AC 2012-4025: DISCOURSES AND SOCIAL WORLDS IN ENGINEERING EDUCATION: PREPARING PROBLEM-SOLVERS FOR ENGINEERING PRACTICE

Dr. Elliot P. Douglas, University of Florida

Elliot P. Douglas is Associate Chair, Associate Professor, and Distinguished Teaching Scholar in the Department of Materials Science and Engineering at the University of Florida. His research activities are in the areas of active learning, problem solving, critical thinking, and use of qualitative methodologies in engineering education. Specifically, he has published and presented work on the use of guided inquiry as an active learning technique for engineering, how critical thinking is used in practice by students, and how different epistemological stances are enacted in engineering education research. He has been involved in faculty development activities since 1998, through the ExCEEd Teaching Workshops of the American Society of Civil Engineers, the Essential Teaching Seminars of the American Society of Mechanical Engineers, and the U.S. National Science Foundation-sponsored SUCCEED Coalition. He has also been active in promoting qualitative research methods in engineering education through workshops presented as part of an NSF project. He has received several awards for his work, including the Presidential Early Career Award for Scientists and Engineers, the Ralph Teetor Education Award from the Society of Automotive Engineers, being named a University of Florida Distinguished Teaching Scholar, and being named the University of Florida Teacher of the Year for 2003-04. He is a member of the American Society for Engineering Education and the American Educational Research Association and is currently Editor-in-Chief of Polymer Reviews.

Dr. Mirka Koro-Ljungberg, University of Florida
Dr. David J. Therriault, University of Florida
Miss Christine S. Lee, University of Florida
Nathan McNeill, University of Florida

Nathan McNeill is a Postdoctoral Associate in the Department of Materials Science and Engineering at the University of Florida, where he is studying the factors that contribute to success in open-ended problem solving. He has a Ph.D. in engineering education from Purdue University, an M.S. in mechanical engineering from the Georgia Institute of Technology, and a B.S. in engineering from Walla Walla University.

Discourses and social worlds in engineering education: Preparing problem-solvers for engineering practice

Abstract

Social and linguistic representational systems, also known as Discourses, shape how individuals perceive their social worlds, including their own identities. Within an engineering context, Discourses shape how students perceive their roles as engineers and provide a window into which social forces shape students' emerging professional lives. In this paper. we investigate Discourses present in engineering education by examining how students approach problem solving.

We focus on data from interviews with eight senior materials science and engineering students at a large southeastern university. Participants solved four engineering problems in a think aloud session and then were interviewed afterward about their problem solving approaches. A modification of Gee's Discourse analysis method was used to analyze the interview data. First, we analyzed students' motifs and identified their top three I-statements. Next, we developed each participant's identities and associated characteristics based on the dominant motifs and I-statements found in the interviews. Finally, Discourses that influenced the identities that emerged from each participant's interview were identified in order to draw connections to wider influences in the social and political landscape.

From this analysis process, six Discourses were identified: pedagogical, economic, individualistic, peer collaboration, math, and research. Pedagogical Discourses were the most frequent in students' interviews (excluding discourses directly related to solving the problems). Many of the Discourses highlighted the practices, expectations, and language uses associated with being a student. We interpreted these findings to indicate that these students perceived themselves mainly as students (i.e., navigating the realm of their academic majors with professors and classmates), rather than as emerging engineers (whose practices are affected by conditions of industry). Our results suggest that problem solving in an academic setting does not encourage students to consider alternative Discourses related to industry and may fail to promote connections to social worlds beyond the classroom.

Introduction

Discourses, identities, and language practices shape each other and influence individuals' experiences. In this paper we argue that the ways in which engineering students see themselves as professionals, learners, and members of society are shaped by socio-political contexts including discussions, social influences, texts, and resources available to them. The contexts within which engineering students work and solve problems influence the Discourses that structure the construction of engineering identity. Thus, we utilize the concept of Discourse, and tools associated with the study of Discourse, to investigate how engineering students identify and define themselves as engineers. This study moves away from the descriptive form of discourse analysis which focuses on how language works and more towards the critical form of Discourse analysis with a focus which incorporates the descriptive component but also speaks to, and intervenes in social or political issues problems and controversies in the world[1]. Therefore,

through a study of participants' articulation of their values and beliefs underlying their problem solving experiences, we also consider possible associations between these values and beliefs and intervening socio-political aspects as representative of the identities students' assume during their problem solving. Gee[1] proposed that a specific identity or role is assumed through the use of language and this identity or role is determined by how an individual speaks or writes in reference to himself or others. It can also be illuminative to ask, "What identity or identities is the language used to enact or is it attributing to others and how does it help the speaker or writer enact his or her own identity?" (p. 18).

Discourses in this study are conceptualized as *whos* and *whats* of social construction of meaning. By "who" we refer to socially situated identities, such as the kind of person that an engineering program seeks to graduate, and "what" refers to socially situated practices and activities that are associated with engineering professions. We will mainly focus on **D**iscourse as defined by Gee[1] who described them as "ways of combining and interpreting language, actions, interactions, ways of thinking, believing, valuing, and using various symbols, tools, and objects to enact a particular sort of socially recognizable identity" (p.29). (Note that these socially constructed activities are typically called "Discourses" with a capital "D" to distinguish them from "discourses", which focus on the ways in which specific aspects of language are used.) Gee emphasizes that it is not important to count or numerically order Discourses; rather, greater value can be found in investigating performances, negotiations, and recognition work that creates, sustains, and transforms Discourses. "Discourses are always defined in relationships of complicity and contestation with other Discourses, and so they change when other Discourses in a society emerge or die."[1] (p. 38) Furthermore, Discourses are coordinations of people, places, languages, and interactions, and as such they are material realities, or maps, that aid in understanding and interpreting social practices.

Identity has recently emerged as a topic of considerable interest in engineering education research[2]. Interest in identity is linked to an increasing focus on situated learning. A situated perspective views knowledge as distributed among people and constructed in a social context. Learning occurs through the meaning making activities of a community of practice. Thus, learning is viewed as an interactive process of identity transformation influenced by socio-political Discourses. A student's identity, as well as those of others with whom they interact, influences opportunities to participate in the practices of a community. The identities of students therefore play a role in students' learning trajectories[2].

Within the engineering education literature, discussions of identity tend to focus on the socialization of students into the academic environment and into the profession. Implicit in these writings is a concern that identity affects students' persistence in engineering education and preparation for the engineering profession. Du[3] and Dannels[4] both argue that becoming an engineer is a process of assuming the identity of the profession. Du[3] writes that students must "develop a sense of belonging to the engineering profession in order to prepare themselves for the future workplace." Johri and Olds[2] also argue that, "In analyzing opportunities to learn in engineering education, learning contexts should be interrogated to discover the ways in which these contexts allow participants to develop engineering-related identities … It is imperative to consider how contexts of learning can support the development of positive engineering identities." (p. 166)

Engineering identity has been examined from a variety of perspectives, including those of elementary school students[5], practicing engineers[6–8], and undergraduates [3,4,9–13]. Several Discourses are prominent in this literature. Engineering is typically seen as problem solving, focused on a technical core [14–16]. However, these Discourses hide the social dimensions of engineering practice. Travelyan[8] found that engineers tend to hide behind a technical façade downplaying the social aspects of their work. He encountered engineers in industry who would claim that they were not really engineers—that their jobs involved only project management. When asked to explain the details of their work, these individuals would describe interactions that required specialized technical knowledge. Travelyan concludes that engineers often equate engineering practice with "hardcore" work such as calculations, design, and modeling. It is telling that in the book describing her study of learning environments in various disciplines, Donald[14] has titled the chapter on engineering education "hard thinking".

Many studies of engineering identity describe Discourses of disconnect. These Discourses involve either disconnects between engineering identity and engineering practice, or disconnects between academic and professional identities[4,5,9,15,17]. The results of these disconnects are that students do not see how their academic training in engineering relates to engineering practice and that there is an apparent emphasis on theoretical knowledge at the expense of hands-on, practical knowledge.

This paper examines identities that students assume while solving engineering problems in an academic setting. Students were asked to think aloud during a problem solving session and follow-up interviews were conducted to gain additional information regarding their problem solving experience. To study the role of socio-political context in shaping engineering identity, this study is guided by the following research question: What Discourses shape students' problem solving practices and identities as engineers?

Methods

Theoretical perspective guiding this research

The methodology and data analysis were guided by a constructivist theoretical perspective. It was our intention to study engineering students' individual meaning making processes and how students describe their existing and emerging identities as engineers. We viewed individuals as active agents gaining knowledge about their social context through their reflections and experiences with their environment. Additionally, a constructivist perspective directed our focus on unique individual experiences that can create a different perception and experience of reality for each individual[18]. Interviews provided insights into students' 'inner voices' including their beliefs, reflections, and evaluations of the think aloud problem solving experience[19]. The students were viewed as active agents, constructing meaning and gaining knowledge as they reflected on their learning process within a social context[20–22]. However, we also acknowledged researchers' impact on the constructed knowledge and were aware that individuals' experiences were constructed in social contexts.

Data collection

Participants were eight senior materials science and engineering students from a large southeastern university. Seniors were recruited due to their advanced academic experience and level of content knowledge in the field and because we were interested in exploring students who would soon be entering the profession. Approval from the university's Institutional Review Board was received prior to collecting data. Pseudonyms are used in this paper to refer to all students.

Data collection involved individual semi-structured, open-ended interviews that lasted up to an hour. The interviews were conducted following think aloud sessions in which participants verbalized their thoughts while solving four materials engineering problems. Each follow-up interview was scheduled approximately two days following each student's think aloud session in order to promote fresh recall of the think aloud problem solving experience.

The follow-up interviews complemented the think aloud protocols, providing students a space to reflect on and explain their problem solving thought processes in detail. A senior and junior researcher were present for each interview. During the interviews, students were provided with their written solutions as well as video clips of their think aloud session to aid in recall if needed. The interview protocols began by instructing students to chronologically narrate their problem solving processes for each problem without using technical language. Specific questions tailored to individual students' critical decision points in the think aloud protocols (developed from the think aloud videos by the research team prior to each interview) were also asked, and additional probes were added as was considered appropriate by the researchers. An example of an interview question is: "You eliminated composites because you said they are 'complex'. What do you mean by 'complex' and why does that eliminate them?" The follow up interviews typically lasted one hour; however, up to two hours were allocated for each. Students were compensated with a $60 gift card to a big box store for their participation.

Data analysis

We view participants' interviews as representative of their explanation of their values and beliefs related to their problem solving. Similarly, in his focus on socio-culturally situated identities as an important aspect of the critical analysis of identities as a building task of language, Gee[1] suggests that it is important to consider the manner in which situated meanings, social languages, figured worlds, intertextuality, Discourses and Conversations-(i.e. public debates, arguments, issues, or themes around issues) are being used to enact or depict identities that are socially significant to individuals. Thus, it was crucial to consider how participants used language when they referenced themselves in the first person. These statements were referred to as their 'I-statements' as far as participants' articulations about themselves and included five such forms of these statements. Gee[1] refers to these I-statements as 1) Cognitive statements referring to what an individual thinks or knows- i.e. I think, I know, I guess, 2) Affective Statements referring to what an individual talks about desiring or liking- i.e. I want, I like, 3) State and Action Statements referring to an individual's state or actions- i.e. I am, I worked, 4) Ability and Constraint Statements- referring to when an individual talks about being able to or having to do things- i.e. I can't say, I have to do, and 5) Achievement Statements- referring to activities, desires and efforts

relating to their achievement, accomplishment or distinction- i.e.- I challenge myself, I aspire to go to an Ivy League School.

Researchers worked together as a team to analyze the data. At first, all the interview data were analyzed individually to determine key themes related to participants' values and beliefs and highlight key portions of data as representative samples. The research team then met as a group to discuss and condense the themes to avoid repetition of ideas. We noted similarities in ways in which participants were either referring to their epistemological or ontological behaviors (i.e. how they conducted inquiry and organized knowledge respectively). Additional differences were identified based on participants' interpersonal connection and intrapersonal awareness. Therefore, a theme such as 'proofing using real-world verification' related to the interpersonal connection grouping of how they conducted inquiry (epistemological), whereas 'prioritizing resources' fell under the interpersonal connection grouping in terms of how participants organized their knowledge (ontological). On the contrary, intrapersonal awareness as a facet of how they conducted inquiry included the theme of 'meaning- making' and the category for intrapersonal awareness under organizing knowledge included the theme of 'abstract vs. concrete thinking'.

Main motifs were then selected as representative of the themes identified as described above. After three main motifs were identified, themes were reviewed for existing I-statements. After doing this categorization , the researchers realized that it would be critical to separate two of Gee's[1] categories, a) State and Action, and b) Ability and Constraint into four separate categories. This decision was important given that participants made distinct reference to these categories and to converge them would have given a faulty representation of participants' experiences. Conversely, the researchers decided to eliminate the Achievement Statement category due to the absence of this category in the data. Later in the analysis process the top three representative I-statement categories were identified and used within and across participants.

Lastly we interpreted the motifs and themes of each participant and created identity identifiers for each student (e.g., 'Process Reflector', 'Expertise Reflector', Organizer' and 'Self-Doubter'). The researchers also considered and collaboratively discussed various socio-political elements shaping the identified characteristics for each participant, so as to determine connections to wider influences in the social and political landscape.

Findings

Discourse analysis revealed that participants assumed specific situated identities as engineering problem solvers and that these identities were also linked with socio-political Discourses. Figure 1 represents a summary of the Discourses and identities that will be described in greater detail in the following sections. As illustrated in the figure, some academic, engineering, and individualistic Discourses were shared among multiple participants, while other participants constructed their identities in distinctive ways.

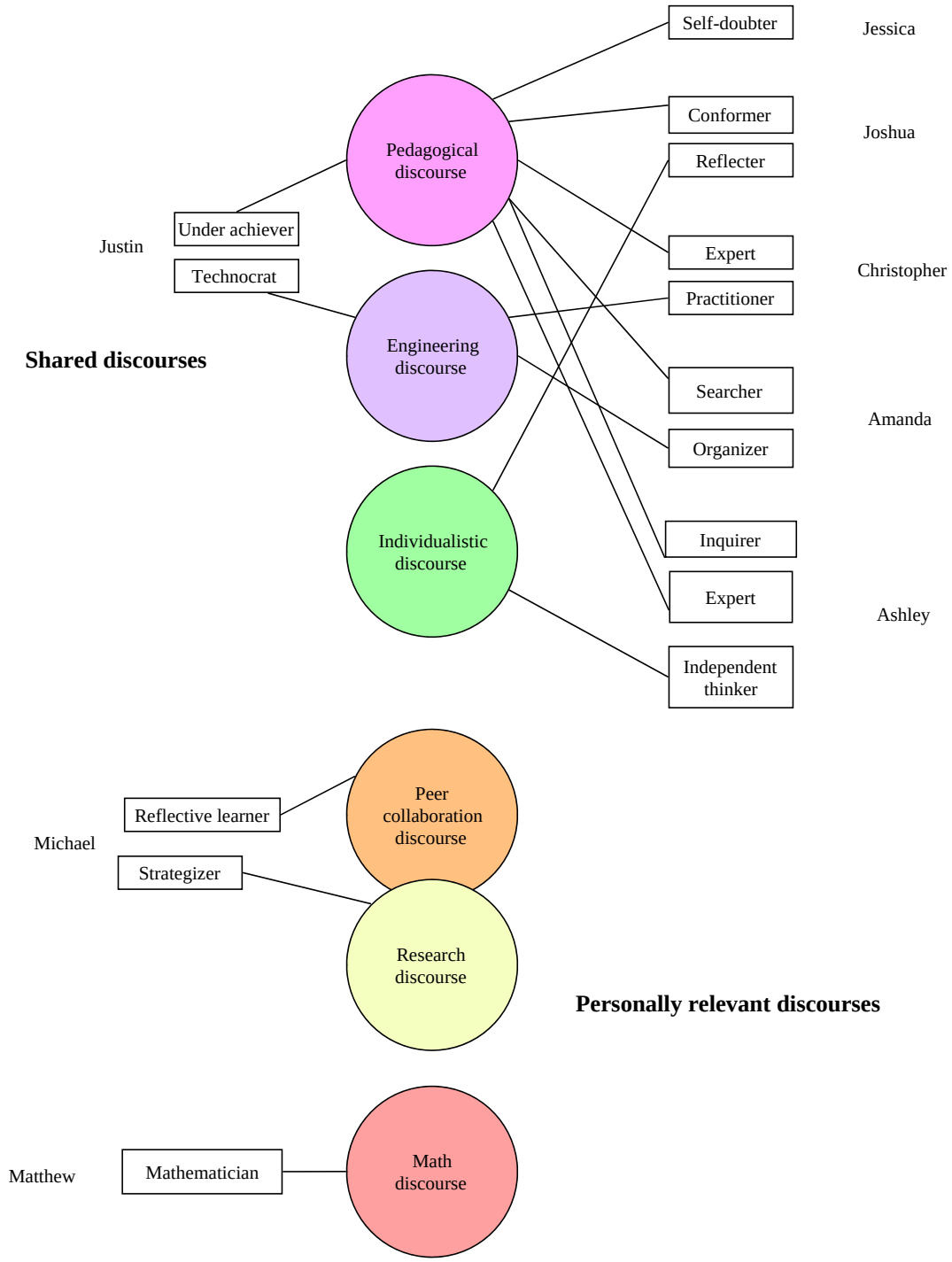

Figure 1: Summary of students' Discourses and constructed identities

Shared discourses

Pedagogical Discourse

The pedagogical Discourse provided a context for the students to describe how they navigated within the realm of their academic majors, learning, and in the context of their classroom

experiences with professors and classmates. For example, Jessica is a female from an underrepresented racial background and exhibited the situated identity of **'self-doubter'** throughout her problem solving experience. Furthermore, there was a strong tone of negativity throughout Jessica's reflections on her problem solving experience. Throughout her Discourse she showed awareness of her weaknesses in problem solving and how this influenced her solution process, and characterized her as a 'self-doubter'. "I double-check a lot…I'm generally checking for things that I know…I personally made mistakes in the past...I always mess up on my units, that's a common error." In her reflections she also exemplified a common thread of negativity and doubt through I-statements such as 'I personally make mistakes", "I always mess up", and "I don't know". Additionally, her situated identity spoke to her tendency to view things in terms of limitations both for herself and the problem solving process. "I didn't know any benchmarks materials to really compare it to…how could I make an assumption?" Similarly, many of her cognitive statements were framed as negatives such as "I don't", "I can't", "I didn't". The negativity throughout Jessica's dialogue illustrates the consequences of a common perception that females are often a novelty in engineering educational and professional contexts. This may lead to feelings of intimidation and self-doubt in their capabilities in the larger socio-political context. When this is considered in light of the double-negative of being an ethnic minority female, this may compound the negatives associated with the experiences of such students in engineering education.

Our interpretation of Joshua's data portrayed him as a **'reflector'** and **'conformer'** within the pedagogical Discourse. Within his situated identity as a 'reflector', Joshua had a strong sense of awareness regarding his actions and emotional and mental states during his problem solving experience. This was evident through the frequency of his state and action I-statements. Joshua stated:

"I am a much more conceptual person than detail oriented…when it comes to doing things like this I'm more apt to make a mistake…I enjoy questions that are more general and just pull on my knowledge of materials in general".

Joshua exemplified a 'conformer' identity as he showed a keen awareness of the processes required to gain even partial credit from professors through his problem solving strategies. However, he also exhibited the 'conformer' identity in his categorization of his behavior in a test situation versus a job-situation where he may have to complete a project. "I guess I started thinking of this not so much as an exam, like a test question...I just thought of it as like a project I was given."

Justin was another participant constructing his identity within a pedagogical Discourse. He showed a strong sense of self-awareness regarding his levels of confidence and doubt during his problem solving. He reflected on his failures and continuously processed his feelings of doubt during the problem solving process. He wanted to provide answers even when he thought that an answer "was going to be wrong and I [he] just wanted it to sound more realistic". Justin described himself as an **'under achiever'**. For example, he described putting forth minimal effort with the goal of simply finishing the problem. "So I saw two variables and I was like okay, I don't have a clue how to get back there…I can just quickly solve the problem, be done with it". In addition, Justin compared his knowledge to real-life knowledge demonstrating a strong

awareness of situations where he thought classroom experiences needed to be validated through connections to the real-world. In some instances he described himself as a **'technocrat'** who focused more on equations and calculations without clearly understanding the context or reasons for using the particular equations. He explained that he understood equations but "did not understand why and how they correlate with real life situations".

"It was hard to relate what I was able to calculate which was corrosion, corrosion rate but then also trying to get the fracture toughness with the applied force. I didn't know how to correlate those two things…I understood equations, I just didn't understand necessarily why and how that correlates to real life situations."

Christopher, in turn, perceived himself as an **'expert'** and **'practitioner'** in the context of a pedagogical Discourse. Christopher drew on his personal knowledge base gained from classroom experience even if the concepts seemed vague to him. His method in corroborating established lexicon and personal reasoning was to default to similar concepts that he knew from experience in the classroom. "I just kind of went with an easy default with steel…just because it's cheaper". Additionally, in his examples Christopher moved from searching through his experience and familiarity with materials mentioned in a classroom context to memory of equations or similar problems in the textbook that he used to direct his problem solving. "I just knew exactly…what chapter to look in and just found where it talked about that and then quickly flipped to it." He exhibited a reliance on his expertise, including relevant engineering problem solving information, heuristics, and procedures to tackle the problems at hand.

In comparison to the expert identity exemplified by Christopher, Amanda's data brought to the forefront superficial conceptual connections. In her identity as a **'searcher'** she was constantly accessing the supplied textbook while problem solving, flipping through various sections. She employed narrow searches for specific information in times of uncertainty. Her many book searches highlighted her need to constantly verify the accuracy of her work through comparisons with example problems in the text with the goal of receiving as much solution credit as possible as she would in a classroom situation. She also emphasized explicating all of her problem steps on paper, making a reference to the value of receiving partial credit for writing out one's work in detail during problem solving. In terms of her I-statements, she used state statements prior to ability and action statements. "I was getting irate with not being able to do anything…I can't figure this out so I'll just figure this out instead…I didn't start doing calculations…I was more trying to find relationships." These I-statements patterns showed a pattern of reflection on her state to determine paths ahead.

Engineering Discourse

The engineering Discourse is reflected in the identities of two participants, Justin and Amanda. This Discourse is reflected in discussions such as efficiency and other reflections on characteristics or behaviors crucial to the engineering field in general. For Amanda this is exemplified through her **'organizer'** and **'simplifier'** identities and in the importance of having a plan in the problem solving process before attempting any calculations, and sticking to that plan in order to achieve success. Amanda showed a preference for planning in her calculations. *"What's the point of solving for it now if I'm going to have to solve for it later, I might as well*

just get everything written out and how I want to plan everything first." She prioritizes organizing the information and having a clear plan prior as a first step in her problem solving process. Therefore, she describes 'writing everything out' in order to have a tangible plan. This supports the engineering Discourse in showing understanding by having detailed plans during conceptualization. It also highlights the importance of efficiency in this Discourse and the ability to achieve a correct solution with minimum resources such as time, energy, and cost. Justin exemplifies an alternative aspect of the engineering Discourse in his focus on the sales aspect of engineering as different from the technical aspect of industry. In this regard he highlights aspects both of engineering and business Discourses given his focus on different elements of each. This exemplifies his situated identity as the **'rationalizer'** as he explains his reasoning for taking certain problem solving approaches. He therefore goes outside the classroom context in explaining what he values as a problem-solver with his appreciation of the business-side of engineering.

"*I can acclimate a lot better to personal relationships and the business orientation of the technical side…it's something I'm naturally inclined to do…I'm better suited for business and things like that...I want to be on the technical side of business."*

He associates the technical side of engineering with a required knowledge base that is important in problem solving, and sees experience in the field as crucial to developing this foundation. "I haven't done what some people have done like 10 years of work in the field so they just know off the top of their head." Justin has a strong awareness of his personal strengths and weaknesses and associates his strengths with the sales aspect of engineering and his weaknesses as the rationale for avoiding the technical side of engineering.

Another participant, Christopher, also makes strong differentiations between aspects of the engineering field and how this affects his approach to problem solving. He has a strong sense of value for the ability to communicate knowledge to different audiences and sees this skill as important in differentiating his problem solving approach. For this reason he sees practical experience in the classroom context as integral to his development in the field and this characterizes him as having a **'practitioner'** situated identity. While he appreciates the scientific focus in the academic context, he views being able to communicate valuable information through practical terms in the field as equally important for engineering professionals. He therefore asserts that in his classes,

'I wish we had more…not necessarily realistic, but less science behind it, I mean the science is good…but more of how you then use that in the job…strain hardening and all these little equations are very useful theoretical or for research but to use that in the field if you're talking to someone...unless they're another metallurgist…they're not going to have any idea what you're talking about...I may know what I'm talking about but it doesn't help me tell them what they need to know."

Therefore, Christopher has a strong value for the scientific background he gains in his engineering classes, but also values the importance of practical communication as an important component in the engineering field.

Individualistic Discourse

Ashley and Joshua made connections to an individualistic Discourse when they described their problem solving processes. For example, Ashley's stories made continuous references to individualistic values such as intentionality, independence, and self-directed learning. She described her **'independent thinker'** identity through her trust in her own experiential knowledge. She showed a strong belief in her ability to solve posited problems and suggested that learned information and her previous problem solving experience should benefit her more than knowledge gained from other problem-solvers or second-hand notes scribbled in textbooks.

"Maybe I don't trust what other people would write in the book…I don't like books that other people have highlighted or underlined...I was sure of myself...I knew what the equation was and I didn't really need the book to validate that."

Furthermore, Ashley accessed resources such as the book simply as a point of verification or validation to verify that she was on the right path. "I looked it up in the book just to make sure...to make sure I had it right". Whereas some other participants showed a level of dependence on the text, Ashley was the opposite in her use of the text solely for verification in moments of doubt. She did not see textbooks as error-proof.

"I usually think I'll be able to solve this problem and I'll be able to find the information I need…I just remembered it from learning it…I know books always have mistakes in them...If it was something I knew less about I would probably be more inclined to believe what the book has to say."

Finally, her independence also came across through her level of confidence in her reflections on things she has done in the past that had been successful, whether it was in the classroom or in her performance as a student. "I guess I've always been a good student myself…I usually think...oh I'll be able to solve this problem and I'll be able to find the information I need." This confident approach and sense of individualism in problem solving as gained through her pedagogical experiences supported the value she places in her abilities during the problem solving exercises.

Personally Relevant Discourses

Peer Collaboration and Research Discourses

Michael's reflections during his problem solving processes were situated within real-life contexts, including both in his present academic as well as future workplace settings. In his description, Michael showed a strong awareness for the central role of peer collaboration Discourses in real-life engineering through his identity as a **'reflective learner'**. He stated that when solving complex engineering problems, "generally you're going to be working on a problem like this [in groups]. I mean it's a rare case that someone tasks to you figuring out what the problem is. That's generally in a group problem". He reflected on working in "a group setting", explaining that while collaborating with others, it is important to "talk it out, figure out

exactly what you're trying to work for" in order to have everyone understand the "scope of the problem" and keep the common goals of the problem "in mind every time you do something."

Michael operated within the research Discourse in his situated identity as a **'strategizer'**. Michael described undertaking the problem solving process with a research-oriented approach. He described first developing a clear conceptualization of the problem, repeatedly stating that at the beginning of each problem he visualizes and contextualizes the problem. Michael used various strategies to understand and "frame" each problem, including drawing from information learned in previous classes, "I took a corrosion class last semester and that was one of the main points of it"; applying heuristics developed from experience, "It's a series of thin strands and thin strands to me means small…1 mm is a good starting point I would think"; and incorporating real-world constraints, "In my mind I see that big, see a steel cable that big, it's not going to be exceptionally large".

For both conceptualizing and solving the problem, Michael emphasized the importance of viewing the problem within a real-world engineering context,

Generally you have probably an expected value of what would compare it to and what I've learned is to be reasonable…if you look at a bridge and it says its' going to be 9 feet by 9 feet no one's going to believe that. If you don't compare your answers you're probably going to get it wrong to what you know in real life.

As such, Michael's reasoning strategies, and decisions reflected the complex and dynamic nature of real-world engineering problem solving. He viewed the problem from different perspectives, applied complex strategies, and presented multiple possible solutions to open-ended problems.

Overall, Michael's identities as a reflector of the peer collaboration Discourse and a strategizer of the research Discourse were solidly contextualized and representative of real-world engineering problem solving.

Math Discourse

The influence of mathematics was evident throughout Matthew's Discourse regarding his problem solving experience. Matthew placed high value on his mathematical background and framed all of the materials engineering problems through a mathematician's lens. This perspective was characterized by a seemingly blind trust in mathematics as an infallible tool that leads to absolute truths. "Well, basically that if you have the right equations then you can solve anything." He approached all of the problems from a mathematician's perspective. Matthew drew on mathematics knowledge from fields including trigonometry and geometry, as well as more specific mathematics concepts in engineering such as Miller's indices and figure of merit to solve the problems.

At several points in his Discourse, Matthew referred to his mathematics background as a core value that defines his identity in problem solving. Based on the notion that connections between engineering concepts and principles can be made by manipulating equations, Matthew described his strategy as "throwing down" any potentially relevant equations that come to mind in order to

understand the problem. “Well, I come from a mathematical background and so a lot of the times if I don’t really know how to approach a problem I’ll just start writing down equations, throw everything I know onto the paper.” Therefore, his identity as a ‘**mathematician’** was predominantly defined by the number of equations he was able to generate for a given problem. “I knew there was an equation and I knew I could probably find the equation in the book. I couldn’t remember the equation…” Matthew’s main form of conducting inquiry during the problem solving session involved searching for equations in the textbook.

Non-contextualized pattern-based confidence emerges in Matthew’s belief that a single mathematical solution exists for each problem. This belief is manifested in his search for an absolute, correct answer that he firmly believes is achievable via a series of mathematical manipulations.

I’m not sure if that was the question that they wanted me to answer. I also remembered that there was a way to calculate the angle using Miller Indices instead of pure geometry…but I didn’t see it (in the book) and so I decided to just go with the geometry of the problem.

Under circumstances in which he was unsure of whether the calculations were moving him towards a solution, and even in situations when he had a suspicion that he may be approaching the problem incorrectly, Matthew did not abandon his attempts to calculate a solution through various manipulations of equations.

Matthew made superficial connections without understanding the concepts represented by the equations he was using. His choices of equations were driven more by superficial understanding. “Because basically throughout the classes that I have had, every time I see a design problem the way to solve it was to use a figure of merit.” For Matthew, the collection of equations generated for a particular problem defined both the problem as well as the problem goal state. Matthew began his problem solving approach by conceptualizing a problem through a series of equations, “to see if I got the equation right, memorized correctly or if I’m supposed to use some other equation, or if I’m even doing the right thing”, and from this point on a search for unknown values in each equation represented the bulk of his problem solving process.

I come from a mathematical background. Usually I’ll just, if I don’t know exactly how to proceed I look for equations that relate to things that I already have and then use that equation as a jumping board to reach whatever solution I’m trying to approach.

Conclusion

This study examined the Discourses influencing student identity as engineers as illuminated through problem solving. For the most part, students in this study did not seem to move beyond the academic context in which they were immersed (i.e. pedagogical Discourse). This may have important implications for students who will shortly transition from students to practicing engineers. Even when the pedagogical Discourse was not explicitly identified as influencing a student’s identity, elements of the academic context were clear. For example, Amanda’s identity as an ‘organizer’ reflects an engineering Discourse, but with a focus on how to solve problems. It is possible that the particular setting for this study emphasized the academic context due to the

seemingly academic nature of the problems. However, we feel that this is an important finding because these types of problems and problem solving contexts reflect a substantial portion of the academic training students receive. Thus, how these types of problems affect student identities is important to understanding how they ultimately perceive their roles as engineers.

Michael was able to see beyond the academic setting and emphasized the importance of understanding the real-world context of engineering problems, suggesting that it is possible for some students to make connections beyond the academic setting. Even in Michael's case, however, the connection to "real-world" engineering was limited to technical aspects. Students did not seem to be drawing on complex Discourses about clients, society, social aspects, etc. It is also important to note that many students choose to study engineering because they are good at, or enjoy, math and science. They retain the math and science identity as engineering students, so they may see the social, environmental, and other considerations as superfluous to their identities. This could be a case for Matthew whose only Discourse and identity had to do with math. It could be argued that this identity does not necessarily make for a successful engineer in practice or may lead to disappointment when a new engineer finds that the job involves very little mathematics and primarily involves working with people.

The results from this study suggest that the students we interviewed approach problem solving from an academic perspective and do not connect their experiences in school with the Discourses associated with practicing engineers. This apparent disconnect between "academic engineering" and engineering practice leads to important questions about the education of future engineers: What are the implications for how students ultimately practice engineering? What pedagogical practices promote self-identification of students as engineers? In order to connect students to the Discourses associated with engineering practice, alternate approaches are needed which move students beyond the limits of the academic setting.

Bibliography

1. Gee JP. *An introduction to discourse analysis: Theory and method*. UK: Routledge; 2011.

2. Johri A, Olds B. Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education*. 2011;100(1):151–185.

3. Du XY. Gendered practices of constructing an engineering identity in a problem-based learning environment. *European Journal of Engineering Education*. 2006;31(1):35–42.

4. Dannels DP. Learning to be professional. *Journal of Business and Technical Communication*. 2000;14(1):5.

5. Capobianco BM, Diefes-Dux HA, Mena I, Weller J. What is an Engineer? Implications of Elementary School Student Conceptions for Engineering Education. *Journal of Engineering Education*. 2011;100(2):304–328.

6. Allie S, Armien MN, Burgoyne N, et al. Learning as acquiring a discursive identity through participation in a community: improving student learning in engineering education. *European Journal of Engineering Education*. 2009;34(4):359–367.

7. Sheppard S, Colby A, Macatangay K, Sullivan W. What is Engineering Practice? *International Journal of Engineering Education*. 2006;22(3):429–438.

8. Trevelyan J. Reconstructing engineering from practice. *Engineering Studies*. 2010;2(3):175-195.

9. Dunsmore K, Turns J, Yellin JM. Looking Toward the Real World: Student Conceptions of Engineering. *Journal of Engineering Education*. 2011;100(2):329–348.

10. Eliot M, Turns J. Constructing Professional Portfolios: Sense-Making and Professional Identity Development for Engineering Undergraduates. 2011;100(4):630-654.

11. Foor CE, Walden SE, Trytten DA. I wish that I belonged more in this whole engineering group: Achieving individual diversity. *Journal of Engineering Education*. 2007;96(2):103–15.

12. McNair LD, Newswander C, Boden D, Borrego M. Student and Faculty Interdisciplinary Identities in Self-Managed Teams. *Journal of Engineering Education*. 2011;100(2):374–396.

13. Tonso KL. Student engineers and engineer identity: Campus engineer identities as figured world. *Cultural studies of science education*. 2006;1(2):273–307.

14. Donald JG. *Learning to think: disciplinary perspectives*. San Francisco, CA: Jossey-Bass; 2002.

15. Hult H, Dahlgren MA, Dahlgren LO, af Segerstad HH. Freshmen's and seniors' thoughts about education, professional identity and work. In: *Australian Association for Research in Education 2003 Conference Papers. Melbourne: ACER Library*.; 2003.

16. Jonassen DH, Strobel J, Lee CB. Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education*. 2006;95(2):139.

17. Shulman L. Signature pedagogies in the professions. *Daedalus*. 2005;134(3):52–59.

18. Hatch, A. (2002). *Doing qualitative research in education settings.* Albany, NY: State University of New York Press.

19. Koro-Ljungberg M. Validity, Responsibility, and Aporia. *Qualitative Inquiry*. 2010;16(8):603–610.

20. Fosnot CT. Constructivism revisited: Implications and reflections. *The Constructivist*. 2005;16(1).

21. Kincheloe JL. *Critical constructivism primer*. New York: Peter Lang Publishing; 2005.

22. Lincoln, Y., & Guba, E. (2000). Paradigmatic controversies, contradictions, and emerging confluences. In N. Denzin, & Lincoln, Y. (Ed.), *Handbook of qualitative research.* (2 ed., pp. 163-188). Thousand Oaks.: Sage.