science program (Chemistry/Biochemistry). The first year of data collection in this project is completed, and this paper will provide early reflections on the research design, specifically the ways in which student interview data can be used to show development of agency through engagement with knowledge.**

Keywords—student agency, disciplinary knowledge, engineering formation, knowledge engagement

I. INTRODUCTION

For engineers, similar to other professionals, expertise is often determined by the development and demonstration of domain specific knowledge [1]. To this end, engineering learning environments and curricula are designed to ensure that students acquire core knowledge in a coherent manner. It is thus crucial that current discussions around curriculum reform are able to draw on research that can show in detail how engagement with knowledge, which is at the core of the curriculum, is central in the formation of student agency, notwithstanding the significance of other broader aspects of the curriculum. The project builds on a broader international higher education literature that characterizes student development in sociological terms, and thus the term 'agency' is used to characterize the ways students develop personally through engagement with knowledge. While there has been substantial research in engineering education about the development of engineering identity as it relates to students' diverse background and experiences, there is a lack of research that investigates identity formation through engagement with the core academic curriculum [2]. The project also dovetails into a unique opportunity presented by an existing international collaborative research project that tracks engineering and science students in the United Kingdom and South Africa, using this same research protocol [blinded]. Tracking US students in this project has the potential to provide international comparisons for US engineering education.

In this paper we focus on the core methodological challenge in this study, which is to identify and track the emergence of student agency through engagement with knowledge, as seen in student interviews.

II. PERSPECTIVES FROM THE LITERATURE

Engineering education research had an early focus on students' acquisition of conceptual knowledge [3]. Researchers often concluded that students can pass formal assessments but not necessarily grasp the underlying conceptual structure of a discipline [4], [5]. This can be related to the approaches to learning that are fostered in a teaching environment, and thus research also explored teaching environments that can foster deep approaches to learning. Engineering education research has also tracked skills development, most especially in the broad domain of problem solving, and linked to work more specifically in engineering design. Several works have documented the need for learning environments that allow students to engage deeply with engineering knowledge in the context of ill-structured problems, real-life contexts, etc. [6]–[8].

A breadth of research has also focused on the design of the engineering curriculum [9]–[11]. From standardized criteria determined by ABET to the core body of knowledge and personal attributes all future engineers are expected to possess, the engineering curriculum has received considerable attention. Current debates have centered on the move towards outcomes-based accreditation systems, which have required curricula to be much more explicit in assuring the development and assessment of learning outcomes. A significant aspect of this debate is on the role of problem-solving and project work in the curriculum, and whether variants of problem-based learning are best suited to the engineering curriculum [7], [12], [13].

[1] Honorary professor, University of Cape Town, SA.

978-1-5386-1174-6/18/$31.00 ©2018 IEEE

While we applaud these important developments to expand the more hands-on aspects of the engineering curriculum, we are concerned that the role of knowledge in the curriculum is being slightly under-played and could leave us with a curriculum with a hollowed-out core. A truly integrated curriculum requires of students a good grasp of core disciplinary knowledge and is able to build knowledge development into the broader professional development of the student [14]. This is more, not less, important in times of rapid knowledge growth, since identifying the core aspects of the curriculum for development of engineering 'ways of thinking' will be crucial in making decisions about selection of new knowledge for the curriculum. Consequently, there is a growing need for studies that explore the unique relationship between the acquisition of disciplinary conceptual knowledge and the development of an engineering identity.

This work is centered on exploring how students develop an identity within their discipline, characterized here in terms of agency, as they engage with disciplinary knowledge. The intent of this work is to demonstrate the transformative power of knowledge: as students are exposed to concepts within their discipline their individual perception of what it means to be an engineer and what engineers do, is likely to develop. Finally, the focus on Chemistry/Biochemistry and Chemical Engineering for this study is also deliberate. As both disciplines derive their roots from very similar bodies of scientific knowledge, it allows for a comparative understanding of how curricular knowledge differences arise due to disciplinary differences, which eventually lead to differences in students' engagement with the curricular knowledge.

III. Method

A. *Theoretical Framework*

This study uses the theory of sociology of knowledge to guide the data collection protocols and data analysis. The sociology of knowledge framework espouses the interplay between how curricula are structured and the development of student agency. Agency in this sense, is determined by what students feel they are competent in doing as a result of their knowledge they have acquired. This theory posits that knowledge, while socially constructed, has its own properties and powers that are distinct from the social groups in which it is generated.

B. *Study Design*

This study is part of a larger research collaboration between institutions in the United Kingdom, South Africa and the United States. In each country, the Chemical Engineering and Chemistry programs at two dissimilar institutions were identified and invited to participate. Additionally, the Biochemistry programs the US institutions were also invited. The method of execution and time of data collection was the same in all cases. In the US, in particular, the two institutions were: U1 – a large, public rural-based research and engineering intensive and U2 – an urban public research institution with a more diverse student intake based on its geographical location.

C. *Participants*

Our participants were first year chemical engineering and chemistry/biochemistry students at the two participating institutions. While our original intent was to only include students from Chemistry and Chemical Engineering majors, we had to include Biochemistry students in our sample as well due to the low number of students in Chemistry at U2. In order to balance this decision, we also recruited Biochemistry students at U1. The students were recruited through departmental liaisons who were first contacted by the researchers about the project. In both institutions, first year students are deemed general engineering students. However, through the liaisons we were able to identify students who had indicated chemical engineering was their potential major. In total, 35 students from U1 and 29 from U2 were interviewed. However, due to scope, only four student interviews are presented in this paper.

D. *Interviews*

Students

The participants were interviewed by the graduate researcher. The interviews ranged from 45 to 60 minutes and were conducted using a semi-structured protocol. Some questions the students were asked were:

1. How did you come to select this institution as the place to complete your degree?
2. Why did you choose to study chemical engineering/chemistry?
3. What expectations do you think instructors/professors have of you?
4. What is chemical engineering/chemistry all about?
5. What do you think Chemical Engineers/Scientists do?

The students' participation was completely voluntary; however, students were compensated for their time at the end of the interview. For the purposes of this paper, we selected four interviews, one from each program, selecting for rich data and a diversity of perspectives, to begin work on our analytical protocol.

IV. Preliminary findings and discussion

As already mentioned, for the purposes of this paper, we focus particularly on the core issue of identifying in the data instances where we can see that student agency has been formed by engagement with knowledge. For this we look especially for indications where students have to make choice, take actions, and show ownership of what they do.

This analysis yielded two broad domains where it could be noted that engagement with knowledge contributes to students' developing agency. The first domain concerns students' responses to the substantial demands of the curriculum and assessment in these STEM degrees and the second domain concerns their specific engagement with the discipline they have elected for their major. These two overarching themes align with the theory of sociology of knowledge and curriculum, in that curriculum knowledge is known to be a recontextualization of disciplinary knowledge even though much contemporary educational discourse conflates these two forms of knowledge [15]. In fact, the discipline and its logic is communicated to students primarily through the curriculum. In our analysis we therefore sought to keep distinct these two levels of engagement: with curriculum knowledge, and with disciplinary knowledge.

Engaging with the curriculum and assessment demands

Following the interview protocol, all students described in detail their class sessions and the assessment demands in the courses that they were taking. What we were interested to note in this analysis was how these structures were shaping of student agency. For example, students gave an overview of the class times they had in the week – in the order of 10-15 hours. Mostly it did not seem an option on whether to attend – within classes there were often quiz type activities or other means whereby attendance was checked. Most courses had homework assignments which were graded, and final examinations. Students gave a sense of how their lives and choices were very much shaped by these fixed commitments. However, within the broader demands each student had to make choices on how they allocated time that was not spent in class. Here we noted distinctly different modes of agency while some overall similarities.

Students had adapted themselves around the set demands and had created their own rituals of when they did individual academic work. For example, Srikesh*, a ChemE major at U1, said, with regard to two days where he only had one class to attend:

> *then Tuesdays and Thursdays I only have discrete math so I'll do a lot of I'll do like work in the morning, go eat and...*

Thanh*, doing Biochemistry at U2, had an interesting response to the question about his schedule. When asked, he responded with an estimate of total hours on homework and on studying:

> *So I spend around 25 hours on homework which is not bad at all. But whereas studying, that's a whole different situation. So I spend around 30 hours, no, it has to be a lot more than that. Like 50 hours. Yeah, I would say 50 hours.*

Only when prompted further (on that he didn't mention them) did he talk about his class sessions:

> *Oh no, I go to classes, but I don't count that in. Because that's more so reviewing rather than me studying the content. Because in class you kind of just click the button, is this A B C or D, you just do the quick math and you click A or B. I don't feel like you learn as much as if you're studying in a study group or something.*

In terms of what they did within these individual study times, all students mentioned practicing examples. Isabella*, also studying ChemE but at U2, also mentioned doing practice problems, but coupled this with note taking and an attempt to identify what she didn't understand:

> *So I take notes before class, and when I'm in class I take more notes. And then after when I'm reviewing, I take ... It's really weird to describe, but I take notes on my notes. Where I read everything and make sure I pull out the key concepts. And then I like to do practice problems a lot. And if something is tripping me up on a practice problem, I try to identify specifically what it is that's tripping me up. And then I either go to office hours, or I ask someone else, a peer that I know that knows how to do it.*

As seen above, she is also doing problems specifically to test out her knowledge and to know when to seek further help.
Students also mentioned searching out resources on the web. Srikesh said:

> *You can kind of explore whichever topics, look at practice problems, look for videos on like, like how to approach problems in different ways.*

Jane*, another student at U1 studying Biochemistry, describes watching YouTube videos in her free time. These videos, she explains, are important because they provide the opportunity for her to see how the concepts she is learning in class are applied.

> *If I have free time, which is pretty rare, I will just watch a video on YouTube involving whatever we're doing because what really gets people in chemistry. I realize now it's because those are what we need to really know going forward, 'cause we can always relearn how to do the calculation for this or that, but in order to apply anything that we've calculated or learned, we have to be able to know those concepts.*

The assessment demands in the courses structured students' range of actions significantly. Mostly they felt the assessment demands were very clear and that courses mostly demanded a 'right or wrong' answer, and this kind of feedback was readily available. When assessment was not in line with what had been covered in class or in the homework, students voiced significant displeasure. For example, in the following quote Srikesh explains:

> *Much of what he was testing on - it had little to do with what he was teaching or he didn't cover it at all. And I think he kind of just assumed that... he'd give us a lot of material and then say that I expect you to scour through all these all this material and know like every minute detail. And I thought that was pretty ridiculous.*

Otherwise students generally felt that the expectations were very clear for what they needed to do, and they moderated their work habits to get the grades they were hoping for. Srikesh, for example, had to change his work habits in the second semester and had already seen the results:

> *I think if I put more time put more effort on to [my exams] I probably would have could have done better at least for last semester. This semester I've been pretty focused so …I've been performing about where I expect myself to be.*

Thus, disciplinary knowledge as represented in the curricula and assessment requirements for these first-year courses largely focused on acquiring relatively close-ended skills, and there was significant scaffolding for students to make this acquisition. All students made accommodations in what they were doing to master the requisite knowledge at the required level.

Prior work has explored the differences in teaching and learning practices across disciplines that arise due to these

*Pseudonym assigned by researchers

epistemological differences in the nature and structure of knowledge across disciplines. For example, given the applied nature of the discipline, it has been shown that engineering instructors tend to emphasize problem-solving [16]. As a result, the assessment activities in engineering tend to be dominated by well-defined problem-solving, and fact-finding and reporting [17]. On the other hand, assessment activities in science are often focused on solving case studies, conducting experiments and theory testing [18].

From this theme we can make some striking observations. The curriculum and assessment structure, as represented from the students' quotes, plays a significant role in framing students' agency. There is notably some choice in how they use their (quite substantial) time outside class. The assessment requirements are very tightly defined, and in most classes, they are working with very specified methods and clear right/wrong answers.

Engaging with disciplinary knowledge and the profession

In this theme we looked for evidence on how students started to make disciplinary/professional knowledge or orientations something that they owned, that was part of how they saw themselves and their roles. At the one end of the spectrum was Thanh, who said in response to the question about his chosen major, Biochemistry:

> *This is when the freshman part of me has no idea. I just know it's a double major pretty much of bio and chem. That's all I know as of right now. So I have no idea.*

He had met a biochemist who was working for a company which made missiles and which he thought was "pretty cool" but beyond that he had no actual idea what being a biochemist might entail.

The engineering students already had somewhat more elaborated ideas on their career, in line with what might be expected for a professional program. Srikesh described chemical engineering and the skills needed as follows:

> *…just analyzing a process creating a process and then like things like working with the team in terms of looking like softer skills like working with the team, communicating your ideas.*

When questioned he did not think he was learning these skills yet in the program.

On the other hand, Isabella already had a strong sense of her own agency in doing engineering type work, partly from her involvement as an intern on an undergraduate research project, and also from a design project she did in her engineering class. Her use of 'we' and 'our' in this extract is notable:

> *So engineering in general is just the application of science. So a chemical engineer would take their engineering based knowledge of problem solving and critical thinking, and apply it to chemistry problems. So if we want to apply our knowledge of chemistry to ways to better garner energy, and renewable resources. And take all our knowledge, all our arsenal of science, and try to work with everyone else and collaborate.*

This language is similarly noted in her description of her engineering class project:

> *So the assignment that I did was for the introductory engineering class. And we had a big project for that class, which was to create a robot that can complete a certain amount of tasks. And also we had specific materials that we can build our robot out of. So the homework, or assignment, that I brought was our final paper. Which went through our whole design process, and our calculations for torque of the arms, so we can pick things up.*

The reason for choosing specific disciplines within science and engineering fields is that we want to avoid the pitfall of assuming science and engineering disciplines to be monoliths. Prior work has established that there are differences across the various science disciplines. For example, Donald [16] notes that physics focuses on a deductive logic building in that the focus is on applying the physical laws to natural phenomena. On the other hand, biology and chemistry rely on inductive logic building by focusing of developing laws based on natural phenomena. This difference manifests itself into how instructors teach the subject and how students engage with the disciplinary knowledge. Similarly, a recent study has highlighted differences in different engineering disciplines in terms of students' approaches to learning, and their perceptions of disciplinary learning environments and teaching methods [19].

Students' engagement with disciplinary knowledge is very varied at this point. The four student interviews included in this paper demonstrates that some students come into their chosen major with some broad idea of the knowledge they will be exposed and how this will shape their future career goals while others are content with just exploring the discipline until they make concrete decisions about where they will end up. We have some students who are not able to articulate much in this regard, and others who already have substantial identification with the disciplines.

This discussion is very preliminary. Our goal is to continue to analyze the interviews and search for similarities and difference across departments and institutions. We also collected course material, classroom recordings and instructor interviews to be able to tell a complete story about the academic structure of departments and institutions and how this plays into the design of the curriculum. One very interesting idea that we uncovered was the role of undergraduate research experience which is very salient at U2. Students have discussed how their involvement in research helped their perception of the program to evolve beyond what they initially thought it was. While U1 is also a research-intensive institution it is still unclear if students are encouraged to engage in research as undergrads or if their involvement is purely voluntary.

V. Current and Future Research Activities

The following table summarizes the breakdown of participants at each institution.

Table 1. Final breakdown of participants by discipline and institution

Institution	ChemE	Chemistry	BioChem	Total
University 1	15	13	7	35
University 2	15	6	8	29

Currently, the first year of data collection is being wrapped up at the two US sites and have already been concluded in the UK and South Africa. The next steps are to analyze each data set independently followed by an integration across all the sites.

ACKNOWLEDGMENT

The authors would like to acknowledge the students and instructors who are participating in this study. We also acknowledge financial support from Virginia Tech.

REFERENCES

[1] S. Sheppard, A. Colby, K. Macatangay, and W. Sullivan, "What is engineering practice?," *Int. J. Eng. Educ.*, vol. 22, no. 3, pp. 429–438, 2006.

[2] F. Dehling, W. Jochems, and L. Baartman, "Development of an engineering identity in the engineering curriculum in Dutch higher education: An exploratory study from the teaching staff perspective," *Eur. J. Eng. Educ.*, vol. 38, no. 1, pp. 1–10, 2013.

[3] R. a Streveler, T. a Litzinger, and P. S. Steif, "Learning conceptual knowledge in the engineering sciences: Overview and future research directions," *J. Eng. Educ.*, vol. 97, no. 3, pp. 279–294, 2008.

[4] M. J. Prince, M. Vigeant, and K. Nottis, "Development of the heat and energy concept inventory: Preliminary results on the prevalence and persistence of engineering students' misconceptions," *J. Eng. Educ.*, vol. 101, no. 3, pp. 412–438, 2012.

[5] D. Montfort, S. Brown, and D. Pollock, "An investigation of students' conceptual understanding in related sophomore to graduate-level engineering and mechanics courses," *J. Eng. Educ.*, vol. 98, no. 2, pp. 111–129, 2009.

[6] K. A. Smith, S. D. Sheppard, D. W. Johnson, and R. T. Johnson, "Pedagogies of engagement: Classroom-based practices," *J. Eng. Educ.*, vol. 94, no. 1, pp. 87–101, 2005.

[7] M. J. Prince and R. M. Felder, "Inductive teaching and learning methods: Definitions, comparisons, and research bases," *J. Eng. Educ.*, vol. 96, no. 2, pp. 123–138, 2006.

[8] R. Felder and L. Silverman, "Learning and teaching styles in engineering education," *Eng. Educ.*, vol. 78, no. June, pp. 674–681, 1988.

[9] National Research Council, *Reaching Students: What Research Says About Effective Instruction In Undergraduate Science and Engineering*. Washington, DC: National Academies Press, 2014.

[10] S. M. Lord, M. J. Prince, C. R. Stefanou, J. D. Stolk, and J. C. Chen, "The effect of different active learning environments on student outcomes related to lifelong learning," *Int. J. Eng. Educ.*, vol. 28, no. 3, pp. 606–620, 2012.

[11] C. M. Brown and W. Lafayette, "Sophomore-Level Curriculum Innovation in Electrical and Computer Engi- neering Sophomore-Level Curriculum Innovation in Electrical and Computer Engineering," 2013.

[12] K. A. Smith, S. D. Sheppard, D. W. Johnson, and R. T. Johnson, "Pedagogies of engagement: Classroom-based practices," *J. Eng. Educ.*, vol. 94, no. 1, pp. 87–101, 2005.

[13] E. H. J. Yew and H. G. Schmidt, "What students learn in problem-based learning: A process analysis," *Instr. Sci.*, vol. 40, no. 2, pp. 371–395, 2012.

[14] K. Muller, "Knowledge, skills and the future of science and technology higher education," *High. Educ.*, vol. 70, no. 3, pp. 409–416, 2015.

[15] P. Ashwin, *Analysing teaching-learning interactions in higher education: Accounting for structure and agency*. London: Continuum, 2009.

[16] J. G. Donald, *Learning to think: Disciplinary perspectives*. San Francisco: Jossey-Bass, 2002.

[17] D. H. Jonassen, "Engineers as problem solvers," in *Cambridge handbook of engineering education research*, A. Johri and B. M. Olds, Eds. Cambridge, UK: Cambridge University Press, 2014, pp. 103–118.

[18] National Research Council, *National Science Education Standards*. Washington D.C.: The National Academies Press, 1996.

[19] A. Agrawal, C. J. Groen, A. L. Hermundstad Nave, L. D. McNair, T. L. Martin, and M. C. Paretti, "Overriding tradition?: An initial exploration of the intersection of institutional and disciplinary cultures from the student perspective," *presented at the 125th Annual ASEE Conference and Exposition*, Salt Lake City, UT, 2018.