Promoting and Studying Deep-Level Discourse During Large-Lecture Introductory Physics

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Abstract. At Oregon State University, the introductory calculus-based physics sequence utilizes social engagement as a learning tool. The reformed curriculum is modeled after the Interactive Science Learning Environment from Rutgers University, and makes use of Peer Instruction as a pedagogical tool to facilitate interactions. Over the past two years we have utilized a number of techniques to understand how to facilitate activities that promote productive discussion within the large lecture classroom. We specifically seek student discussion that goes beyond agreement on conceptual questions, encouraging deeper discussions such as what assumptions are appropriate, or how different assumptions would change the chosen answer to a given question. We have quantitative analysis of engagement based on video data, qualitative analysis of dialogue from audio data, and classroom observations by an external researcher. In this paper we share a subset of what we have learned about how to engage students in deep-level discussions during lecture.

Keywords: Communities of Practice, Active-engagement, Large lecture, Discourse.
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INTRODUCTION

At Oregon State University, the introductory physics sequence is undergoing curricular reforms including both pedagogical and the physical classroom environment. The reforms heavily utilize social engagement in physics discussions as a learning tool. The reform curricular is modeled after the Interactive Science Learning Environment (ISLE) aimed at developing scientific abilities in students: representing information, conducting experiments, thinking divergently, collecting and analyzing data, constructing, modifying and applying relationships and explanations, being able to coordinate these abilities [1]. Implicit in these goals is a set of meta-goals including helping students develop scientific discourse, metacognition, self and peer evaluation, brainstorming multiple explanations, reconciling different solutions, understanding when models apply (assumptions), and discussing open-ended situations.

These goals are in part supported by providing opportunities where students can engage in developing them during in-lecture activities. Within the large lecture, the students initially are newcomers to the learning environment, and the instructor is a reflective practitioner and broker: a representative of the physics community.

SITUATED PERSPECTIVE

The knowledge we build encompasses ways of communicating and behaving, which is situated in the context of both the environment and its participants [2]. Knowledge is developed with members in a Community of Practice (CoP) through “social relations in which persons and practices change, re-produce, and transform each other [3].” As newcomers interact with others in the community “through a social process of increasing centripetal participation, which depends on legitimate access to community practice [3],” they come to negotiate and make sense of the shared practices. Through this process, newcomers can become more central members of the CoP [2].

The identity development toward becoming a central member of the CoP includes actively participating in social interactions with others, perceiving and being treated as a valued member who can affect change in the practices, and believing that engaging in these practices will achieve the common endeavor. It is the social interactions where students make meaning in class that mediate the building of a shared repertoire of knowledge with sophisticated discourse. Therefore it is important to examine how to support discourse during class interactions.

INSTRUCTIONAL MODEL

Within the large lecture, we aim to use activities to achieve student learning goals and to model scientific discourse for students in a number of ways. We have a model for developing, implementing, and assessing activities. In this instructional model, meta-goals are set prior to the course, and classroom activities are written to support them. In the classroom, the instructor uses some of the lecture time to discuss subtleties regarding the meta-goals, such as how to approach open-ended problem solving, and demonstrates the type of dialogue she hopes the students will develop. When addressing the full class for open discussion, she models group discourse by posing questions that facilitate discussion beyond Socratic dialog. When students break into small groups for activities, the instructor wanders among the students, interjecting where appropriate to model discourse within the small groups. Students slowly acquire the discourse and practice it with their peers. After each class, the instructor and an independent research observer meet and discuss classroom dialogue and whether activities met the goals they were intended to meet. This post-class dialogue helps us refine the activities and scaffold in new meta-goals.

Modeling discourse via whole-class discussions

Traditional lecture-mode provides excellent opportunity for modeling discourse. Not only can the instructor use the type of language and argumentation she wants to encourage in the students, but she can negotiate discourse when posing questions to the whole class for open discussion. It is important for the instructor to act as a Broker; she models discourse from the physics community and helps the students feel comfortable trying out such practices for themselves. This not only involves appropriate use of terminology but also the practice of valuing explanations from all members of the community, contributing to shared knowledge development. An example of this follows.

In one lecture, a student interrupted with a question. Instead of launching into another explanation, the instructor asked “what is your understanding so far?” In posing this particular question in return, the instructor afforded the student an opportunity to share his understanding and convey to the class that the instructor is not the sole authority within the classroom community. It became apparent that the other students recognized this shift to shared authority when a second student immediately understood the first student’s explanation and contributed a great explanation for the first student. The second student had held the same view a few minutes prior and had just come to make sense of it himself using the modeled ‘if then’ reasoning used in the ISLE curriculum. Through this process, the students constructed shared meaning as a whole class through actively speaking or being engaged in listening.

Activities to promote discourse

From the very first week of the course, students’ expectations are challenged by giving questions with multiple correct answers. They quickly realize an unexpected classroom norm: their voting machines will always be set to ‘multiple-mark’ mode (instead of multiple-choice), so any given question may have multiple acceptable answers. This then leads to posing open-ended questions to the students, where either there is no one correct answer (such as multiple equations which can all be used to solve a kinematics problem), or where the ‘correct’ answer depends on interpretation or assumption choices for that particular situation. These questions lend themselves to productive scientific debate and often spur conversations involving many students sharing their ideas in front of all 200 of their classmates.

Questions are written during the term based on student ideas and reasoning they bring up during lecture. For example, within the ISLE experimental cycle, student-generated explanations can be used to spur further discussion about how to test those explanations, or whether the tests of them matched the prediction they would generate. This type of on-the-moment question brings the students contributions to the main stage: their words become the basis of the class discussion. Other questions use the community-developed knowledge to address new situations, placing their generated ideas as the foundation for understanding science.

Facilitation prompts for group work

Through our instructional model, we have found particular prompts which help promote discourse during group activities. These prompts have been measured to increase student participation in peer instruction [4]. Each of these prompts is situated within the CoP framework, as holding that model impacts the way the instructor views discourse with the students. Some of these prompts are:

- Encouraging discourse and acknowledging struggle: "Go ahead and **talk to your neighbors**, this is **not particularly easy.**"

- Encourage students to teach and value social learning: “I see from the results that it would be **helpful to talk to your neighbor**, so go ahead and do that.”
- Encouraging re-thinking of classroom social norms: "If you are not near a neighbor, just shout. It can get **loud in here** that's **fine with me**.”
- Giving students responsibility for their thought process: "Give it a try. See what **you** think.”
- Expecting students to immediately use methods just modeled for them: “Give **you** a chance **to think about how to apply** these things.”

Modeling discourse via interacting with small group during group work

Small group discussions provide space for students to take control of the reasoning process and practice authentic scientist talk patterns. The instructor is also able to promote opportunities for shared authority with students while circulating among them during group work. The students in the discussion below converse with the instructor after having spent a few minutes reasoning amongst themselves about how to solve a kinematics problem. The first student (S1) posed the question at the teacher (T) with the expectation that the teacher is the source of “right answers.”

S1: [Looking up at T] Will the bullet have a trajectory like that or will it just go straight?
S2: The bullet’s gonna drop a little bit…
S1: Yeah…
T: It will drop a little bit. So you are both right, the bullet’s gonna slow down but does that tell us what’s going to happen?

Instead of answering right away, the teacher waited to see if others in the group would contribute. The second student jumped in right away to contribute his understanding. In this way S2 is afforded an opportunity to contribute similar to one he might encounter in a team project environment in the workplace. After the two students have voiced their thoughts, it would be typical of classroom talk for the teacher to evaluate their answers; instead, the teacher waited a moment longer which allowed S1 to acknowledge S2. In doing so, S1 validated S2’s right to answer as a contributing member of the group. The teacher then took her turn to contribute to the knowledge building process by validating the students’ ideas and directing the task of meaning making with a guiding question. She also used the word ‘us,’ emphasizing that she is not acting as the authority but rather as a partner within the classroom community. This pattern of discourse served to encourage the curricular goals of student taking ownership of knowledge. By having the teacher take a smaller, passive role instead of the traditional active role of knowledge provider, the role of knowledge development became available for the students in the discussion.

Evidence of students adapting discourse practices within groups

By audio taping student groups we collect samples of discourse during the large lecture. This allows us to assess whether students are adapting the practices being modeled, and acquiring the meta-goals for the course. In the discussion below, the class was asked to work in small groups to figure out a problem involving a cat falling off a roof. (These are not the same students from the previous dialogue.) The students first negotiate the initial and final points for an open-ended situation.

S4: We just need to define this…
S3: …the states. So initial is… exactly what it says, just after leaving the roof. [S4 writes]
S5: [to himself] Well initial and final would be the same… but…
S3: [to S4] And then you have to state the origin is… the ground.

The students demonstrate the practices of defining the origin, enforced by the instructor, and using a set of terms and phrases common to the discipline of physics. While these are productive practices, having practices dictated by the instructor can act as constraints for how the students approach and discuss physics. Boaler [5,6] suggests that constraints limit students’ ability to use classroom knowledge in situations outside of class where situations differ significantly from inside the class. While the authors would argue this is a case of productive constraints, it is a consideration worth keeping in mind.

Later in the same discussion, the group of students tackled the open ended aspect of the question by discussing the selection of their system:

S5: [turns to face each other] Would the system be the… I know it’s the cat and Earth at least, but would the… roof be part of the system or…
S3: It wouldn’t need to be.
S5: Yeah…
S3: Cause the only thing interacting is the cat with the ground, with the Earth due to gravity.
S5: Yeah.
S3: That’s our only interaction. We’re going…
S5: It’s pretty much just the position and place. [pause] Doesn’t add or take anything away from it, except just gives it a position for the cat to be on.

One practice in which the students engaged was to support their claims with justification. This practice was required in homework and lab write-ups, was modeled by the teacher, and was elicited by the teacher when students answer questions before the whole class and in small group discussion.

Due to the open-ended nature of the question the students were trying to answer, students had more freedom in how to answer and defend their choice with reasoning in the process of creating the shared meaning. The justifications of S3 tended more towards reasoning similar to those given by the teacher who used interacting objects to decide what needed to be in the system; S3 cited interactions in his explanations twice in this discussion. In contrast, the justifications of S5 tended more towards reasoning that had to do with the physical situation; S5 explained the purpose of the roof in the problem and reasoned why it did not need to be in the system. Both types of justification were accepted by the two students engaged in the discussion which suggests that the students were aware of the greater degree of flexibility afforded by the type of question and multiple explanations are acceptable.

S4's re-engaged later in the discussion (full transcript not given) to mention that the group had not answered the mathematical representation question posed within the problem. This suggests that his physics learning identity in this CoP is that of a received knower [7]. In comparison, S3 appeared to have a physics learning identity more consistent with that of a connected knower who was able to make sense of the physics knowledge constructed in a variety of practices. Considering the different types of learning identity shown within just a small portion of transcript emphasizes the need attend carefully to the classroom practices, the student learning identities, and the knowledge built as students participate within the learning community.

Post-class reflections to refine activity facilitation

During one class, students were engaged in an ISLE-based observation experiment where they were describing and representing the motion of a ball popping out of a cart in different reference frames. After class, the research observer and the instructor journaled about the class activities and discourse, then discussed their observations. It was noted that the second section of the class tossed out a wider range of ideas, and we realized that constraining the task for the students limited their reasoning. We later changed the activity to include brainstorming multiple explanations before drawing representations. Both sections were able to discuss limits and assumptions, and even bring up assumptions on their own (fairly early in the term), allowing promotion of broader discourse about projectile motion including friction and drag.

WHAT WE'VE LEARNED

We find that our instructional model enables us to promote scientific discourse even among a class of 200 students. This is facilitated on multiple levels: through careful activity choice, through modeling discourse, through providing students ample opportunity to practice discourse, and through making careful observations to modify instructional materials both to include student contributions as discussion questions for later days within the class and for improving the way questions are written for later terms.

We find that using CoP as a theoretical framework affords ample ways of encouraging and analyzing student discourse. When the instructor views the classroom as a learning community, it changes the types of prompts given to students, and the type of dialogue exchanges between the students and herself. In our observations, this classroom behavior encourages active-engagement and discourse development among the students.

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