Board 53: WIP: Learning Assistant ”Noticing” in Undergraduate Engineering Science Courses

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Hernán Gallegos is an undergraduate student at Tufts University. He is studying Mechanical Engineering and minoring in Engineering Education. His academic interests lie in trying to aid students to understand engineering concepts and how they can enhance their learning through various resources. With this in mind, he is working within the Engineering Learning Systems lab under Professor Kristen Wendell, a Mechanical Engineering Professor. With this opportunity, Hernán is able to further his understanding of both engineering and education to aid the generations who aim to become future engineers.

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Work-in-Progress: Learning Assistant “Noticing” in an Undergraduate Engineering Science Course

Many engineering educators are exploring new approaches to support more productive learning behaviors during required engineering science courses. These approaches range from pedagogy workshops for faculty to programs fostering student reflection and meta-cognition. Some engineering departments are also establishing “learning assistant” (LA) programs that incorporate pedagogically trained undergraduate students as members of course instructional teams [1], [2], [3]. Under this model, undergraduate students receive a stipend or course credit to serve as facilitators of student thinking for a course they have already taken. When interacting with students during class sessions, learning assistants (LAs) typically focus on asking open-ended questions to prompt sense-making [4], [5]. They focus on supporting the learning process rather than on tasks typically associated with traditional teaching assistants, such as providing homework solutions or grading exams. LAs are trained in student-centered pedagogy through a weekly “pedagogy seminar” offered specifically for them and led by an instructor with expertise in science or engineering education [6].

Empirical studies have shown that students in STEM courses with LAs make higher gains on concept inventory tests than students in similar courses without LAs [7]. There is also evidence that serving as an LA fosters disciplinary identity [8], and that the presence of LAs narrows the traditional learning gap between students from dominant and non-dominant (i.e., underrepresented) populations [9]. However, little is known about the mechanism through which LA programs support these improved outcomes. One hypothesis is that LAs may notice and respond to aspects of student thinking that complement what faculty instructors notice.

In this pilot study, we implemented a small LA program in the thermodynamics course required for mechanical engineering students at a private university in the northeastern United States. A total of 41 students were enrolled in two sections, which were taught by two different mechanical engineering faculty members. Both instructors agreed to include an undergraduate LA as part of their instructional team and incorporate small-group problem-solving as part of class time. The learning assistants were Janelle, a black female fourth-year student, and Jasper, a white male third-year student. Each assisted in all regular class meetings of their assigned thermodynamics section and also ran a weekly recitation session. We conducted a qualitative case study to investigate the research question, *What aspects of engineering student thinking and related features of the learning environment do undergraduate learning assistants notice in an introductory engineering science course?*

Theoretical Framework

This study is grounded in the *responsive teaching* perspective on instruction [10]. This perspective holds that effective instruction involves three overlapping phases of interaction with students: eliciting, noticing, and responding to student thinking – or, more specifically, eliciting students’ own ideas related to a problem or phenomenon of interest in the discipline, noticing the beginnings of disciplinary content in those student ideas, and responding in a way that helps the student make progress toward constructing more accurate and robust disciplinary knowledge and practices. Because this study is a preliminary investigation, we focused data collection and analysis on just one of the three major components of responsive teacher: *noticing*.

Data Collection and Analysis

Following descriptive case study methodology [11], we collected multiple sources of data to capture evidence of the LAs' emerging capacities for noticing student thinking. Primary data sources include field notes from the weekly pedagogy seminar sessions and end-of-semester interviews with the LAs. The pedagogy seminar (see Appendix) was co-developed by a mechanical engineering faculty member who conducts engineering education research and an advanced doctoral student in engineering education. The doctoral student facilitated the 11 seminar sessions, and the faculty member participated in four of them. A research assistant observed the sessions and kept field notes. The research assistant conducted an end-of-semester interview with each LA. The interviews were semi-structured and asked the learning assistants to describe their role in the thermodynamics course, their thoughts about strengths and weaknesses of the LA program, and their perceptions of its impact on themselves, students, and faculty. Similar interviews with both faculty members serve as a secondary data source.

Drawing from grounded theory methods [12], the first author conducted line-by-line open coding of the interview transcripts and pedagogy seminar field notes for evidence of LA noticing of students' thermodynamics ideas and practices and the aspects of the learning environment that influence them. After open coding, we grouped all tagged data excerpts into categories of noticing. Finally, we used constant comparative analysis to refine category definitions [13].

Findings

We organize our findings by three major categories of LA noticing: *noticing students' disciplinary ideas and practices, noticing the influential features of the learning environment and social dynamics,* and *noticing changes in one's own learning*. However, before describing the evidence of LA noticing, we note that this pilot LA program was generally perceived as a success for student learning. The students in the course gave the program favorable ratings on both course evaluation surveys and separate program surveys. Both faculty members continue to work with LAs in subsequent semesters and in additional courses. Moreover, in interviews, the faculty identified several ways in which the program supported their teaching efforts. One professor reported that he interacted with more of the class, especially students who kept a low profile; enabled more students to interact with other students; and obtained higher quality information about student thinking, especially about the reasoning behind their problem-solving procedures. The other professor noted that she was able to listen to more conversation of more students; that students learned more than in the past about how to work together; and that students were both more active (with the information) and more interactive (with each other).

Category 1: LA noticing of students' ideas and practices in thermodynamics. Here we highlight the three kinds of noticing disciplinary ideas and practices that occurred most frequently. The Appendix lists all the codes that resulted from our analysis.

Students' intense focus on equations and limited vision for physical context. At two different pedagogy seminar meetings, Janelle's reflections focused on students' tendency to limit their problem-solving approach to equation seeking. For example, she described a group that "didn't know where to start" because they were only "searching for an equation." She also discussed a student who had come to the LA problem sessions at least three times and who was "really good with equations," but Janelle believed it was her responsibility to "push [the student] into thinking more conceptually." In her end-of-semester interview, Janelle reflected, "While teaching, I realized this, not everyone can take a step back….They're like really focused on equations."

Students' misdiagnosis of their own understanding. Twice during the pedagogy seminar, Jasper reported on interactions with students where he had discovered the students were mistaken about the status of their own understanding. In one instance, Jasper had to re-phrase a student's question to accurately express the student's confusion, and in the other instance, Jasper saw that students were incorrectly judging that they did not understand a concept because Jasper's problem-solving method was much more efficient than theirs (but not necessarily more correct).

Students' novice conceptions of the first law and related definitions. Jasper noted in his interview that some students were reading the first law of thermodynamics (energy conservation) very literally, and he and Janelle needed to talk with students "about fundamentally what the first law means and how you can interpret it." They also both shared in multiple pedagogy seminars that students were still wrestling with the meanings of key quantities; they were "having trouble with heat versus temperature."

Category 2. LA noticing of the influence of learning environments and social dynamics. Below we describe three aspects of the course's learning environment that LAs most often noticed as influencing students' thermodynamics thinking.

Range and evolution of discourse dynamics within small groups. Variation in discourse style across small groups was a recurring theme in pedagogy seminar. The LAs noticed that in some groups, all students spoke up with ideas and questions for solving the in-class thermodynamics problems, while other groups were dominated by one or two very vocal students, and yet others were universally quiet. Jasper realized that sometimes they were talking but with very low voices "kind of like they don't want anyone to hear if they do really know what they are doing." Janelle noted that when groups had members with pre-existing friendships, they were more likely to see turns of talk spread evenly across group members.

Tensions in achieving equitable discourse. The LAs reported seeing more frequent advances in understanding in the groups with more equitable distribution of talk, and they asked for advice on how to help all groups function that way. They paid attention to what happened when they did try to intervene for more productive small-group talk. Janelle described one outcome of forcing someone who resisted joining a group to do so: "they're just like bad group members and just like take over everything." She also noticed groups that functioned well even when one or two members talked "slightly" more than others. In her observation, there was a difference between unproductive dominance of the conversation and productive leadership.

Instructional team demographics and characteristics. At a larger grain size than small-group dynamics, both LAs seemed to notice a relationship between students' sense of welcome and inclusion in a course (though not necessarily thermodynamics) and their likelihood for deep content learning. It was not that they directly described episodes of inclusion or exclusion in thermodynamics class, but that the LA program seemed to inspire them to articulate a general noticing of the role that inclusive practice plays in students' engineering learning. For example, in his interview Jasper talked about the importance of diverse instructional staff:

> "I think it's important who the LAs are and like, in the future should be, should be vetted based on like how they can make themselves more accessible, or not accessible, but…. Cause it's already easy for, for like, white male nerds from high school to assimilate into the engineering program. Because all of the professors are pretty similar to that model. So I think just like anything different from that is good for identity wise. Cause otherwise, you have people who don't seem themselves in professors and don't see themselves in a lot of their classmates, uh, and I think that's problematic. Or at least like something we should avoid."

During pedagogy seminar, Janelle and Jasper talked at length about the silencing and lost opportunities for learning that can occur when a student is teamed with peers who happen to already have strong expertise in the content of the course; they discussed how such heterogeneous grouping can make a student feel like her or she does not belong in the course. After this discussion Janelle noted that "privilege/power dynamics" play a role in learning and requested more discussion of that topic. But, both she and Jasper thought that the presence of LAs overall had made thermodynamics more "welcoming" for students.

Category 3. LA noticing of their own learning. The LAs reflected substantially about how the LA experience influenced their own ideas and practices in thermodynamics and related fields.

Uncovering connections between thermodynamics, heat transfer, and fluid mechanics. Janelle and Jasper both noticed that their LA work deepened their understandings of fluid mechanics and heat transfer, topics they had studied in between their two exposures to thermodynamics. Janelle reported, "seeing the material again you're like, whoa, energy is just energy," and "after taking fluids and heat transfer, I can see how everything comes together now." Similarly, Jasper shared that he saw thermodynamics connecting to heat transfer, "especially in terms of like heat rates, versus heats – I think I got a lot of connectivity back to thermo from that."

Improving problem solving by looking for overall structure and systems perspective. Another area where both assistants noticed self-growth was in taking a more holistic approach to engineering problem solving. Janelle realized as she watched students do their thermodynamics problem that "sometimes you can do the homework without understanding the concept," but "when you have to teach it,… you're less worried about the nitty gritty…you're trying to explain what the different parts of the system are." She concluded that it gave her the "ability to zoom out and ask what is going on, what are we doing." Jasper also observed changes in his strategy for attacking problems. He saw that initially he "would skip steps that I didn't even know I was skipping," but he learned by the end of the semester that "I gotta think about this a little bit more, … more like in an objective structure, like in how I see some problem."

Conclusion

This qualitative analysis is a first step at characterizing the extent to which and the ways in which learning assistants can demonstrate responsive teaching capacities. These findings may have implications not only for the design of learning assistant programs in engineering departments but also for faculty professional development.

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Appendix

All Categories of Learning Assistant Noticing

Noticing students' ideas and practices in thermodynamics	Noticing social dynamics and the learning environment	Noticing own learning
1. Students' intense focus on equations and failure to see physical context 2. Students discovering consistency across two different solution approaches 3. Students need the problem to be fun 4. Students struggled too much or too little for optimal learning 5. Students' misdiagnosis of the source of their confusion 6. Limitations in students' interpretation of the first law and related definitions 7. Limitations in students' sense for units 8. Confusion with thermodynamic tables 9. Limited physical intuition; limited concrete understanding of physical devices and systems 10. Students who love to talk can still give inaccurate explanations 11. Students can realize and correct their own errors through discussion of concepts 12. Students can make productive changes to their own learning approaches	13. Benefit of recitation: students who attended gained understanding over multiple sessions, or better saw connections between concepts 14. Range and evolution of "chemistry" and equity in group dynamics, affected by pre-existing friendships 15. Important to get people to talk, but forcing people into groups can have negative consequences, including dominating the discourse 16. One student talking more than others wasn't always problematic 17. Demographics and characteristics of LAs matter for inclusion, which is worth talking about in engineering courses 18. Physical setup of class and location of students influences learning	19. Seeing how thermos, fluids, and heat transfer connect 20. Conception of energy as basis for better intuition about physical systems 21. It is productive to focus on explaining at a holistic systems level, or look for the structure of a problem, before focusing on equations or starting solution steps 22. Increased self-awareness of greater interest in concepts than practices

Pedagogy Seminar Syllabus

Week	Topic	Readings to Discuss
1	Effective Questioning/Questioning Strategies	Blosser, P. (2000). *How to Ask the Right Questions.* National Science Teachers Association. Michaels & O'Connor. (2012). *Talk Science Primer.* TERC, Cambridge, MA.
2	Introduction to thinking about learning, constructivism	Hartle, Baviskar, & Smith (2012). Field guide to constructivism in the college science classroom. *Bioscience, 38*(2). Introduction and Chapter 1 from Duckworth, E. (2006). *'The having of wonderful ideas' and other essays on teaching and learning.* (3rd ed.) Teachers College Press.
3	Conceptual knowledge in the engineering sciences	Streveler et al (2008). Learning conceptual knowledge in the engineering sciences: Overview and future research directions. *Journal of Engineering Education.* [Read ONLY pgs. 282 to 289]
4	What is thermodynamics expertise?	Turns, S. (2012). Applying knowledge from educational psychology and cognitive science to a first course in thermodynamics. *Proceedings of the American Society for Engineering Education Annual Conference*.
5	Diversity & inclusion in engineering	Chapters 1 & 4 of Camacho & Lord. (2013). *The Borderlands of Education: Latinas in Engineering.* Lexington Books.
6	Responsive teaching (with video cases)	Chazan & Ball. (1999). Beyond being told not to tell. *For the Learning of Mathematics, 19*(2).
7	Formative assessment	National Research Council. (2015). *Reaching students: What research says about effective instruction in undergraduate science and engineering.* National Academies Press.
8	Alternatives to the traditional lecture format	Waldrop, M. (2015). "Why we are teaching science wrong and how to get it right." *Nature*.
9	Personal epistemology	Lising & Elby. (2005). The impact of epistemology on learning: A case study from introductory physics. *American Journal of Physics, 73,* 372-382.
10	Culture of classrooms; inclusion	Secules, S., Gupta, A., & Elby, A. (2016). Turning away" from the Struggling Individual Student: An Account of the Cultural Construction of Engineering Ability in an Undergraduate Programming Class. *Proceedings of the American Society for Engineering Education Annual Conference*.
11	Marginalized Identities of Sense-makers	Danielak, B. A., Gupta, A., & Elby, A. (2014). Marginalized Identities of Sense-Makers: Reframing Engineering Student Retention. *Journal of Engineering Education*, *103*(1), 8-44.