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A Faculty Team Works to Create Content Linkages among Various Courses to Increase Meaningful Learning of Targeted Concepts of Microbiology

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As research faculty with expertise in the area of host–pathogen interactions (HPI), we used a research group model to effect our professional development as scientific educators. We have established a working hypothesis: The implementation of a curriculum that forms bridges between our seven HPI courses allows our students to achieve deep and meaningful learning of HPI concepts. Working collaboratively, we identified common learning goals, and we chose two microorganisms to serve as anchors for student learning. We instituted variations of published active-learning methods to engage students in research-oriented learning. In parallel, we are developing an assessment tool. The value of this work is in the development of a teaching model that successfully allowed faculty who already work collaboratively in the research area of HPI to apply a "research group approach" to further scientific teaching initiatives at a research university. We achieved results that could not be accomplished by even the most dedicated instructor working in isolation.

INTRODUCTION

As research faculty with a shared research interest in the area of host–pathogen interactions (HPI), we often collaborate to share ideas, discuss data, and talk about current findings. But when we think of teaching our courses, we generally operate as individuals, teach the way we learned, and rarely assess our learning outcomes. With the increasing amount of data on how students best learn science, we felt it was time for a change in our approach to teaching. Our goal was to form a teaching group that is analogous in function to a research group where teaching would benefit from the same approaches that we apply to our research.

We are responsible for teaching seven undergraduate courses with content relevant to HPI. Our courses have typically been developed in isolation. By working as a team we felt that we could address our concern that students were hearing the same information in multiple courses rather than developing the breadth and depth of understanding that we would like. Our goal was to create bridges between our courses that would minimize overlap in course content and support a teaching model where concepts and ideas introduced in one course would become the foundation for concept development in successive courses. We developed a strategy designed to ramp up students' knowledge of a particular research area through a series of courses. This can be applied to any topic and in this case, the test system is HPI.

Our new "teaching group" strategy coordinates curriculum and syllabus development to provide an integrated and comprehensive view of HPI. In this article, we share the steps taken to form our team and the progress that we have made in collaborative work: creating a bridging curriculum,

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instituting new approaches in our classrooms, starting the development of a tool to assess learning of fundamental concepts in HPI, and engaging research faculty in regular conversations about teaching and curriculum reform.

THEORETICAL BACKGROUND

The teaching standards set forth by the National Research Council (NRC; 1996) and the American Association for the Advancement of Science (AAAS; 1993) call for the science curriculum to emphasize research processes such as understanding, reasoning, and problem solving. Handelsman *et al*. (2004) have coined the term "scientific teaching" to encourage faculty to approach teaching with the same rigor as they approach their research. Therefore, colleges and universities have initiated numerous efforts to improve teaching and learning on their campuses (NRC, 2003). These efforts have attempted to answer the questions: "What to teach?" and "How to teach?" Concerning the question "What to teach?", Johnson and Lawson (1998) indicate that most college biology instructors assume that students' prior knowledge plays an important role in their ability to acquire new concepts. Thus, a common goal of introductory courses is to provide students with the basic conceptual knowledge needed to enroll in advanced courses, with advanced courses built in a way that provides a continuation in terms of content and skills. However, at most colleges and universities, the process of selecting course content is an extremely local enterprise. Although these decisions are occasionally made by a small group of faculty, the norm is that they are made by a single professor with the responsibility of teaching the course (Tanner and Allen, 2002). The idea that learning goals and specific course content are articulated into a meaningful progression for undergraduates is rarely discussed among faculty members responsible for different courses within one department.

Concerning the question "How to teach?", Fink (2001) has proposed that to create significant, lasting learning and to develop scientific thinking skills, teachers should adopt active-learning strategies (i.e., asking students to do something and to think about what they are doing), and they should teach science as science is done (i.e., based on inquiry, research, and teamwork).

In spite of the difficulties in implementing active-learning strategies in large classes, instructors have been able to apply active approaches in large classes (Allen and Tanner, 2006) by using problem-based learning (PBL) or case study methods (Reddy, 2000; Donham *et al*., 2001; Shipman and Duch, 2001; Smith *et al*., 2005), by using cooperative learning or group discussions (e.g., Cooper, 1995), and by using techniques to encourage students' questions and participation in class (Sokolove, 1998; Marbach-Ad and Sokolove, 2000). And yet, as Lazerson *et al*. (2000) noted, "for all the pedagogical innovations– even the advent of the Web–there has been precious little deeper reform." One explanation for the lack of reform contributed by faculty at research universities is that teaching changes are not generally tied to university incentive and rewards systems. Research remains the primary avenue to individual and institutional prestige and advancement. Additional explanations include notions that research faculty members have not been trained to lead inquiry-based, student-centered learning, that student-centered teaching will result in the loss of control of the classroom, that content coverage is the primary teaching objective, and that the standard lecture format is the best method to meet this end (Frederick, 1994; Cooper, 1995). Also, faculty members may lack confidence in their ability to introduce scientific research or investigative approaches into their classes.

OUR TEACHING TEAM

At the University of Maryland, HPI is one of five major research foci within the College of Chemical and Life Sciences. As faculty with a research interest in HPI, we meet monthly to work on a variety of collaborative research efforts, share ideas, critique data, and present and discuss the latest findings in the field. Our research group includes full, associate, and assistant professors as well as graduate and undergraduate students. We find significant benefits in meeting as a research group, one of which is the opportunity for senior faculty to mentor new faculty and students in the research process.

We also share responsibility for teaching seven microbiology courses. These courses include one introductory General Microbiology course that serves 800 students per year and six advanced courses that require General Microbiology as a prerequisite. The advanced courses have a cumulative enrollment of approximately 400 students each year. Table 1 shows the basic design of each course: lecture, lab, or discussion. At the onset of this project, the majority of the courses were taught using traditional lecture format. The

Table 1. The seven undergraduate courses in the project focusing on various aspects of HPI

Course	Lecture	Laboratory	Discussion session	Annual enrollment
General Microbiology (BSCI 223)[a]	+	+	Online discussion	800
Microbial Genetics (BSCI 412)	+	+		60
Immunology (BSCI 422)	+		+	100
Immunology Laboratory (BSCI 423)		+		60
Epidemiology (BSCI 425)	+		+	70
Pathogenic Microbiology (BSCI 424)	+	+		100
Microbial Pathogenesis (BSCI 417)	+		Discussion-based class	25

[a] The General Microbiology course serves as a prerequisite for all of the other upper-level classes.

exception is General Microbiology where significant experimentation with student-centered pedagogues has been ongoing for some time (Smith *et al*., 2005). Instructors for Pathogenic Microbiology also began using case studies in the laboratory to give context to the lab protocols before the formation of our teaching team. All of the courses have an emphasis on HPI. This shared interest in HPI research and teaching motivated us to form an HPI teaching group in fall 2004. Our members include all the faculty teaching in the HPI courses (Table 1): nine faculty members from the Department of Cell Biology and Molecular Genetics with active research programs (four full professors, two associate professors, and three assistant professors), two instructors (one instructor serves as the HPI teaching group coordinator), an assistant professor with a joint appointment in the College of Education who has expertise in biology education, and several graduate students with a strong interest in teaching. Each semester, one graduate student was supported by funds from a Howard Hughes Medical Institute grant received by our College of Chemical and Life Sciences as part of a curriculum development initiative. This student was considered a teaching and learning fellow.

Each semester, we set several goals for our group and decided upon one or more projects to pursue. To speed our progress, for specific projects, we also formed subcommittees that met weekly. The core of each of these subcommittees was the teaching group coordinator, the science education faculty member, and the teaching and learning fellow. This core group served to review the science education literature and research teaching methods (such as case studies, project-oriented labs, and debates) for the subcommittees as well as for the full HPI teaching group. Our monthly HPI teaching group meetings have been well attended with an average of nine faculty members—all ranks represented—at each meeting, and we have had regular meetings since fall 2004.

In our first semester, we established three goals: to 1) select topics to provide bridges in our HPI courses, 2) select and refine methods to teach core principles, and 3) design a tool to assess our curriculum development progress.

Select Topics to Provide Bridges in Our HPI Courses

Views regarding the importance of prior knowledge have been around for many years in the science education literature, largely in terms of the assimilation theory of meaningful reception learning by Ausubel *et al*. (1978). These authors implied that meaningful learning depends on the ability of the teacher to teach the subject matter at hand in a well-organized way that connects the new knowledge with the learner's cognitive structure (Ausubel, 1968). Novak (1977, 1990) determined that learners acquire a hierarchically organized framework of specific concepts, each of which permits them to make sense out of new experiences. If these prior concepts are lacking, no new concepts can be acquired. Redish (2003) champions this approach in the teaching of physics at the university level as a major mechanism for ensuring students' long-term memory and recall.

To help students build bridges between content presented in our courses, we used two complementary approaches.

In our first approach, we identified the following six topics as fundamental to the understanding of HPI:

- Basic structures of bacteria (particularly the cell surface structures)
- Metabolic processes (how bacteria grow in response to their environment; how these processes are influenced by changes in the environment)
- Bacterial genetics (genetic variation, gene transfer and mutation, gene expression in response to changes in environment—*lac* operon example)
- Pathogenesis (identification of virulence factors, the role of normal flora, identification of pathogens in the lab)
- Antibiotics (targets, how bacteria acquire resistance)
- Immunology (antigens, antibody, vaccines, pathogens that replicate intracellularly)

We felt that by using these topics to guide concept development in our sequence of courses, students, as they move from the prerequisite General Microbiology course to more advanced courses, will develop a deeper understanding of each topic.

In our second approach, we chose two "anchor" organisms (*Escherichia coli* and *Streptococcus pneumoniae*) to be used as exemplars of fundamental HPI concepts in all of our courses. We hypothesized that with each successive presentation of a topic, the students would be able to build upon prior knowledge that is linked to a familiar anchor organism.

We reviewed various organisms that would best serve as anchors. The rationale for the choice of *E. coli* and *S. pneumoniae* was as follows:

- They represent one example from each of the two categories of eubacteria: the Gram-positive bacteria and the Gram-negative bacteria.
- They allow demonstration of the role of common microbiota as well as pathogenic organisms in HPI.
- They express a variety of characteristics that are relevant to interactions between hosts and pathogens: virulence, horizontal genetic exchange, antibiotic susceptibility, and antibiotic resistance.
- They both cause diseases of current significance.
- They are both well studied.
- They can be used to relay a range of immunological and genetic principles.

These important human pathogens possess all of the basic structural features of bacteria, and they can serve as a model for understanding the current theories regarding HPI. Each faculty member modified course content to highlight these target organisms. Table 2 provides examples of how the biology of *S. pneumoniae* was integrated into the various classes.

Each faculty member worked individually to modify his or her course to include the anchor organisms and core topics. Collaboratively, in our teaching group meetings, we worked to eliminate redundancy in our courses and to develop complementary activities. One such project was the agreement that all of our courses would adopt the University of Maryland hosted online course management system WebCT (WebCT, 2004). This established a standard recog-

Table 2. Plan for using *S. pneumoniae* to link courses in the study of HPI

	General Microbiology	Microbial Genetics	Immunology	Immunology Lab	Pathogenic Microbiology	Microbial Pathogenesis	Epidemiology
Content	Characteristics of the organism, definition and identification of virulence factors, relationship between host and pathogen is defined, host response	Transformation as a means of genetics exchange	Immunogenicity of capsules, properties of vaccines	Application of immunological techniques in research	Vaccines for the prevention of disease	Genetic basis of the virulence of gene expression	Epidemiology of pneumonia
Lab Protocols	Identification of *S. pneumoniae* via growth on blood plates and with use of standard biochemical tests: inulin fermentation, taxo disc sensitivity, bile solubility	Transformation of Gram-positive bacteria	NA	Immunodetection of vaccine antigens/human serology, phagocytosis of bacteria	Protocols that highlight characteristics of *S. pneumoniae* pathogenesis	NA	NA
Appreciation for current topics	Case studies, written reports	Lab developed in context of a problem, e.g., genetic exchange and pathogenesis of *S. pneumoniae*	Case studies	Lab developed in context of a problem, e.g., clinical unknown from patient with symptoms of pneumonia	Case study or problem-oriented lab	Review of primary literature	Case study
Framing good questions	Problem-based learning questions	Frame a question to be tested in lab	Based upon issues raised in case studies, students will frame questions for library research	Frame a question that can be answered by new protocols learned in lab	Based upon issues raised in case studies, students will frame questions for library research	Upon reading literature students will generate new questions	Based upon issues raised in case studies, students will frame questions for library research
Library research	Address case study questions and discussions	Address the project portion of the lab	Address issues in case studies	Define questions that may be answered by protocols learned	Address case study questions that may be answered by protocols learned	Identify problems facing field	Address case study questions and discussions
Lab research	Project-oriented labs	Write lab protocols and team project	NA	Application of standard protocols to answer larger questions	NA	Assessment of methods in primary literature	NA
Discussion	In lab for discussion of data, in lecture for discussion of case study questions, online for discussion of issues	Presentation of data from project-oriented labs and poster session	In groups–case issues	Presentation of data from project-oriented labs and poster session	In groups–case issues	Review of primary literature	In groups–case issues
Writing	Lab reports, group-authored assignments, answers to case questions exams	Group-authored assignments, answers to case questions exams	Essay questions on exams, lab reports, poster session	Lab reports, poster session	Lab reports, group-authored assignments, answers to case questions exams	Essay questions on exams	Essay questions on exams
Presentations	Web page, written report, oral presentation	Oral poster presentation of research findings	Debates in discussion sections	Poster presentation	Web page, oral presentation, poster presentation	PowerPoint presentation	Debates in discussion sections
Group work	Lab group of 3, discussion group of 6, group-authored assignments	Lab work, group presentation	Case study discussions	Lab work, group presentation	For lab work, and all presentation	For presentation	Case study discussions

nizable to the students and gave us a framework for sharing course content, standard lab protocols, images, and surveys.

Select and Refine Methods to Teach Core Principles

Once we identified common anchor organisms and six topic areas of HPI that would be integrated across all of our courses, we began discussing teaching methods. Our teaching challenge was to identify strategies that would engage students in deep and meaningful understanding of the HPI concepts and in research-oriented activities that expose the process of science. To start, we concentrated on case-based approaches. The case method of teaching seeks to engage students in learning complicated concepts by presenting concepts in context (e.g., clinical setting, research study, everyday life, current events). This method was a method with which some of our group had experience.

In General Microbiology and in one of our advanced courses (Pathogenic Microbiology), case studies had been used before the formation of the HPI group to give context to student learning and to challenge students to think critically. In these courses, we have found the benefits of case study teaching in encouraging discussion, teamwork, problem solving, and active learning (Smith *et al.*, 2005; Shields, unpublished observations). We recognized the potential of case studies as a means to reinforce the students' understanding of HPI concepts and to introduce students to the process of research science. Instructors in General Microbiology and Pathogenic Microbiology began to develop new cases and to refine existing cases to be relevant to our anchor organisms. To date, one new case has been added to General Microbiology and one new case to Pathogenic Microbiology, both on various aspects of the microbiology of *S. pneumoniae*.

For our Immunology laboratory course, we developed a case-based method that we call "literature-based learning" (Parent *et al.*, 2005) to more fully immerse students in the research process. Before our curriculum reform initiative, the course focused on teaching a variety of standard protocols that were implemented by the students as they were instructed. The revised course required students to learn protocols in the context of published research studies and to apply their understanding and newly learned technical skills to address authentic immunology problems in an end-of-semester experimental design team project. In the revised course, learning immunology techniques was coupled with reading of primary literature that used that technique. For each set of new lab techniques, students received excerpts from the literature. Following a modified interrupted case-based learning approach (Herreid, 2001), students first received research article introductions. From these articles, they identified the research question and suggested techniques (from those that they had implemented in the lab) that could be applied to address the question. This was followed by discussion, distribution of the remainder of the article, and a follow-up discussion where student ideas were contrasted with author ideas. An evaluation conducted at the end of the pilot semester indicated that all students (52) responded with positive comments regarding the experimental design project, 92% of the students responded positively to the use of the research papers, and 96% said they would recommend this course to other students. We feel that the course design allowed the students to gain a meaningful understanding of immunological concepts, because they were actively engaged in research activities (reading primary literature, applying standard techniques to novel problems, developing research questions, working in groups, and developing and implementing protocols).

With the case study projects, our teaching team began our scholarly approach to teaching. We thoughtfully selected case studies and courses that would support the learning goals; we reviewed pertinent science education literature; and we facilitated the formation of subcommittees that included faculty members involved in the specific courses targeted for case studies with the core team to design, implement, and assess the work. During all three stages, the subcommittees reported back to the larger teaching team for comments and feedback. Our case study work has been promising and is ongoing. For other teaching challenges, we continued using the scholarly approach. We investigated additional teaching methods. In the Spring 2006 semester, we revised the Immunology lecture and discussion sessions by incorporating active-learning approaches such as concept maps (Novak and Gowin, 1984; Novak, 1990) and "Just in Time Teaching" style questions (Marrs and Novak, 2004). In the Immunology discussion sessions, students were organized into small groups and given real-life clinical problems to solve. Several of these problems involved the immune response to Gram-positive or Gram-negative bacteria, or their products. This project is in the implementation stage.

Design a Tool to Assess Our Curriculum Development Progress

Physics educators have dramatically altered the way physics is taught in response to student performance on the Force Concept Inventory (Hestenes and Wells, 1992; Hestenes *et al.*, 1992). Seeing the value in using a standardized instrument to measure what students know about fundamental concepts has encouraged several groups of biologists and chemists to develop concept inventories (Odom and Barrow, 1995; Anderson *et al.*, 2002; Mulford and Robinson, 2002; Khodor *et al.*, 2004). We have directed our assessment toward students' deep/meaningful understanding of HPI topics. We had previously identified the broad topics that we felt were important for students to understand (core topics). Our challenge was thus to measure that understanding.

To develop the assessment tool, we focused on the following three major steps:

1. Establish the Goals of the Assessment Tool. We wanted to build an assessment tool that would reveal the development of concept knowledge, critical thinking skills, and data analysis skills as students progressed through the HPI curriculum. The assessment tool needed to be easy to administer and score, given the large enrollment of our seven courses (Table 1).

2. Learn about Assessment Tools That Would Serve Our Goals. To build questions that targeted our core topics and could be used to evaluate students' level of thinking and understanding in each course, we considered the work of Bloom (1984) and Mayer (2002). We discussed the characteristics of questions that reflected rote learning as opposed to meaningful learning, and we learned how to write questions that could reliably assess a deeper level of understanding.

3. Design the Assessment Tool. One of the most significant exercises that has engaged our group has related to the creation of an assessment tool. Most of us had previously depended upon college-designed end-of-the-semester instructor course evaluations and student grades on exams for feedback on the success of individual teaching efforts. As a teaching group we decided to take a systematic approach to the analysis of our work.

To this end, we experimented with assessments. In each successive version, our team felt a greater sense of understanding of the assessment process and a deeper realization of the value of assessment in teaching. We have worked through two versions of an assessment tool:

First Version. Each faculty member submitted two questions that he or she thought a student should be able to answer at the completion of the course. We rated these according to cognitive level (Bloom, 1984; Mayer, 2002), and we devised a tool that targeted the six HPI topics. We piloted the tool in three courses. After analysis of the results, we felt that we had learned quite a bit, but our tool was not yet meeting our needs. Our concerns were the following:

- The approach to the development of the tool was too individualized. The questions were written by distinct faculty members and merged.
- There seemed to be large gaps in the content assessed.
- We did not know how this tool could be used to monitor students' development in meaningful understanding of host pathogen concepts.

Second Version. We took a step back. We considered as a group this question: "What do we want our students to truly understand and remember 5 years after they have completed our set of our courses?" We discussed this question and answer in detail. We then considered the great strides that physics educators have made when using the Force Concept Inventory (Hestenes and Wells, 1992; Hestenes *et al.*, 1992) to analyze how students learn the physics of Newton's laws. We looked at the literature and we found two concept inventories used in biology courses (Odom and Barrow, 1995; Anderson *et al.*, 2002) and a chemistry concept inventory (Mulford and Robinson, 2002). We decided to follow the approach of Odom and Barrow to develop an HPI concept inventory. Presently, this tool is in the development/implementation stage. A pilot of the tool is ongoing.

FEEDBACK FROM THE TEACHING TEAM

The assessment results generated enthusiastic discussion within our group about what we are teaching, what students are learning, and how to assess both. We all feel that the community that we have developed is a good resource for exchange of ideas about teaching. We spent substantial amount of time reflecting on the value of this group to our own professional development. Often within the very busy life of a research faculty member at an academic institution, discussions about teaching are "put aside." We felt that having regular group meetings "pushed" us to think about teaching and to discuss teaching issues with our colleagues. The meetings provided support for improving teaching, especially for new faculty members. As one assistant professor remarked, "This group provides a mentoring aspect to new faculty, new faculty are at the table with established faculty . . . For new faculty members, just beginning to teach, the discussions in the group have provided a mechanism to learn about teaching, ways to teach besides 'lecture', ways that experienced teachers are using active learning and technology in their courses."

One of our tenured, experienced faculty members stated, "I wish I had been in a group like this when I started as a new faculty member. I felt that teaching a course was thrown at me—this would have given me a place to ask questions." Another senior faculty member indicated that the content discussions in the meetings have caused him to rethink what he has been teaching: "I think I will shift to some areas that allow students to learn about how pathogens interact with the host and include some immunology and move away from diagnostics. I want to help students to see the connections between our courses. I want the student to do less memorizing and more understanding." Another faculty member commented how educational theories that were discussed within the group changed his teaching: "The discussions we have had in making the posttest, such as decisions about the level of questions to ask, according to Bloom's taxonomy, helped me formulate my exams."

SUMMARY

With modest funding used to support one graduate student each semester, to provide a stipend for our team member from the field of science education, and to purchase lunches for our regular meetings, we have found a way to engage research faculty in a long-term, ongoing teaching group. Our meetings have been regular, well attended, and productive. We have discussed science education literature, set goals for our teaching, implemented new teaching strategies based upon published models, and assessed our initiatives. We have achieved our goal of developing a teaching group functioning analogous to a research group with research faculty engaged in "scientific teaching" (Handelsman *et al.*, 2004).

Our initial focus was to begin improving our courses and to develop an assessment tool that could measure student learning gains as the course development project progressed. We are simultaneously developing our courses and our assessment tool. For our courses, we have chosen a set of core topics and two anchor organisms to help students build bridges between the material presented from course to course and at the same time we started to implement and assess innovative approaches for teaching (Parent *et al.*, 2005).

Tanner and Allen (2002) indicated that at most colleges and universities, the process of selecting course content is an extremely local enterprise, and although occasionally these decisions are made by a small group of faculty members, most often they are made by a single professor with the responsibility of teaching the course. Within our HPI courses, our group has allowed this work to be shared among a dedicated community of faculty members with shared research and teaching interests.

Our scientific teaching group is analogous to the traditional research group found at most research universities:

The members in this group have a research focus in the HPI area. The group has brought together research faculty members, instructors, and graduate students to initiate curriculum reform. The scientific teaching group provides community and opportunities for mentorship to new faculty and graduate students, who will one day be faculty members themselves. We feel that the model of bringing faculty who have common research interests together to assess, discuss, and improve how we teach is the key to engaging research faculty in needed reform in how science is taught at research universities. The ongoing work of our group supports this model. We report our experience here to add to the growing conversation about how to change the way we teach science, especially at large research universities.

This study represents the beginning of a long-term project that we feel could serve as a model for other faculty in and beyond our institution. We are now approaching our teaching responsibilities with an understanding of the scholarship of scientific teaching, with the added value of mentoring, collaboration, and publication. This approach brings increased recognition for the critical role of faculty in improving science education. This collaborative structure provides better coordination between our courses and increased emphasis on innovative teaching and learning approaches. The teaching team formed among faculty with common research interests has created a synergy between research and teaching that is unusual in research institutions.

FOR THE FUTURE

Our teaching group continues to meet regularly, so that innovations in one course can inspire complementary changes in other courses. We plan to continue reviewing the design of our courses and to maintain our efforts in developing, implementing, and assessing teaching strategies that encourage meaningful and research-oriented learning in our courses. Furthermore, we will investigate methods to more significantly engage graduate students in our efforts. With the large enrollments in our courses, graduate students acting as teaching assistants play a key role in supporting student learning. For our innovations in teaching to be a success, we need graduate students who understand our goals. In addition, to support the national call for transformation in science education, we must train graduate students in pedagogy that will support this transformation.

This past semester, we carefully reviewed published concept inventories and revised our assessment tool along the lines of a HPI concept inventory. We plan to look very closely at our assessment goals. Are our core topics focused enough? Are our questions targeting the important concepts? What are the common alternative conceptions students hold regarding HPI and how can these conceptions be addressed in our courses? Once we are satisfied with our assessment tool, we will use the questionnaire in all seven of our courses as a pretest and a posttest, and collect data on students' backgrounds (e.g., year in school, previous courses taken). We will then use the assessment of student learning to guide us in the further development of our courses. With data about the effectiveness of the tool in assessing student learning we will work to disseminate the tool and gain a wider understanding of the best methods for teaching and learning HPI concepts.

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