A Case Study of Students' Engagement in a Control Systems Homework Problem

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***Abstract*— (*Abstract*)**

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I. INTRODUCTION

Despite intensive education reform efforts and initiatives to improve undergraduate engineering education, many engineering students still graduate with gaps in their disciplinary knowledge and skills [1,2]. Sense-making about scientific concepts is not always privileged in typical engineering courses, which instead often focus on textbook coverage. This focus on "covering the content" may contribute to the difficulty some students have in building deep conceptual knowledge. Discipline-based education research in science and engineering has demonstrated the effectiveness of student-centered instruction in "improving students' conceptual understanding, knowledge retention, and attitudes about learning in a discipline (p.14)," yet many instructors continue to rely on lecture-based pedagogies [3]. More studies focusing on student-centered strategies and instruction practices within disciplines, especially at the undergraduate level, will strengthen reform efforts and initiatives [1].

Practitioners and researchers of undergraduate engineering education have been interested in better engaging their students in their courses [3, 4]. Students are asked to participate in many activities during a course: prepare for class by reading, listen to a lecture, ask questions, respond to questions, complete homework assignments, conduct laboratory experiments, and design prototypes. There are many activities to consider when thinking about students' engagement. We are specifically interested in three major categories of activities typically used as graded assignments in engineering courses: homework problem sets, laboratory exercises, and design problem projects.

For our research program on the dynamics of learning in undergraduate engineering courses, we are building ethnographic records of engineering students carrying out these three kinds of activities (problem sets, labs, and design projects). The first phase of the research effort involves collecting video and interview data from a range of engineering courses – both engineering science and engineering design – and developing and iterating on an approach to characterize productive disciplinary engagement in that data set. The focus of our data collection is on required courses for a degree in mechanical engineering. The collection of data includes first year courses, comprised of students going into a variety of majors, required courses for sophomores and juniors, and elective courses usually taken senior year. Participants self-selected to participate in the studies by consenting to participate in research.

Productive disciplinary engagement (PDE) is a construct developed by Engle & Conant [5]. In their definition of the construct, *productive* means that students are intellectually progressing. *Disciplinary* refers to students using language of and taking up practices of the academic domain being studied. When students are productively disciplinarily engaged, they are immersed in the practices of the discipline that result in deep learning.

The analysis presented in this paper is focused on a smaller case study derived from the first phase of our overall project. The key data for this case study consists of video recordings of three students working on a homework problem set for an engineering science course, specifically a junior level mechanical engineering course on control systems. One episode from the homework video data stood out to researchers at first for the remarkable collaborative stance taken by the three students and the strong peer support that seemed to be offered by their student-to-student discourse. While our analysis ultimately revealed limitations in the productive disciplinary engagement afforded by this particular problem set, we still wanted to understand how the students' ways of working on this activity were influencing their learning.

Koretsky and Nolen [6,7] have applied the construct of PDE to better understand how undergraduate students work on engineering design problems. In their analysis of chemical engineering students working on a senior design problem, they coded for smaller elements of PDE, which they called *knowledge construction* or engineering practices, and elements that are not considered PDE, which they called *task* *production* or school practices. We utilized their definitions of task production and knowledge construction to guide our examination of the students' activity in the controls problem set session.

After analyzing the data for instances of task production and knowledge construction, we examined how these elements indicate the students' epistemological framing. In general, examining people's *framing* means attempting to understand their expectations of a situation based on previous experiences they've had [8, 9]. *Epistemological* framing [10], specifically, looks at framing during learning activities; it refers to learners' expectations of how knowledge will be used and developed in an activity and their sense of an activity's goals and purposes, which may or may not align with the goals established by the instructor. While some believe students become fixed in their stance toward an activity [11], we believe students' framing can shift while participating in an activity. Previous research on epistemological framing has examined students working on physics activities [12, 13].

In our analysis, we aim to investigate two research questions 1) How are students' ways of working on this problem set influencing their learning? and 2) How do students ways of working on this problem set and accompanying discourse during a homework session inform us how students are framing what they are doing?

II. METHODS

This qualitative study uses microethnographic methods [14] and draws on an a priori coding scheme for task production and knowledge construction proposed by Koretsky and Nolen [7] to examine video of three students working on a homework problem from an introductory controls systems course. In Koretsky and Nolen's descriptions, task production involved "cognitive talk oriented at the completion of the set work that was prescribed by the instructor (p.4)," whereas knowledge construction involved "cognitive talk directed at making meaning, trying to build connections between ideas and understanding, and answering how and why questions (p.4)" [8]. Examining a homework task instead of a design task, we tailored these definitions to the analysis of the homework session.

The specific problem discussed in this session is the fourth problem (Figure 1) on the eighth problem set assigned in the semester long course. The problem asks students to examine two input and output signals of a model of a system that is not dependent on time. Using the plots, they must determine a number of values of the system. Also given in the problem is a proposed equation of the function of the system, and the students are asked to determine which of the two plots is closest to the equation.

C, S, and L, the three participants in this homework session, were female mechanical engineering students in their junior year. After noting individually to the researcher they frequently work together on homework, the researcher asked the students if she could visit and video record their homework session. During the homework session, video was taken of each individual's paper as well as multiple views of the room. After the session, copies of the students' homework were collected. Interviews were conducted with each of the students one year later, but these were not analyzed for this paper. Besides this homework session, the researcher observed these students in lecture session and lab session; they usually sat close to each other in the classroom and collaborated on in-class laboratory activities as well.

4. (25 points) The input signal and output signal at steady state for a first order linear time invariant system for several different input frequencies are shown below.
   a. For each plot, determine the input frequency ω, the input amplitude A_i , the input phase ϕ_i, the output amplitude A_o, the output phase ϕ_o, the magnitude $M(\omega)$, and $\phi(\omega)$.
   b. Assuming the transfer function of the system is $G(s) = \frac{K_{DC}}{\tau s+1}$, which plot corresponds to an input frequency of $\omega = 1/\tau$?
   c. From which plot can you estimate K_{DC}?
   d. Plot the entire Bode plot using MATLAB.

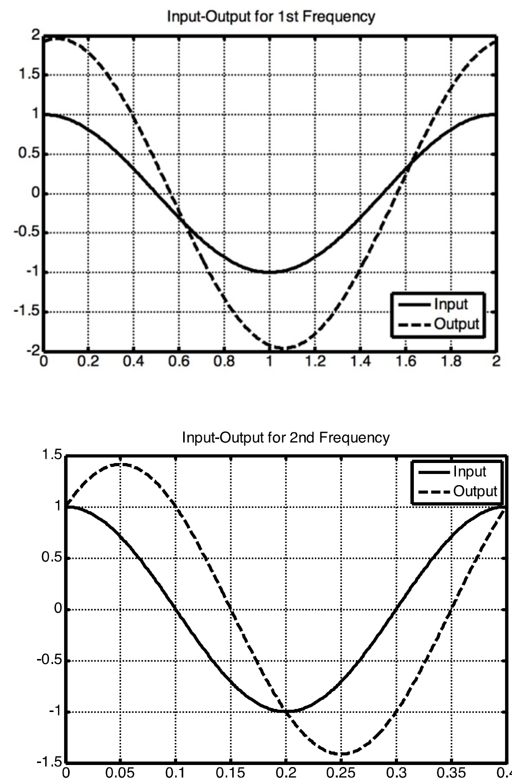

FIGURE 1: HOMEWORK 8, PROBLEM 4

Analysis began by viewing and taking notes on one of the videos taken at the homework session. One researcher then transcribed the fifty-one minute clip excluding the sections of off-topic talk and then closely reviewed the trascript to begin to characterize the sections of student discourse. Portions of the video were viewed and discussed by the research group with a focus on identifying instances of task production and knowledge construction.

III. Analysis and Results

A. *Question 1: Understanding the influence of students' ways of working on their learning from problem sets*

We found that during the homework session, the students spent the majority of the time engaged in task production and found little evidence of sense-making or knowledge construction. In fact, we found only once instance of students making a bid to switch the conversation to knowledge construction.

Throughout the transcript, the students' talk centered much of the activity on finding a numerical answer for a certain variable, discussing how to find these numerical answers, and checking with each other to determine if they had the same answers. Little talk was spent on how these variables were related or what they represented in terms of the control system being analyzed in the problem.

The one moment that interrupts their task-centered discourse begins with one participant asks the group to help her understand three of the different variables. This triggered a brief moment of discussion about the meaning of variables but the discussion quickly returned to the manipulation of variables.

> C: wait I don't see how this is different
> L: what do you mean?
> C: like what's the difference between phi omega and the other two
> S: I'm not particularly sure
> L: oh wa-wa-wa-wait I've written this down somewhere
> S: what does peak to peak output amplitude mean
> L: yeah no no look cause this is so we have phi out plus equals phi in plus phi of omega okay so I'm just getting this out of the way cause this is.....
> L: but you can also do it this way but we don't have either phi out of phi omega

By asking these questions, C is trying to pull the group away from pushing forward on the task and taking a moment to sense-make about the difference between variables. S supports the idea by asking a question herself. Yet, L, turning to her notes, brings the group back to equation manipulation and task production. C does not press the group to pause for sense-making for the rest of the session.

While we acknowledge some task production is productive for the completion of homework assignments, the absence of knowledge construction causes us to wonder how students are thinking about building their knowledge. We continue our analysis with an examination of their epistemological framing to try to help us answer this question.

B. *Question 2: Indications of the students' epistemological framing*

By examining the students' ways of working through the problem, we see indications that the students frame this homework assignment as a task to complete instead of an exercise to sense-make and build knowledge. While there are few bids to shift the frame into sense-making, as exemplified in the transcript above, the majority of the students' frame orientation is to achieving consensus on the best answers to the homework problem. A focus on completion of a task like this is sometimes referred to as the 'classroom game' [15,16].

Another aspect of the students' framing of the homework activity involves where they expect to find knowledge to complete the task. For example, in the episode below they are discussing how to calculate M-omega.

> S: Phi of omega was maybe supposed to be this, the phase, where it says harder. And m of omega was supposed to be this (taps on paper), and then the original phase output….I don't know. I'm just throwing out ideas here.
>
> L: No, I see what you're saying. Oh, cause, yeah, no. I think you're right cause look, cause he's saying this. I think whatever this omega J is equal to, the m omega right? Is this what he's saying? With this? (shows paper to S)

Confused about how to conduct the calculation, S and L look through their notes that the professor gave in class. In both the first excerpt of transcript and again here in the second, L referenced her notes as the place to find knowledge. She shows an orientation to the notes for knowledge, instead of to her own resources for sense-making

The discourse of the three students shows the students frame the activity as mostly a task to complete instead of an opportunity to build knowledge. L's talk and gesturing reveal an expectation that her class notes serve as the source of the knowledge needed to clarify their confusion. This expectation is an important dimension of L's framing of the homework problem set.

IV. Conclusions

In this case study we examined a homework session for beginning elements of productive disciplinary engagement. We found much of the activity the students were doing was oriented to complete the homework problem and not taking opportunities to build knowledge. Building on our analysis, we looked for indicators of the students' epistemological framing. The students discourse and ways of doing the activity pointed to their framing of the problem as a task to complete instead of an opportunity to build knowledge.

This case serves as a preliminary step in examination examining engineering activities for elements of productive disciplinary engagement. Going forward, we hope to contribute to the growing body of literature with our analysis of engineering learning activities.

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