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Student Perceptions of Project Mentoring: What Practices and Behaviors Matter?

Dr. Marie C Paretti, Virginia Tech

Marie C. Paretti is an Associate Professor of Engineering Education at Virginia Tech, where she co-directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication in engineering design, interdisciplinary communication and collaboration, design education, and gender in engineering. She was awarded a CAREER grant from the National Science Foundation to study expert teaching in capstone design courses, and is co-PI on numerous NSF grants exploring communication, design, and identity in engineering. Drawing on theories of situated learning and identity development, her work includes studies on the teaching and learning of communication, effective teaching practices in design education, the effects of differing design pedagogies on retention and motivation, the dynamics of cross-disciplinary collaboration in both academic and industry design environments, and gender and identity in engineering.

Mr. Benjamin David Lutz, Virginia Tech

Ben Lutz is a graduate student in the department of Engineering Education at Virginia Tech. His research interests include engineering design teaching and learning as well as school to work transitions for recently hired engineers.

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Abstract

While significant work in recent years has begun exploring the structure and teaching practices of project-based courses and design environments [e.g., 1, 2-6], less work has been done to explore how students experience these practices. Data from studies that examine faculty beliefs suggest that faculty are intentional and passionate about their work in mentoring design teams, making choices to explicitly foster specific skills and promote students professional development. But what do students experience? How do they perceive and respond to teaching and learning in project-based environments?

To address this question, this paper presents initial findings from case studies conducted at multiple universities. Each case includes observations of classroom practices, interviews with faculty, and interviews or focus groups with students. Observation data was collected via detailed field notes, while interview and focus group data was audio-recorded, transcribed, and coded using qualitative analytic techniques [7, 8]. For each case, the observation data was used to help guide the interviews and focus groups, which followed a semi-structured protocol.

The paper presents findings from two cases studies. Preliminary analysis suggests that while students identify many of the same practices faculty describe (including coaching, role modeling, being pushed to explain plans and decisions), they also tend to place more emphasis on the rapport they are able to develop with their mentors and the encouragement and affirmation they receive, but may be less aware of the ways in which faculty mentors seek to protect students from both project failures and learning failures. The findings thus provide rich insights into how students experience teaching and learning in design environments, what they value about those experiences, and, perhaps most importantly, what dimensions of mentoring are more and less visible as meaningful supports.

By better understanding students' experiences and perceptions, the findings from this study can help design educators better address student needs, refine their project mentoring to more effectively achieve core learning goals, and support students' professional development.

1. Introduction

Senior capstone design and project-based courses represent a critical component of undergraduate engineering education. By providing opportunities to solve real-world problems under the guidance of experienced mentors and industry partners, these courses provide students with new and relevant experiences aimed at preparing them for work after graduation. Given the diverse and complex nature of projects in these courses, teaching and learning needs may differ for individual students as well as for teams. As a result, instructors in project-based environments must often tailor their instruction styles and practices to accommodate the needs of a particular student team and the unexpected turns of a particular project. To meet these varied needs, instructors and project mentors employ a variety of pedagogical tools to foster the development of students' technical and professional skills.

Faculty Practices in Project-Based Learning

Despite the diversity of projects and contexts in capstone courses, research suggests strong similarities in faculty practices. For example, findings from large national surveys[1, 5, 9] show significant consensus regarding the goals and structure of capstone courses. More recent work by Pembridge [6, 10] based on interviews with a diverse pool of capstone faculty identified nine salient mentoring functions implemented by instructors, listed in Table 1.

Table 1: Capstone Design Mentoring Functions[6]

	Function	Operational Definition
Career Development	Employability/ Sponsorship	Provide students with access, opportunities, and materials that will assist them in attaining employment.
	Exposure/ Visibility	Provide students with diverse opportunities to exhibit their skills and knowledge that facilitate acclaim and feedback and enculturate students in engineering practice.
	Coaching	Impart knowledge pertaining to technical engineering and professional skills through a variety of pedagogical approaches.
	Protection	Prevent student from failing to learn, failing projects, and poor relationships with clients through administration and execution of the course.
	Challenging Assignments	Develop students' technical and professional skills by providing them with complex realistic projects.
Psychosocial Development	Role Modeling	Develop attitudes, values, and behaviors of the field through interactions with the students.
	Acceptance/ Confirmation	Aid in the development of a student's self-efficacy and identity as a practicing engineer.
	Counseling	Guide teams and students through difficult interpersonal and personal problems
	Rapport	Develop interpersonal relationships with students that establish an environment in which students feel comfortable approaching the faculty.

Based on a model of mentoring drawn from industry practices[11] and adapted to education by multiple researchers, these practices are divided into career development and psychosocial development functions. That is, not only do capstone mentors provide students with the information and technical skills needed to successfully complete a project, they also serve as role models and counselors, imparting values, sharing experiences and developing rapport with their students to prepare them more fully for professional work.

Research has also used cognitive apprenticeship[12] as a framework to understand faculty practices in project-based learning environments. Using this framework, Hunter, Matusovich, & Paretti [13] identified three primary techniques used by instructors in open-ended, ill-structured problem solving environments: 1) modeling (explicating personal experiences and values), 2) scaffolding (providing support and tapering guidance as students make progress) and 3) coaching (observing students and providing feedback). Coaching was found to be the most common strategy implemented by instructors, as it is defined most broadly and takes on a wide range of forms. Notably, these practices intersect closely with the mentoring functions defined by Pembridge.

However, most prior research on the practices of capstone faculty, including those noted above, focus on self-reports by course instructors and project mentors. Less is known about how students perceive and respond to these different pedagogical strategies. Some work in this area does exist. For example Pierrakos et al.[14], through a survey of learning outcomes (both technical and professional) in senior design, found that students value the learning that takes place in the capstone experience. Additionally, the same survey found that the gains reported in professional skill development were ranked higher than those related to technical learning outcomes. The findings from Pierrakos et al. are especially important for two reasons: First, students believe they are developing the professional skills needed for successful engineering practice. Second, because most engineering programs do not offer many other opportunities for students to develop these skills, it is critical that they develop them in senior design. Although Pierrakos has explored students' self-reported learning gains in project-based learning environments, the way in which students and mentors work together to accomplish those gains throughout the course is less clear. Studies by Matusovich et al.[15] and Pembridge[16] have also explored student beliefs through interviews of first-year students and surveys of capstone students, respective.

Still, much work remains to be done in understanding how students themselves experience project-based environments, including capstone courses. Understanding students' perspectives are essential if design educators hope to continue to enhance these learning environments. Describing educators' self-reported practices provide an important starting point, but ultimately, from an educational perspective, what and how students learn from these practices is essential to identifying those practices that effectively support learning. By gaining insight into how students perceive and respond to various mentoring functions, faculty can adapt and tailor instruction in ways that improve the efficacy of the learning experience. In order to better understand how learning takes place in design and project-based environments, it is crucial to study the perspectives of the students in those environments. It is important to know not only what faculty say and do, but how these behaviors affect students. To this end, this paper presents the following research question:

> How do students describe faculty practices and interactions in capstone design settings?

Methods

To explore student perceptions of mentoring practices, this paper presents data from a multi-case study, focusing on the findings from two senior-level project-based courses conducted at two different institutions. Following Yin[17], case study methods were chosen as an effective method of capturing in situ practices to explore how teaching and learning occur in the dynamic, ill-structured space offered by capstone courses. The full set of case study data includes observations of faculty-student interactions, interviews with faculty, and interviews and focus groups with students. By collecting data from multiple sources, the case studies allow for triangulation of findings at both data collection sites and provide a basis for a more in-depth exploration of student perceptions. In this paper, we focus on the findings from the student interview data, though we note that prior research has shown strong agreement with respect to practices across all three data sources.[18]

Cases

Both data collection sites were large, comprehensive universities, with one located in the mid-Atlantic and the other in the Mountain West. The course studied at the mid-Atlantic site was a one-semester course focused on innovation and entrepreneurship, in which student teams developed a product or service in order to launch a startup company. In the Mountain West, the course was an in-major capstone design class. The following sections describe each site in more detail.

Mid-Atlantic Site

The entrepreneurship course was team-taught by four instructors; three of whom had startup experience. One was simultaneously working as a faculty member and startup co-founder; another had previous startup experience but was currently working as a faculty member leading an interdisciplinary technology-focused research initiative; and the third was serving as a regional leader in startup and economic development. The fourth, despite having no formal startup experience, had experience using the start-up development model that formed the basis of the course as well as a strong foundation in learning theories and the entrepreneurship education literature. In addition, other experienced start-up mentors from the community moved in and out of the course and engaged with student teams. In total, the course consisted of 25 students (all seniors or graduate students) from various engineering departments, divided among 8 projects; team size varied from 2-4 students. Because only one woman was enrolled, participants are not identified by gender.

The course moved between informal presentations, in which each team presented the week's findings to the class for review and feedback, and working sessions, in which the teams met individually with one of several mentors. Students were also encouraged to seek out additional mentors who could help them succeed; the instructors created multiple opportunities for teams to meet new mentors, including two mandatory mentor mixers/socials and "start-up events" within the local community.

Mountain West Site

The in-major senior design course was led by a course coordinator who held whole-class meetings and oversaw all projects (approximately 40). Each project also had a faculty mentor; this case followed one mentor who acted as "project director" for the three projects, two of which were divided into subteams; 24 students were involved across these teams, and subteam size ranged from 4-6. The project director was an adjunct faculty member with many years of experience as a design engineer and as a capstone design mentor. Of the three design teams included in this case, one team had an industry client/sponsor who was present for nearly all of the weekly meetings and also provided feedback and guidance regarding the students' designs.

The course coordinator met with the entire senior class regularly and gave brief lectures about design and team processes salient to capstone design projects. The project director held weekly meetings with each team (subteams met together); the project director structured these meetings to parallel workplace design meetings; one student from each team or subteam would give a presentation covering the results of their past work, current analysis, and future goals.

Data Collection

Data collection included observation of faculty-student interactions, interviews with mentors, and interviews with students. All procedures were governed by Virginia Tech's Institutional Review Board (IRB# 13-077).

Observations

For both cases, whole-class presentations and discussions, as well as conversations between teams and mentors were observed each week. For the Mid-Atlantic case, data was collected via extensive field notes and attempted to capture as fully as possible all course events and discussions. Observations were conducted by two of the authors until agreement was reached on the content observed and all subsequent observations were conducted by the first author to ensure consistency in the data. For the Midwest case, the focus was exclusively on the project director's practices; classroom discussions were recorded and the project director's comments were transcribed verbatim; in addition, two members of the research team took supplemental field notes. The observation protocols were based on the mentoring functions listed in Table 1, but the field notes attempted to capture as fully as possible all faculty practices, including ones not represented by the mentoring framework.

Interviews

Individual semi-structured interviews were conducted with 4 students from the Mid-Atlantic site and 9 students from the Mountain West site. The interview protocols were developed based on the mentoring framework as well as the in-class observations and analysis. Student interviews explored interactions with mentors, how those interactions affected learning and project work, and the extent to which the advice or knowledge participants gained from their mentors was perceived as useful for their careers. The use of semi-structured interviews provided common data surrounding the central themes of the protocol, but also allowed the interviewer to explore specific or unanticipated topics more deeply [17, 19]. All interviews were audio-recorded and transcribed verbatim.

Data Analysis

As noted above, this paper focuses on the analysis of student interviews. Data analysis consisted of *a priori* coding of all interview transcripts using the functions listed in Table 1 as the primary codes. To ensure reliability across researchers, the initial round of coding was reviewed and discussed by the research team until consensus was reached regarding the definitions of each code. Following consensus, two members of the research team coded the same subset of transcripts in order to achieve inter-coder agreement across the mentoring framework. The remaining data was then analyzed by the same two members of the research team.

Results

Across the data, three mentoring functions appeared to dominate students' descriptions of effective and meaningful faculty practices: 1) coaching, 2) protection, and 3) rapport. Coaching is perhaps the most common practice associated with mentoring, but both protecting students from failures, especially failures to learn, and building rapport suggest that faculty practices play a strong role in creating an environment that supports student learning. Establishing rapport with students, in particular, appears to be the way in which mentors create an environment of trust and respect. When working on a real-world project, students find value in mentors' ability to be candid and genuine when providing guidance. In a way, developing rapport provides students with a sense of credibility and honesty in their mentors, and that trust impacts the way in which students both respond to and act on advice being given.

The following sections describe the three codes in more detail, with examples from the data of how students respond to these faculty mentoring practices.

Coaching

Coaching is the dominant practice by which mentors help students gain and implement the technical skills needed for their capstone projects. It takes a range of different forms, including direct instruction, probing questions, and advice about external resources. In a project-based course, moreover, different students are typically responsible for learning different things so that they can all contribute to the project, and different projects often demand different skills. Mentors do not necessarily teach those technical skills, but rather suggest potential routes to take with project development and help students identify the skills they will need to take those routes. Shown below is an example from a student interview describing how the mentor would observe a student's work and provide coaching suggestions:

> *Ok! Ok umm [mentor] is very, very smart and very intelligent with engineering. He's a great engineer. But more importantly, he didn't teach me how to, I learned how to, through the process of the project, I've learned how to use [software] simulations to look at tube some tube deflection, some tube stresses, things like that. [Mentor] didn't teach me how to do that, what he did was help guide me on things I want to examine and things I want to try to isolate or things I want to focus on. And so what [mentor] would do, is I would say 'Ok. Here's my first cut of the FEA. It's really basic, there's not a whole lot of detail here.' He would say 'Oh ok. That's cool you got it to work. We need lateral displacement.' He was good at trying to gear my mind towards 'Ok, yea its great you got it running, but thing is that's not really what matters.' And he says this tons, 'What's your so what? That's great you did all this analysis, but so what? How does that impact what we're doing right now?' [Student 1 Interview]*

Here the student is aware that the mentor did not "teach" the skills in a traditional sense. Instead, the mentor observed the student's work and provided feedback and encouraged the student to go further and refine the analysis that had been done. Importantly, the student acknowledges that the mentor did not give instructions for using the software, but rather explained how to make the analysis more meaningful for the project. Consistently across the interviews, students described examples such as the one above that recognize the ways in which it is not a mentor's job to teach specific skills, but rather push the students to further develop and integrate them for their project.

Protection

Like coaching, protection is linked to student development, and is particularly important in open-ended, project-based courses where the "answers" are unknown to the mentors as well as the students. Although protection from project failure is likely common in industrial or workplace environments, protection from failing to learn is often the larger concern in academic settings. In order to provide this protection, mentors keep track of team progress, supply resources, ensure accountability and focus on student learning. The two comments below illustrate different dimensions of such protection.

> *There is one more thing I can add before I forget this thought. Is that it's very clear that his goal is always for us to grow and learn. For example when he and [industry client] had opposing views on using tubes to weld the frame. He said something, [the industry partner] said something, and instead of him defending himself he addressed us and said 'Ok look guys, you have two opposing views from 2 experts.' and he addressed that situation that this is a situation you will run into as engineers. And so he took a step back and you know took kinda the bird's eye view of 'How can I guide these students in the right direction because they're going to come into this. They're going to be face with this situation.' And so I appreciated that, how it was not about him anymore. And that's where I say he's humble. It's not about him trying to prove to us how knowledgeable he is. He's fine if we accept another person's, you know, opinion. But he just wanted to step back and let us appreciate the situation. [Student 2 Interview]*

> *So we first of all believe in his ability to help us. And we also believe in his, the fact that he genuinely cares about the success of this team and how he shows that is a little bit difficult to describe. A lot of it is that he's just very involved. Even though we see him only once a week, he knows exactly where we were, where we need to be, he's got all the milestones, he knows what's coming up next for us, and makes sure were on track. And he tells us you know 'these are the areas that you neglected. Make sure to focus on these.' And so it just shows that he's not just there to just nod his head and say were doing a good job. Because when were not, he'll definitely tell us. And he picks out certain areas. He tries to find out exactly who did research on this part so he can pinpoint them. Not just to throw a spear at them as he says. Although he enjoys that, seems like it but also to just guide them in the right direction. And sometimes he, and the reason I say he is humble is because a lot of time he will admit that he doesn't know the answer. He'll say 'I don't know the answer to this.' and that's what probably makes him a very successful instructor. Not because he knows everything, but because he knows what to look out for. And that probably comes from his experience in the field. [Student 2 Interview]*

In the first instance, the student recognizes that the mentor is not only protecting the students from conflicts between different project stakeholders, but also exposing that protection in order to help students learn to negotiate such conflicts in the future. In the second case, the student has a strong sense of the mentor's awareness of the project, and the ways in which that awareness enables him to be alert to gaps or areas of weakness in the project, again as both a hedge against project failure but also as a support to student learning.

Rapport

Though perhaps not a traditional "teaching" practice, establishing rapport with students appears to be critical in capstone environments to support learning by creating a climate in which students respect and value the advice of their mentors. Students regularly discussed the ways in which mentors developed a relationship where they felt comfortable asking for help. This rapport also seemed, in each case considered to date, to enable mentors to be more blunt or straightforward with their criticisms because they could be sure that students understood the motivation behind it and would not take it personally. As shown by the excerpt below, one student acknowledged the seemingly harsh nature of the feedback, but also discusses how it is understood that all the advice given is done so to improve student learning.

> *He's uhhh ummm I don't know he just provides a lot of input and he's hard on us but it's not because he hates us. It's because he wants us to succeed and somehow he conveys that to us. [Student 3 Interview]*

It is important to note, that building productive relationships takes time and effort on the part of the mentor. In order to establish the rapport needed to give feedback in a seemingly harsh manner, mentors must get to know their students and make them feel comfortable around them. Shown below is an example of how a mentor, who initially seemed intimidating or scary to students, was able to overcome the perception and create an environment of mutual respect.

> *So and he was just like, it was kind of scary at first because like we didn't know who this guys was and he was like really intimidating and were being called into this big conference room to talk to him. …But I got called in and he's like 'Oh so like why do you want to do this project? Do you have any experience with [this area]?' And I'm just like 'Uhh I don't know. I'm just kind of overwhelmed.' And then he ended up just like, he was looking at my resume and he noticed that I was living in [location] this summer and I had lived there before. And then we just ended up talking about the city that I lived in in [location] for the next five minutes and then he was like 'Ok well you can go now.' …So umm I felt like it definitely more of a behavioral thing that he was looking for... So there was that but he also I could tell he was just trying to see if I was a person he could work with for an extended period of time without feeling like you know having tension between us. [Student 4 Interview]*

Here, the student admits to being initially intimidated by the mentor but, after a short discussion during the interview process, realized that he was actually just trying to get to know the student and make sure they were a good fit for the project. By showing a genuine interest in students, mentors can establish rapport and create an environment in which the students feel comfortable approaching and talking to their mentors.

Implications and Future Work

Initial findings from this study indicate three major mentoring functions that contribute to student perceptions of mentoring. Although separate, these three salient functions work together to promote an atmosphere of mutual respect and enhance teaching and learning in project-based courses.

In terms of coaching, mentors need to be aware of the balance between providing direct instruction and allowing students to learn on their own. While it is useful for mentors to have the technical knowledge and skills relevant to the project at hand to help guide students in the right directions, knowing how and when to ask critical questions and provide that guidance is critical for effective student-centered learning. By keeping up with the status of the project, or providing protection, mentors can be better prepared to gauge the kind and amount of guidance given to students as well as the timing with which that guidance is provided. Lastly, in order for the feedback or advice to be perceived as valuable to the students, mentors need to establish rapport with their students in a way that makes them appreciate and understand where criticism is coming from. As efforts to implement project-based learning increase, curriculum developers need to be aware of and consider the strategies that promote student success in these kinds of environments.

As this multi-case study continues, future research will add data from additional cases to more fully characterize both the similarities in mentoring practices and the variations that emerge in how those practices are enacted by different faculty. Across the cases considered here, the faculty mentors had widely varying levels of experience and personalities, yet in each case students seemed to recognize and describe similar practices. Better understanding both how students experience a wide variety of mentors and how these practices support learning can help design instructors more effectively explore and develop their own practices in ways that align with their natural teaching styles, as well as identify areas where they may need to gain additional skills. Future research will also seek to understand how these student perceptions of mentors affect learning outcomes for their respective courses in order to further enhance the efficacy of mentoring functions within ill-structured, open-ended, real-world problems.

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