Reflective discourse techniques: from in-class discussions to out-of-classroom problem solving

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Abstract. Some instructors give prompts that encourage students to articulate their beliefs and conceptions, as well as encouraging students to understand the thoughts of their peers. This reflective discourse is used in a classroom at Lane Community College, where the instructor explicitly has discourse goals in his course structure. We investigated whether students mimic this discourse when solving problems outside of the classroom context. In order to examine this, we interviewed groups of students in this calculus-based introductory physics class, after the end of spring term 2012. The students were asked to solve open-ended problems using a think aloud protocol in small groups, with analysis of their discourse focused on whether students applied the reflective discourse practiced during the course. Students were then asked a series of follow-up questions to reflect upon their experiences in the course. This paper will address the findings of this study.

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INTRODUCTION

Many physics instructors implement reflective discourse in their classroom in effort to help students express and evaluate their own thoughts and understanding. This is useful for encouraging students to reflect upon and articulate their beliefs and conceptions, as well as learning to understand and incorporate the thoughts of their peers. This kind of discourse in the classroom can also help achieve non-content goals. However, students do not necessarily acquire all of the instructor's goals for a given course [1]. For goals such as scientific thinking, instructors typically want students to utilize these beyond the end of the physics course. The research question posed in this paper is do we know if students implement specific tools scaffolded through instructional discourse practice after the end of the course?

In this paper we present a subset of a larger study, where we observed the third term of the calculus-based introductory physics sequence at a local community college (LCC). In this class, reflective discourse was a core part of the instruction. This type of discourse involves 3 main elements: students expressing their own thoughts and conceptions, exchanges between teachers and individual students that are focused on questioning that helps students better articulate their conceptions, and students trying to understand the thinking of each other [2]. We set out to investigate whether the types of discourse encouraged in class happen unprompted, out of the context of the classroom during group interviews using a think-aloud protocol.

MOTIVATION

Many reforms are focused on helping students acquire the critical thinking skills necessary to be successful in physics. Critical thinking [3] is the "purposeful, reasoned, and goal-directed" [p. 450] use of cognitive skills, without prompting or scaffolding. It requires evaluation of the thinking process and reasoning that goes into solving problems. Indications of positive change can include self-reports and superior responses to novel, open-ended questions [4].

Context

This project is a part of a multi-faced project at OSU involving a large-scale discourse community of faculty from both OSU and two local community colleges. This group meets regularly to discuss PCK, as well as to share and develop activities and assessments. One of the faculty members, DG (a co-author on this paper) is faculty at LCC, and has been involved in the physics education research community for many years. His courses are activity-based, use current PER findings, and his students achieve strong conceptual learning gains (typical FCI [5] normalized gain scores are 0.45). Our focus was on the third term of his introductory calculus-based physics course.

The course contained 12 students; most of which were physics and engineering majors planning on attending either OSU or the University of Oregon after completing courses at the community college. The instructor utilized a variety of reforms in his classroom, including the Investigative Science Learning Environment (ISLE) [6], peer instruction, and reflective discourse. His use of reflective discourse is notable because he is explicit with his students about how this discourse is helpful to them and encourages them to take responsibility for the construction of their own knowledge.

The class met for 7 hours a week in the same room. There were no separate hours assigned to lab, lecture or recitation. Instead, these activities were worked seamlessly in to the curriculum; incorporated as needed to build upon a particular concept or skill.

In interviews, the instructor identified 7 non-content goals, or 'components of parallel curriculum' as: student participation, the evolution of knowing, representation of the physical situation, reflection, problem solving, sense-making, and the relationship between math and physics. Reflective discourse was a strategy used by the instructor to help him achieve his physics content goals, and he considers it essential for achieving his non-content goals. Much of the course structure was centered on giving the students opportunities to analyze and verbalize their own thoughts, listen and incorporate the ideas of others, identify their points of confusion, and learn to evaluate their own understanding. This critical thinking was scaffolded through the discourse, modeled by the instructor, and practiced by students in groups and full-class discussions.

These non-content goals were purposefully built into the curriculum alongside the physical concepts. The instructor was explicit with his students about his intentions and expectations behind what he does in the classroom. Students were encouraged to reflect not only upon their physics knowledge, but also their own learning throughout the course.

Methodology

Two pairs of two students, all of which were representative of the student population, were recruited to be a part of this study at the end of finals week of the third term, after the completion of this course sequence. During the interview, they were given instructions to familiarize themselves with the think aloud protocol by using it while solving a quick practice problem in pairs. After they completed this task, they were asked to work together to solve the following problem:

> Your physics assignment is to figure out a way to use electricity to launch a small plastic drink stirrer with a length of L. You decide that you'll charge the little plastic rod by rubbing it with fur, and then hold it near a long, charged wire. When you let go, the electric force of the wire on the plastic rod will shoot away. Suppose you can uniformly charge the plastic stirrer to Q and linear charge density of the wire is λ. What is the electric force on the plastic stirrer if the end closest to the wire is a distance of R away?

This problem is a modified version of a challenge problem from the Knight [7] textbook, which was not the text they used in the course. Information was purposefully removed to make the problem more open-ended and just beyond the scope of a typical introductory physics sequence. The only prompt given to the students before they started was to solve the problem with their partner using think-aloud protocol.

The students were recorded on video as they worked through the problem together on a white board. Their faces and upper body were captured, along with the solution written on the board so that their writing and their gestures could be analyzed along with their discourse.

After completing the problem, the students were asked a series of follow-up questions prompting them to reflect on their roles as students in the class and their view of the instructor's role in class. They were also asked to reflect on their problem solving throughout the course sequence, and discuss the most useful thing they learned from the sequence. The paired interviews (including the problem-solving task) lasted about an hour and each student was given $10 for their participation in this project.

The videos were then transcribed and analysis was conducted to find evidence of the discourse practices scaffolded in class by the instructor. This discourse was then compared to that observed in class. In this paper, we report on two of the purported non-content goals to analyze the discourse of the students while solving the problem: representation of the physical situation and reflection.

RESULTS

Representation of the physical situation

One major point of emphasis throughout the course sequence was the importance of starting from and agreeing upon a representation of the physical situation, both verbally and pictorially. The discourse was modeled in class as students were asked to:

analyze and verbalize what you know about the situation, listen carefully to others and incorporate their thoughts, come to a consensus with group, identify any points of uncertainty, start from a physical representation and plan the approach from there.

Both pairs of students started the solution to the problem by agreeing upon a physical description and representation of the situation, deciding an appropriate approach, and working from there to develop a mathematical representation and solve the problem. The following excerpt is from the interview with the first group of students. They started by replicating the diagram provided with the problem on their whiteboard. This conversation followed:

> 1: Okay. So we've got the contribution from all the charge bits in our charged wire [2 nods in agreement]. And we're just asked… Oh, okay. So we need the contribution from each of those bits on all the bits of our other charged thing. Symmetry's going to keep all components that aren't along the axis of the plastic Rod going to zero [2 looks at where he's pointing and his face…then nods in agreement]. So…coulombs law [says very hesitantly and looks to 2 for affirmation]… Seems like something we might get back to…
>
> 2: Yeah.
>
> 1: Talking about force. But I don't know if that's a good spot to start
>
> 2: yeah I think that's an appropriate approach. Trying to decide how to… Interpret the fact… I guess where assuming this is like a, infinite line? [1 looking at 2, listening carefully]
>
> 1: I think we should.
>
> 2: Okay so that's, alright. So in that case…alright. So like you said [referring back to something 1 said, as to incorporate his thoughts], well let's just look at the form of coulombs Law to kind of guide us. So, [writes out coulombs law and looks at 1] that's correct?
>
> 1: I think so

In this excerpt, the students started by using words to describe the physical situation. While they shared their interpretation of the situation, they looked to each other for affirmation and incorporated each other's ideas. Finally, they came to an agreement about how to approach the problem starting from a physical principle. This discourse mimics the discourse that was scaffolded by the instructor throughout the course sequence when solving physics problems.

The focus on starting from a representation of a physical situation was further illustrated by the students' responses to the follow-up questions. When asked by the interviewer if there were any particular techniques used to solve the problem that had been used in class, student 1 from the second pair of students who were interviewed stated:

> "Physical representation [laughs] it's like tattooed in my mind. Um yeah usually um state what you know right. Draw a picture and then go from there. That's always what we do in class from, since day one, so"

Student 2 added

> "I think that the most important thing about that that I had to learn, um aside from actually applying that framework time and time again was really start from the beginning each problem fresh. And use, use that framework from the first step to the last step. Still draw a picture, still think about what you know and what your approach is and where you're going to go with it and then try to do some mathematical representation things like that."

These examples illustrate how the non-content goal of representing the physical situation manifests in the students' discourse and reflection upon their own approach to problem solving.

Reflection of knowledge

Reflection is a key theme in this instructor's introductory physics sequence. The instructor encouraged students to reflect upon and express their understanding and uncertainties. As seen in the previous excerpt, students started the problem solving process by describing their understanding of the physical situation. These groups also reflected upon and shared their points of uncertainty with each other. For example, while the first interview pair was working through the problem, student 2 said:

> "I'm still trying to reconcile how to get over this thing being infinitely long and calculating that. I'm trying to recall how to interpret that."

This example illustrates how the students identified and expressed their points of confusion with each other while solving the problem. This reflection of knowledge was also apparent in the follow-up questions. When asked about their role while working in groups with other students, Student 2 from the first interview pair said:

> "To express your questions or your misunderstandings or try to help your peers and their understanding if you happen to have some insight that they don't. Because a lot of times you're able to perhaps reach them on a certain level, with certain vocabulary and limited understanding that instructor may not be able to."

This quote demonstrates that the critical thinking practiced in classroom discourse transferred to the students' reflection of their problem-solving approach after the completion of the course. They expressed understanding of the importance of identifying their points of confusion and the value of sharing these thoughts with others.

Reflection of problem solving

Another major component of the reflection scaffolded in this course is having students analyze their approach to solving problems. After the students solved a problem they were often encouraged to reflect upon their solution and evaluate whether they answered the question they set out to answer.

In the following excerpt, the second interview pair reflects upon the meaning of and the path to the solution after coming up with an equation.

> 2: Well so what does that represent? That's all the force on the, um, plastic stirrer. On every point of the plastic stirrer starting from a distance R away from the wire?
> 1: Yeah, so the force, um, summing up all the forces due to the electric field of the wire, summing up the forces from R to L gives you the total force on the total stirrer.
> 1: Ok. Is anything you want to add or change or something like that?
> 2: A big F right there. [referring to her lack of an identifying variable on the left hand side of the equation to represent 'force'] No, no I don't think so. Yeah and that's, we'll call that total.
> 1: Yeah.
> 2: Where's the, uh, problem statement?
> 1: Right there. Oh yeah, sorry I moved it
> 2: yeah, I feel like we described we set out to describe.
> 1: Are we done?
> 2: Yeah, I think so. I think you were right that, that uh the first approach is kind of a dead-end because we don't need to consider the field due to, due to the, uh, due to stirrer
> 1: I yeah I forgot about that cause, like, always in my mind if you're going to be talking about like, electric fields. I'm like 'oh I totally to sum up all the charges', but like, when we're talking about force that's mostly, you know, [inaudible]
> 2: yeah okay we feel good about that
> 1: yea

In this episode, the students analyzed their solution, asked whether it answered the question they set out to, and reflected upon the approach they used to get there. Early in the problem solution they attempted to use the superposition principle, however became confused about how to proceed. Student 1 suggested they "ignore this for now. Let's just maybe explore that idea [finding the field external to the stirrer] a little bit." After finding a solution, they analyzed the meaning of the formula and reflected upon the two different approaches they took. They came up with an argument to support their choice and then came to an agreement with each other about whether the problem was completed.

This episode illustrates that the students put into practice the discourse and reflection emphasized in class. They were thinking critically about the solution to the problem and the reasoning behind it.

CONCLUSIONS

Reflective discourse in the classroom helps model critical thinking and achieves non-content goals. These types of discourse happen, unprompted and out of the context of the classroom. This was evidenced by students' reflection upon their own knowledge and reasoning embedded in their discourse with each other. A larger study is currently underway to include all of the data from the interviews and triangulate it with an interview with DG and in-class observations of how DG modeled the discourse practices in the classroom.

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