Promoting productive communities of practice: an instructor's perspective

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Abstract. At Oregon State University, we are reforming our large-enrollment introductory calculus-based physics sequence. We are integrating course goals and materials borrowed from ISLE (Investigative Science Learning Environment) which promotes student practice of processes of authentic scientists, and Peer Instruction which helps them engage in these practices. To help our students be able to justify their own knowledge, and develop ownership of that knowledge the instructor works to develop a productive community of practice [1] enabling students to participate in social interactions and make meaning of their experiences to build a shared repertoire of knowledge. This paper reports on strategies the instructor uses, challenges faced, and present evidence of both successes and failures in terms of achieving this aim.

Keywords: Community of practice, ISLE, Peer instruction, Legitimate peripheral participation
PACS: 01.40.Fk

INTRODUCTION

At Oregon State University, we are reforming our introductory calculus-based physics course sequence. These are large-lecture courses that enroll about 200 students per section. A committee developed a list of goals (both content, and higher-order) including: help students obtain a base set of tools and skills which will aid them in learning and applying new knowledge, which includes modeling and building strong scientific abilities, and representational fluency and harmonicity. This past year we switched to the Knight [2] textbook (with accompanying MasteringPhysics) due to its use of multiple representations.

I wrote this paper in first person since it is a paper on my perspective implementing change in the classroom. One of my first changes was to incorporate some materials from the Investigative Science Learning Environment (ISLE) [3], since it is strongly aligned with our goals, and I made extensive use of Peer Instruction [4]. I also hired a graduate student from the Science and Math Education Department to do research on the curricular changes, including daily classroom observations and follow-up discussions (she is the second author on this paper).

This paper focuses on our progress this past year, and relates our socio-cultural framework to the methods implemented to support the goals. Applying this framework helps us better implement our curricular reform, and document what is likely to be successful for other instructors who teach using the revised materials. This paper details specific events in the classroom, supported by qualitative data, and sets the stage for data we will be taking in the upcoming year. We have taken a host of quantitative data, most notably we have reported an increase in normalized gain from the Force Concept Inventory (FCI) [5] from 0.32 in my first year to 0.40 in my second year (which included incorporation of ISLE and the new textbook change) - which is remarkable considering we have not yet made any changes to the structure of the course, the labs, or the recitations. This is also higher than the more traditionally taught section which used the same Knight textbook and MasteringPhysics resources (0.34).

COMMUNITIES OF PRACTICE MODEL

Since one of the major goals of my classroom is to have students take ownership for their knowledge development, it is crucial that they can be participants in the authentic practices of physics provided to them. Participation in the classroom requires discussion with direct-neighbor peers, and opportunities provided by the instructor during lecture are intended to encourage discussion between peers within the larger room and with the instructor. A student needs a sense of identity that permits them to feel they belong to the community and can be involved with such discussions, and feel that practicing physics fits their identity. We see (anecdotally) three types of students who enter this course: those who feel they do not belong within the community and are intimidated by it, those who interested, but often tentative, and those who feel they already know what they need for their major and do not need to belong to this community. This is in part a consequence of the fact that over half of the students are engineering majors, many of whom already had courses such as statics and circuits, and in part because most students taking the course are only taking it to fulfill requirements for their major. The reputation

of physics as a hard subject does not help this situation.

The communities of practice (COP) [1] model provides the language to describe this situation, and a framework for considering how to promote productive participation. In the community of practices model, as students become more central participants, they have more opportunity to be involved in making meaning within the community. Since many students start with identities that place them fully outside the community, it is unreasonable to expect to move all of them to being central participants. Legitimate peripheral participation (LPP) [6] is the idea that people who don't yet feel part of the community can participate in low-risk tasks and practice the vocabulary and norms of the community, and slowly become part of it. These are the students who do not feel comfortable speaking out to the whole class, but may still be mentally engaged in the conversations, and able to participate by at least testing ideas out with their immediate neighbors. These students may either remain in a position of LPP, or may feel more involved in the community over time and become more central members. This discussion could also be framed in terms of student attitudes and epistemologies, but we feel that the COP framework provides a broader picture to aid in implementing our goals and assessing our reform.

Instruction and authority

In the COP model, the instructor has one foot in the classroom community, and one foot in the community of practicing physicists. The instructor takes the role of the broker: an agent that acts between two communities, and in our case, attempts to help guide the classroom community closer to that of the practicing physics community by opening new possibilities for meaning. The instructor sets the classroom norms, and provides opportunities for students to practice participation in the community. It is important the instructor sees him/herself as a broker and not as an authority. It has been reported that students respond differently even when asked the same question, if they think they are reporting to an authority figure [7]; they try to match what the authority figure wants to hear, which limits their exploratory thinking. The instructor needs to guide thinking, and to set up a situation where 'right' and 'wrong' are reasoned through by the students, and not simply matching 'authority'. This helps students feel they can communicate their ideas with the instructor, and helps them take ownership for their knowledge and knowledge production. Even 'A' students in the classroom have reported (in interviews to be published later) feeling they can not participate in full-class discussions because they don't already know the answers - it is crucial that an environment is set up that minimizes the persistence of this attitude.

ISLE and Communities of Practice

ISLE is a curriculum built around helping students develop an explicit set of scientific abilities, and involves the use of a learning cycle that takes students through observations and explanations, then tests of those explanations. Once the models that come from the explanations are robustly developed, they are applied to investigate new situations. Ideally, students would carry out the ISLE cycle with their own experimentation, but in the current phase of our reform, we spend the bulk of our time in the large lecture room, and ISLE observation and testing experiments are done as lecture demonstrations. Students do not start the learning cycle with predictions; when observation experiments are conducted, students look for patterns and learn to describe what they see in an objective fashion. There is no judgment or authority in this step of the process, it is simply gathering data. Then students are asked to brainstorm multiple explanations for the observation. This step of the process is crucial; it is an opportunity for students to safely participate - allowing them to bring forth prior ideas in a non-condemning way, and not letting those students who 'know the right answer' have the upper hand. When Eugenia Etkina conducts this step in her classroom she often uses the wording 'crazy ideas' to allow the students as much freedom as possible. In the words of Saalih Allie, this opens up the 'idea space' and allows students maximal opportunity to take ownership and minimizes the feeling that they are meant to be guessing what some 'authority' wants.

Once multiple explanations have been brought forth, students propose tests of their explanations that must be accompanied by a prediction ('if then' statement) *based on that explanation* of what will happen in this new test. The 'idea space' is not left open at this point - but the students are the ones closing the space, not the instructor, and students are drawing on solid scientific resources. They are also able to productively test their prior ideas by using them as 'crazy explanations' and see for themselves that those explanations do not hold up under subsequent testing. When students close the idea space themselves in this way, we hope it is because they have considered multiple explanations, understood the implications of each, and been able to test them scientifically and draw their own conclusions about which ones are productive. This helps students take ownership for their knowledge and knowledge development. In view of the COP theory, it provides students a non-threatening place to voice and test their ideas, and build collective knowledge with their peers. For students who are uncomfort-

able voicing their explanations, LPP can help them, either through listening in on the discussions, or by trying them out in smaller, non-threatening situations when small group discussion is encouraged.

Peer Instruction and COP

Peer Instruction allows students to interact in small groups during lecture, giving them opportunity to test ideas with each other, often leading to a refinement of their ideas. This is an effective and easy way to help students have low-risk involvement, thus promoting LPP. I tie Peer Instruction to specific activities, for example using a peer instruction question during the ISLE testing cycle. This allows students to participate in the development of the knowledge of the entire class without the need to speak up in front of 200 other students. I also circulate among the students and give them experience voicing their ideas directly to me - hopefully helping them feel like a more central participant. I often share various student ideas with the class to emphasize the idea that multiple explanations can have their strengths in different circumstances, or that multiple representations may all be valid and helpful for specific situations.

THE REALITIES IN THE CLASSROOM

There are a lot of things that I need to learn in order to successfully implement these methods. I need strong Pedagogical Content Knowledge (PCK) [8]: the teacher knowledge that bridges the gap between understanding the content and knowing good teaching practice. This knowledge is very helpful for applying the ISLE curriculum, for example the instructor must be prepared to test explanations students come up with - a knowledge of what kinds of ideas they may bring helps the instructor be prepared for different experimental investigations. There is also a learning curve to being able to establish the dialogue needed to encourage productive student participation in the activities. The idea of when to open the 'idea space' and use words such as 'crazy ideas' and how to productively help students close it for themselves and converge on a productive explanation clarifies how to implement the ISLE cycle and promote a productive COP.

Learning to manage, negotiate, and establish classroom norms in a large lecture course is also challenging. Viewing the goals and classroom activities in light of the COP model brings awareness to why certain days activities yielded great success and why other days they seemed to flounder. Viewing myself as a 'broker' in the classroom instead of the authoritative figure that dictates right and wrong helps me engage with the class in a more productive manner. Viewing students as a developing community helps me accept where they are on any given day, and encourage movement without judgment. Considering student identities helps me understand why some clumps of students choose to congregate and resist participating in the larger community, while others are able to move from uncertainty to amazing growth in their confidence about doing science. Being aware of these issues with a productive framework will help us improve our reform implementation in the future.

Research methods

Sissi Li attends each lecture and records what happens based on an observation rubric we have devised. This enables a look at the type of dialogue that occurs within the classroom. She also takes audio and video recordings of the full class, the instructor, and of a small subset of student groups. We meet at the end of each class to discuss activity implementation and we journal after class, keeping an instructor and observer log. Sissi gave a survey to my students, conducted focus groups, and conducted interviews at the end of the year aimed at looking more deeply at identity issues. All sections of the course are given standard assessments such as the FCI and The Colorado Learning about Science Survey [9]. We collect exams, course grades, passing rates, and other demographics we can use to compare with the baseline established before changes were implemented and with non-reformed sections of the course. The information presented here comes from audio and video data, the observation rubrics, discussions, and journals. A more systematic look at the data is occurring this summer.

Specific classroom experiences

This past year, we observed students increase their ability to dialogue about multiple explanations, they initiated in-depth dialogue about context and assumptions of standard questions, they produced multiple representations during class and used them to start example problems, and they sometimes interjected and answered each other, creating spontaneous student-lead full-class discussions. One instructor who visited my classroom said he had never seen a more interactive lecture environment at our university. As an instructor, while I was disappointed that some students never seemed to feel comfortable with the classroom environment, I witnessed many students blossom throughout the year and become very comfortable and confident having sophisticated scientific conversations. In addition, most students reported valuing the group work in lecture.

However, students seemed to be irregularly responsive, and there was a base set of students who dominated conversations. Students struggled to use new ideas without heavy scaffolding, and huge improvements in student reasoning seemed to be lost when we moved onto new content, or even onto a new way of looking at the same content. I introduced induction through a series of observation and testing experiments. Students seemed engaged and vocal during that class, and were able to answer my questions and ask good questions of their own. The next class when I applied mathematics to the topic, the students seemed unable to apply their conceptual reasoning and explanatory model they had developed the previous day. When I prompted them to remind me of the rule we had established they were silent, and only when I reminded them of specific observations did someone chime in with the explanation - then jumped straight to how it applied to what we were currently doing with the mathematics. This seemed to leave many students behind, enforcing the unproductive idea some students hold that only particular students are part of the community.

I struggled with how to get students to provide multiple explanations after the observation portion of the ISLE cycle. Dominant students wanted to provide the 'correct' explanation and I had difficulty encouraging alternative ideas. Understanding the notion of opening the 'idea space' and why to use wording such as 'crazy ideas' will improve this in the future. My students eventually bought into the ISLE cycle by chance, when a student offered an unconventional explanation for an observation as a joke, and I was able to then ask for an 'if then' prediction and test that explanation. This lead to a productive conversation about what was happening, and increased student participation in future ISLE cycles.

In another lecture I had just completed an explanation, when a student interrupted and said "can you explain that more?" Instead of launching into another explanation, I asked "what is your understanding so far?" I was acting in the role of the broker, helping the student practice dialogging in a scientific fashion. The student then explained their reasoning, and a second student immediately understood the first students viewpoint, and chimed in with a funny implication of that viewpoint that lead to laughter in the entire classroom (including the initially confused student). The second student explained that he had held the same view a few minutes prior and had just come to understand my explanation and had made sense of it himself using that 'if then' reasoning. This was a wonderful moment where students seemed comfortably engaged in the process of building knowledge through participation in the COP.

In one lecture I gave a multiple choice question that had two correct (mathematically equivalent) answers. In both of my sections, students quickly saw one of the answers as correct and voted on it, and were ready to move on. However, I wanted to challenge them to see the other answer. In my first lecture section I asked students to "vote again, and see if you have any different ideas" and though I was able to bring up the fact that another correct answer existed, students did not seem engaged. In the second class, I asked them to "vote again, and see if you can change your neighbor's mind" - there is a clear visible difference in the videos from these two classes: in the second, students were more vocal, and many students leaned forward and nodded, realizing there was more to the question than they initially observed. This exemplifies the power of peer interaction in developing the COP. We often saw at the start of the term that students simply verified their answers with their neighbor, but it takes appropriate guidance for students to engage each other in meaningful discussions.

WHERE TO GO NEXT

The COP framework helps us consider how to effectively implement our course goals, and provides guidance for dealing with issues in the classroom. It also provides a basis for assessing the implementation of our course goals, such as how to frame survey and focus group questions. We will look more systematically at the interplay between how I opened the idea space and student participation. Knowledge we are gaining by applying this framework to our curricular implementation is also being documented and used for future instructors who teach these reformed courses. This study will be expanded in the upcoming year, and combined with the traditional quantitative data that we continue to take, we will be able to provide a strong assessment of our ongoing curricular reform efforts.

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