Cultivating a Community of Practice in Engineering Education

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Abstract

Over the past several years, as part of an NSF supported engineering research center, we have worked in cross-disciplinary teams to enhance learning and instruction in the field of biomedical engineering education. Our collaboration involved working with faculty and consultants with expertise in learning science, assessment and evaluation, learning technology, and engineering. As cross-disciplinary teams we worked together to identify learning goals, develop new instructional materials that embody modern theories of learning, and implement appropriate formative and summative assessment plans to monitor our progress and make continuous improvements. In this paper we identify and organize the knowledge that arose from our collaborative process, and discuss the process that emerged as we formed an effective community of practice.

Introduction

We used the principles of the *How People Learn* (HPL) framework to guide our instructional design and collaboration[1]. The HPL framework suggests that an effective learning environment should be (a) learner-centered, (b) knowledge-centered, (c) assessment-centered, and (d) community-centered. In this study, we examine how the HPL framework guided our process of working together to develop course materials, and characterize social processes that emerged and contributed to cultivating a community of diverse practitioners with the shared enterprise of improving instruction. Specifically, we describe how the practitioners bridged these diverse communities, and how they developed a shared language, common goals, and mutual resources/capabilities.

In contrast to curricula design in K-12 education, our cross-disciplinary collaboration presented unique challenges and opportunities. In K-12, those who collaborate to develop teaching materials and instructional methods usually possess sufficient understanding of the subject matter. That is, both the teachers and learning scientists (or educational researchers) understand the subject matter such that all collaborators can develop learning and assessment materials, and evaluate and interpret student responses. In our work the teachers (faculty) possess domain expertise acquired through advanced graduate study, research, and years of practical experience. In this sense, the subject matter in higher education is taught at a level beyond the general understanding typically possessed by a learning scientist.

Another contrast is that K-12 teachers have training and experience in pedagogy and instructional methods while faculty in higher education have limited training in instructional design. In fact, faculty in engineering education typically focus primarily on research, while K-12 teachers' job is teaching. Even so, overtime faculty gain functional experience and can recognize students' difficulties. They also gain some local understanding of what teaching approaches work or not. However, most of the time faculty do not have any formal knowledge of pedagogy, and thus, their explanation of phenomena observed in the classroom is very much intuitive. Similarly, the tools faculty use to improve their teaching are limited to intuition and their experience as former students, which is certainly not representative of their entire classroom.

Thus, our project created cross-disciplinary teams to develop instructional materials together where each member brought unique knowledge: (a) Engineering faculty possessed subject matter expertise and teaching experience, (b) learning scientists (LS) possessed expertise in learning theory and instructional methods/pedagogy, (c) learning technologists brought knowledge about information technology, and (d) assessment consultants helped design assessments and analyze results. As a result, the process of collaboration was not straightforward and required that certain conditions be fulfilled. First, the collaborative work required the development of a common vocabulary in order to ensure effective communication. It also required negotiation on work methods that all participants accepted and valued since each group member brought into the partnership his or her interest, common practices, and set of values and belief.

In this paper we focus on the interaction between the domain experts (faculty) and the learning scientist (LS). The reality was that these members of the group became mutually dependent on each other in the process of the development. Faculty are experts in their domain, however, this does not necessarily mean they are experts in teaching the domain, or are capable of interpreting a theoretical framework such as HPL into practical classroom activities. This is a primary reason why they needed learning scientists. Learning scientists are familiar with theories of learning and models of instruction and are capable of conducting educational research; however, they did not master the domain and needed the faculty to interpret situations and student performance.

Lave and Wenger (1991) claim that learning is situated, that is, occurs through a process of legitimate peripheral participation in genuine activities of a community of practice (CoP) and through continuous negotiation on the meaning of the activities and the knowledge entailed.[2] Becoming knowledgeable involves not only mastering factual knowledge but also being immersed into the culture of the practice, that is, having the competency and the disposition to apply this knowledge in ways acceptable and negotiable by other members of the CoP. Wenger (1998) asserts that a community of practice defines itself along three dimensions[3]:

- What it is about – its *joint enterprise* as understood and continually renegotiated by its members.
- How it functions – *mutual engagement* that bind members together into a social entity.
- What capability it has produced – the *shared repertoire* of communal resources (routines, sensibilities, artifacts, vocabulary, styles, etc.) that members have developed over time.

Based on this theoretical idea we claim that our collaboration cultivated a CoP whose joint enterprise is improving engineering education. The mutual engagement consisted of the process of developing instructional materials/methods in a cross-disciplinary manner and the shared repertoire consisted of the materials developed, the capability to jointly develop and assess future materials, and the ability to interact with each other in an effective way. In addition, a different vocabulary has been developed to communicate with non-participants of the community who has shared interest in engineering education, but did not participate in the current project.

Method

During the project different cross-disciplinary teams worked together on specific courses/topics. Members of the entire community met in larger bi-weekly and quarterly meetings to discuss issues and share ideas. In the current study we focus on the local interaction between two faculty and two learning scientists during the development of course materials and examine the process of how these diverse practitioners worked together. We interviewed the faculty and learning scientists and asked them to retrospectively describe the process by which they collaborated. We used a semi-structured interview protocol. Sample questions from the interview protocol are given in Figure 1. The interview protocols were slightly different for faculty and learning scientists.

- How did you design your module to be community, learner, assessment, and knowledge-centered?
- In what ways did you need help/guidance in changing your course to be more HPL?
- What things helped you the most/least?
- How did you work together with the learning scientists?
- Describe a typical work session/meeting.
- How did you communicate?
- What were your expectations from this interaction? Did it meet your expectations, why or why not?

Figure 1. Sample questions from the interview protocol used with faculty.

The interviews were transcribed and the analysis consisted of the following three phases. First, three different researchers analyzed each interview individually. This process consisted of looking for activities done in the process of developing a challenge problem, designing detailed HPL-like instructional materials before bringing the problem/challenge into the classroom, and implementing and assessing the instructional materials. Then, we examined how the HPL framework facilitated the work process as well as how the HPL framework was interpreted and applied.

The Process of Development

Based on our analysis of the interviews the development process consisted of the following phases: (a) Identifying a need to change the teaching approach, (b) designing a challenge problem, (c) working on the details of teaching that supports the challenge, (d) designing assessment to measure the effectiveness of the challenge, (e) observing faculty teaching and jointly making ad-hoc decisions regarding teaching approaches, (f) analyzing assessment data,

(g) refining the challenge including the addition of detailed lesson plans, and (h) repeating the process.

The faculty usually identified a need that could be met by employing a different teaching approach. The joint assumption was that knowing something means being able to solve problems using this knowledge, and that challenge-based learning--learning by attempting to solve an open-ended realistic problem--is effective. So one joint objective of each team was to find a good challenge problem.

"...students have a difficult time understanding all the different parameters and boundary conditions that go with each of these models [of light propagation]. So what we had was a learning problem. Students have a hard time learning which models to use and understanding each of the models and we needed a different approach to teaching this and learning it. So what did we do? Well, we gave the students a design problem actually. We asked them to come up with a method of measuring the oxygen content inside somebody's head." [quote from faculty 1]

The LS helped by posing reflective questions such as 'what do you want students to know and what do you expect students to be able to do?' These questions helped the faculty organize learning goals in terms of key concepts and core practices. LS also explained what the features of good problems are. For example, one of the learning scientists explained that a good problem should be realistic in the manner that (a) it is derived from the practices of the future CoP, (b) the knowledge required for the solution is accessible, (c) the solution is not straight forward and there are multiple possibilities that needed to be examined, and (d) decisions should take into account realistic considerations, such as money, ethics, and so forth.

However, while it was clear that students would work on the challenge problem, the faculty were not so clear about how to integrate the challenge assignment into the course. LS provided guidance and practical suggestions for creating an HPL environment throughout the challenge assignment and entire course. For example, the LS negotiated for *challenge first* and *assessment first* that became principles of our collaborative instructional design.

"I was thinking of coming at it a slightly different way, introducing the challenge a little later in the sequence of activities than I actually wound up doing... And in one meeting with [LS1] she said, well, just give them the challenge right up front. That was sort of a key meeting." [quote from faculty 2]

By *challenge first*, we mean that the challenge was posed to the students in the early stages of the course and the course provided scaffolding to the solution. That way, students are motivated and moreover, their learning trajectories are aligned to find ways to solve the question, while in traditional lecture-based course, mostly students accumulate information, postponing the cognitive process to several days before the exam or assignment. By *assessment first* we mean that quite early students knowledge was assessed either by asking them to generate initial ideas for possible solutions, or by collecting survey data. Once the instructors became aware of the students' initial understanding they tuned the instruction accordingly.

"That's been a tremendous help to me – to understand the idea of assessments from the point of view of a learning scientist. That was not something that came naturally to me. The idea that, you know, I knew intuitively that you test students along the way and that's a good way of them understanding what's going on, but, you know, the idea of formative versus summative assessments, that wasn't part of my vernacular at the time." [faculty 1]

"…we're getting their ideas as opposed to my ideas basically. We're getting them to think about things that they've already known previously. So we're seeing whether they can use their knowledge to generate a solution to a problem. We're getting some assessment done at the same time to think about whether these ideas are reasonable. We're having them work in little communities with each other rather than with my telling them everything. So there's definitely an assessment centered and a community centered aspect to this." [faculty 2]

Next the LS had to explain that posing a challenge per se is not sufficient to ensure that HPL centers are *constantly* addressed. The concrete practical implication was that teaching should consist of more than a challenge and lectures. For example, LS1 would observe class and sometimes talk with students and faculty after the lesson in an effort to compare what happened to what was intended to be achieved, and make ad hoc pedagogical decisions. It also required the instructors to acquire different teaching skills such as facilitating vivid discussions, learning not to lecture the answer, and giving students sufficient time to answer questions. In this way LS worked as interpreters of the HPL framework such that they provided practical HPL-based teaching suggestions, and they negotiated its effectiveness with faculty, who sometimes had their own naïve ideas on teaching and HPL.

"So he [faculty 1] had a challenge already and he also had this idea of doing experiments. And then I started to talk to him about, well, what are you going to do differently, say, during the class time? Is there anything that you might do? So they [students] do these experiments, so then what? And then thinking about, well, if we're using HPL as the framework, what are some other things we might do to make this challenge more assessment centered or learner centered? … is there something we can do in the class like, for example, have students, find out what students already think about the challenge? And it sort of mapped onto the legacy cycle in that there was a generate ideas part to the legacy cycle. So he wanted students to do that and I said, well, can we do that in class? Can we have students brainstorm ideas? And so that was one thing we did in the class." [LS 1]

Discussion

The Faculty Role

Faculty and learning scientist both played critical roles in the collaborative process and brought essential expertise to developing rigorous HPL course materials. Faculty played an important role in defining the learning goals, creating course and assessment materials, and evaluating student performance. The faculty played a central role in the process since they possess content expertise necessary to understand the subject matter. In addition, faculty were the end users of the materials that were developed. In this sense the collaborative process not only helped develop course materials but also helped inform instructors about HPL-based teaching practices.

Reforming instruction, therefore, consisted of changing course materials and expanding faculty's understanding about teaching and learning.

This was accomplished through several ongoing collaborative activities. Observation of classroom activities, debrief meetings about the observations, and evaluation of student responses all contributed to a broader awareness of the impact of pedagogical practices.

The Learning Scientist Role

In our collaborative work the LS play the role of *teaching consultants, mirrors, interpreters,* and *reflection encouragers.*

Mirrors - LS observed lessons to experience the classroom environment, how faculty implemented the materials, and how students responded to the implementation. The LS reported these observations to faculty as a reflection of the teaching practices.

"…so [LS1] is really great because she's more like a sounding board or a mirror or something. She will question things that you're doing more than telling you what to do." [faculty 2]

"We had this session where the students did brainstorming. And I asked them a question and I must have waited two seconds for an answer. Didn't get one, and provided my own. And after class she [LS1] said to me, "give them time to answer." It had never occurred to me that sometimes I get going and I'm going so fast that I don't take the time to recognize the students are having a real hard time keeping up with me. And they need time to process the question I'm asking and then have the intestinal fortitude to actually raise their hand to respond. And it took LS1 being blunt saying, "you didn't wait long enough. If you're going to ask a question you've got to wait long enough at least to let them think about the question. And if you really want an answer from them you'd better wait even longer." [faculty 1]

Teaching consultants – frequently, LS offered suggestions for different teaching approaches. They also took the responsibility to translate classroom practices into the HPL framework and helped faculty develop teaching skills required for the facilitation of active students.

Interpreters – The LS had to negotiate the meaning of HPL as a very interactive lesson (lectures are ok if they support a challenge posed before), assessment first to enable learner centeredness, and so forth. For example, often faculty state that there is a lot of material to cover and too little time. This time constraint often led faculty to conclude that "lecture first and challenge after" is a suitable way to cover all factual knowledge and incorporate challenge problems.

"I was a resource in terms of interpreting what the HPL framework meant. What do those terms mean? So I was an interpreter for the learning science [HPL terms] as well as someone who could offer suggestions on classroom techniques, classroom strategies in making it concrete, giving sort of, here's an example of what you might do to make it learner centered." [LS 1]

Reflection - having the need to design a HPL-based environment in a domain LS did not master led them to develop a technique for collaboration that was based on having the faculty conduct systematic reflections. In fact each LS described a process of inquiry that took a lot of time. First, they would ask faculty about the learning goals. Faculty usually would generate a list of topics as a first response and then LS would guide faculty to prioritize this knowledge such that appropriate concepts and skills are aligned with the challenge activity. Then LS would conduct a second inquiry regarding how the challenge activity could be integrated into the classroom in an HPL way. Similarly, when designing an assessment tool, LS asked reflective questions to help faculty generate appropriate assessment questions and techniques for analysis.

Another aspect of reflection was provided when LS observed the teaching in the classroom. Reporting back what they saw helped faculty understand the impact of the teaching approach, and provided guidance for refinement.

Mutual enculturation

Both faculty and learning scientists learned from each other. For example, faculty 1 stated that he adopted the teaching tips LS1 provided him, while LS1 learned strategies for advising faculty about teaching, and how to engage domain experts in performing educational research in a complex domain area. Faculty 1 also learned about the power of assessment. Several factors contributed to faculty developing a deeper understanding of the nature of teaching and learning, and to improve their teaching. These factors include having the need and opportunity to reflect on one's teaching, being exposed to and applying a theoretical framework, and reviewing the results of assessment that showed students' misunderstanding and sometimes showed that the instruction, in fact, did not achieve its goals. In addition, all our interviewees mentioned that when they interact with someone outside their group they have to translate the HPL-based vocabulary to language non-participants can understand and appreciate.

Summary

In this paper we describe our cross-disciplinary collaborative effort to develop instructional materials in engineering education. We focus specifically on the local interaction between two different faculty and learning scientists, and how these diverse members negotiated work patterns and the meaning of the HPL framework in terms of pedagogical practices. Based on the theoretical idea posed by Lave and Wenger we claim that our collaboration cultivated a Community of Practice whose joint enterprise is improving engineering education. Our preliminary findings suggest that both faculty and learning scientists played specific and critical roles in advancing the joint enterprise. Faculty possess essential domain expertise and are the instructors, and implementers, of the course materials. Learning scientists played several roles such as teaching consultants, mirrors, interpreters, and reflection encouragers. The LS and faculty worked in a symbiotic way using reflection as a key strategy for mutual work, constantly negotiating the meaning of the joint enterprise, as well as developing shared understanding of how the HPL framework can be applied in the context of engineering education. We also developed a shared repertoire of HPL-based vocabulary and design principles for our collaborative work.

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