

Descriptive Account

Managing Problem-Based Learning in Large Lecture Sections

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Abstract

Problem-based learning can enhance reasoning and concept development among undergraduate college students by presenting content within authentic contexts. However, large lecture sections present problems and barriers to implementing PBL. This article discusses approaches used by the author to infuse PBL into large biology lecture sections, and explores ways in which challenges to PBL in these settings may be overcome.

Keywords: Problem-based learning, undergraduate, teaching, classroom management, social interaction, enquiry teaching, biology

Introduction

Problem-based learning (PBL) has been widely used at the university level for professional training in medicine, law, engineering, and business, where it serves as essentially a cognitive apprenticeship for the professions (Barrows & Tamblyn, 1980). PBL fosters active learning strategies/hypothesis formation and cognitive activities that depend on prior knowledge in a wide range of areas as well as requiring the use of generic problem-solving skills. Learning enhancement occurs when students struggle with problems and must master content to solve the problems, rather than simply learning by rote memory (Norman & Schmidt, 1992). Students who learn in PBL contexts often retain that knowledge longer (Breton, 1999), and may be better at applying the content to a real-world problem (Vernon & Blake, 1993).

PBL requires the use of small group discussions, and works well in small classes where group discussions can be managed easily. However, large lecture sections are a fact of life at universities, particularly in lower-division introductory courses. Providing PBL in large lecture sections is a difficult challenge. Classes are often held in large lecture halls with theater-type seating that is not conducive to group work, and with poor acoustics that can turn even quiet discussions into an ear-splitting din (Ebert-May *et al.*, 1997).

With some careful forethought, though, PBL has been implemented in large lecture sessions including; endocrine physiology (Walters, 2001), business (McWilliams & Henderson, 2006), literature (Yohannes, 2007), biochemistry (Hodges, 2006), and biology (Ebert-May *et al.*, 1997). The following relates the evidence-based approaches of the author to implementing PBL in large biology lecture sections.

Throughout this paper I will use two examples of PBL units that I have successfully employed with large lecture sections. The first, titled "Atkins or Fadkins?" (Bledsoe, 2009) used fad diets as a vehicle for non-major biology students to understand homeostasis across multiple human systems. In the second, designed for a unit on evolution, students were asked to explain why Darwin's theory of natural selection is still accepted by science today (in modified form), while earlier theories of Lamarck and Buffon are not. This was designed to teach not only about evolution, but also the 'Nature of Science'.

Begin with the end in mind

Handbooks and research articles on preparing PBL for the classroom (Markham *et al.*, 2003, for example) generally agree on the principle underlying *Understanding by Design* (Wiggins & McTighe, 2005); before choosing cases, problems, or learning activities, the instructor must define the learning goals in terms of concepts, skills, and reasoning abilities to be mastered.

Once learning goals are defined, the instructor can construct a driving question. A good driving question needs to be open-ended enough that students must find and synthesise information, even create new knowledge, as they work toward a solution (Markham *et al.*, 2003). There need not be a right answer; in fact, most real-life questions do not have one right answer, or may have answers that are complex, intertwined, and cross-disciplinary. For example, “Why are populations of Columbia River salmon declining?” is a driving question we are currently considering as an overarching problem for an introductory nonmajors biology course that includes an ecology unit. The question has multiple answers, some of which are ‘hot-button’ issues for the students in our program whose families may be employed by industries that contribute to the problem but also contribute to the local economy.

The scope of the project should be determined during the planning stage. Problems or cases can require anything from one class session to an entire term to complete. Generally, a PBL curriculum is defined by open-ended problems that require multiple class sessions and reflective thinking to solve, rather than coursework that has students solve multiple, small, well-defined problems within the same class period (Bledsoe, 2007). However, other curricular needs may limit the time that can be devoted to PBL. Devoting every class all term entirely to one problem may not be practical. However, a single problem may span the whole term if it is touched on once or twice during the week and tied to the rest of the curriculum.

The students’ role in designing the project and carrying out activities can also be considered. Allowing students to generate problems from their own interests can create high motivation, but requires considerable time both in and out of class. Students may be granted limited or unlimited autonomy as they work on problems, depending on whether the problem requires guided inquiry to achieve a desired answer, or broad exploration around a less-defined, open-ended problem with no established solution (Markham *et al.*, 2003). In general, ill-defined, open-ended problems work best in smaller classes where the instructor can give more personal attention. Well-defined problems with clear goals have been applied effectively to large lecture sections where students must work more or less autonomously, and require structure at the start of the problem (Walters, 2001).

In designing the “Atkins or Fadkins?” problem, two end goals that I had in mind were understanding homeostasis in human systems and understanding how one’s health choices can affect homeostasis. Students were given a scenario in which two imagined friends are discussing diets, where one friend appears thin to begin with says how he is planning to go on a special high-protein diet while another friend protests that he should not. The driving question became “Should Mitchell be on this diet?”. The question had a desired answer – his weight was already in the normal range so there was no need for him to go on a reducing diet – but I wanted students to explore internal and external triggers that can affect appetite and eating, as well as health effects of food choices and some of the social issues around food and diets. Among the desired outcomes were a more critical view of diet information, a better understanding of their own physiology, and a more compassionate view of the reasons why human body size varies.

The Evolutionary Theory problem had two goals: firstly, to understand what natural selection is, and secondly to develop an understanding of aspects of the 'Nature of Science' (i.e. that science is a human endeavor, that science is evidence-driven, and that scientific knowledge is tentative and subject to change; Lederman, 1998). The driving question for students was in summary, "Why did Darwin's theory of natural selection survive, while earlier theories have been discarded?". I wanted students to be exposed to some original writing, or good translations of early naturalists such as Lamarck and Buffon, rather than textbook summaries of what they said. Students were to compare all three using modern knowledge of genetics to decide which theory was best supported. Among the desired outcomes was a better idea of what evolutionary theory says and what it does *not* say, a better understanding of where evolutionary theory came from, and a better understanding of what a scientific theory is.

The courses in which these units were used were 10-week nonmajors biology classes that met for 50 minutes three times per week. In this limited time frame, with full sessions of up to 70 students, there was too little time to allow students to develop their own questions or to spend much time in group discussions. A teacher-directed, highly-scaffolded design was considered appropriate, with open-endedness in the final solutions.

One particular issue that the college instructor should consider in this early planning stage has become increasingly a part of curriculum planning in our department. This is the degree of consistency that is expected between instructors who teach the same course. Such expectations may be imposed by the students or by the departmental administration. Students often demand consistency in the name of fairness and may complain bitterly if they have to carry out a complex project in their course while a friend in a different section of the same course has no project to grapple with. For this reason, the department may impose some degree of consistency between courses that may prohibit instructors from introducing new activities. Instructors in this situation may be able to agree on delivering the same or similar PBL units across their sections, or may negotiate for an amount of points that may be used to the instructor's discretion for in-class work, quizzes, or PBL units.

The physical layout of the lecture hall may also create issues, since lengthy group discussions are difficult to carry out in the typical lecture hall. However, it is acknowledged that booking alternative rooms or library sessions can be a daunting task. Lecture instructors can use the lecture hall to best advantage for information delivery and well-structured small group discussions that have a short time limit, and assign further information-seeking to out-of-class time.

Creating problems or cases

Several online sources keep libraries of problems and cases that can be used 'as-is' or adapted for a specific course. For example, the National Center for Case Study in Teaching Science (NCCSTS, 2011) at the University of Buffalo has a large collection of peer-reviewed cases for teaching science. The Problem-based Learning Clearinghouse (Institute for Transforming Undergraduate Education, 2011) from the University of Delaware stores a wide range of problem-based lessons in many disciplines. Both sites require registration in order to keep instructor materials out of reach of students. While these libraries may not have exactly the right case or problem to fit a chosen driving question, they can provide inspiration and models.

Problems or cases should be designed to enhance both content knowledge and student reasoning. A problem that requires a student only to hunt for the "right" answers in a textbook provides little challenge. Well-designed PBL encourages hypothesis-driven reasoning to arrive at a solution. With practice, students develop increased willingness to explore multiple possible solutions and use more content knowledge in their solutions (Hmelo, 1998). Content knowledge

becomes more meaningful to the student, and consequently is better retained (Whitehead, 1929; Bransford *et al.*, 1993). However, meaningful learning can be highly situational and influenced by the task at hand. Students take their cues from instructors, written directions, and each other as they determine what knowledge is meaningful and appropriate to apply to the problem (Bledsoe, 2007). Therefore the language an instructor uses to present the problem is critical in order to move students in the desired direction, but not give away too much information.

In developing the “Atkins or Fadkins?” case, the primary challenge was to focus on a case that would involve most of the body systems and the concept of homeostasis, then develop a problem question for that case. Student prior knowledge about body systems was primarily in the area of human health, so I developed a case involving students discussing fad diets as a familiar opening to unfamiliar concepts (Bledsoe, 2009). While strong prior knowledge in students can be an asset in solving problems, prior knowledge also creates a set of expectations regarding the outcome and can even lead students astray (Bledsoe, 2007). In this example, many students had prior knowledge obtained from diet books and websites that was in direct contrast to the information in their textbooks and research-based websites. As the fictional students in the case discussed commercial diet aids, I wanted my students to critically examine the claims regarding diet aids using their textbook and the National Institutes of Health website as authoritative resources. Throughout the unit, students were to think about how the body systems in question contributed to homeostasis, and how some fad diet products or practices might be detrimental to homeostasis and general health. The unit I designed was broken into three parts, each associated with the body systems that were being studied that week, and each beginning with a segment of a story. After reading the story, students had a set of questions to begin discussing in class in their groups. They were to answer the questions more fully at home, then return with their answers to further discuss what they found before turning in their question sets, which were graded for individual accountability. After all of the question sets had been graded and returned, students wrote a final essay in which they framed their response to their “friend,” advising him about his diet choice.

In developing the Evolutionary Theory case, I wanted students to compare three historical theories of organic change. This problem required students to confront their prior ideas about evolution, their definitions of the word “theory,” and their ideas about the Nature of Science. Students also had to master the basics of population genetics to comprehend modern evolutionary theory. In this case too, prior knowledge created a set of expectations, and had the potential to lead students astray if they did not thoroughly examine their ideas about evolution. As with the “Atkins” problem, this problem involved in-class readings and discussion of question sets, completion of the question sets at home, further discussion in class, teacher feedback, and a final summative essay. The flowchart for the instruction in these two units is depicted in Figure 1.

Planning the assessment

It is often easier to create problems or cases than it is to assess them. This is why it is critical to develop assessments during the planning stages. Well-defined end products and assessment plans help clarify desired tasks and outcomes for the students; without these, students become nervous as they wonder what exactly they are to do, and whether they are putting their best efforts into the parts of the project that matter most when they are assessed (Markham *et al.*, 2003).

The end product should be defined early in the planning stages. One possible product is a short paper, written by groups or individuals and graded outside of class. Papers require that students organise and synthesise information, which is challenging for many undergraduate

students but is an essential skill for many professions. Writing a paper forces individuals to be accountable for their own learning, rather than letting others in the group do much of the work. The downside of a paper is that the audience is usually limited to the instructor alone. Students do not benefit from hearing other solutions to the problem. Grading individual papers creates a heavy load for the instructor, and writing assignments must be crafted carefully to reduce students' ability to plagiarise by copying text from the internet.

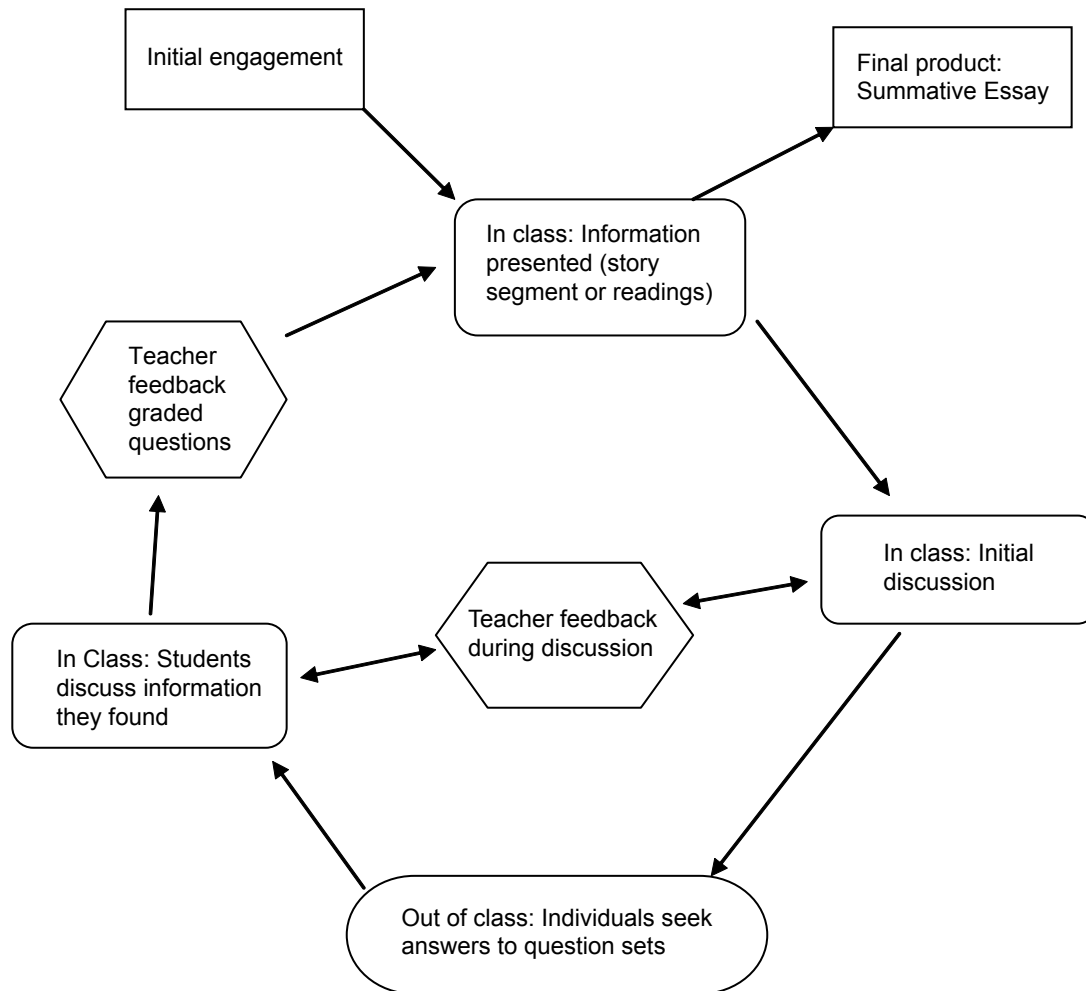


Figure 1 The structure of delivery for instruction and assessment in the example PBL units. After an initial introduction to engage students in the problem, each unit went through multiple cycles of added information, discussion, responses to questions, and feedback before students produced the final summative essay.

Group presentations, poster sessions, and web seminars are means of extending the audience, allowing students to hear one another's solutions. The time required for presentations may be prohibitive in very large lecture sections. Web seminars allow students to participate on their own time, but require student familiarity with the supporting web platform (Hung & Der-Thang, 2001; Shieh, 2006). In all class-based presentations, whether in person or via web seminars, engaging the audience is critical. Otherwise students may become disengaged, or try to leave once their group has presented. Audience participation helps create engagement. The audience may, for example, assume the role of a grant committee assigned to evaluate proposals. In the case of poster sessions or web seminars, students may be required to visit at least three other groups and fill out an assessment rubric. Table 1 summarises literature concerning the benefits of three different large-effort final products, issues surrounding each, and possible solutions.

These outcomes of PBL units are typical of large-effort products that require a well-designed grading system. Other PBL units have used smaller-scale products to assess formative or summative learning, products that require less grading time, including: whole class discussions (Walters, 2001; Yohannes, 2007); ongoing assessment via clicker technology (McWilliams & Henderson, 2006); and, outcomes of written exams (Ebert-May *et al.*, 1997).

Table 1 Benefits and issues associated with several final products of PBL units, and potential solutions

Product	Benefits	Issues	Solutions
Final Paper (Markham <i>et al.</i> , 2003; Yohannes, 2007)	Allows in-depth thinking and analysis Familiar format for most students	Limited audience High grading load for instructor	Best papers can be posted online and awarded bonus points. Keep papers short. Have a clear rubric. Assign group papers, where each member has a specific section to contribute.
Presentation or Poster Session (Sluijsmans <i>et al.</i> , 2001; Markham <i>et al.</i> , 2003)	Extends the audience. Capitalizes on social learning	Time-consuming Lack of audience participation	Put a tight time limit on presentations. Provide examples of posters or final presentations as models for length and appearance. Using a short rubric, audience can take the role of raters, such as role-playing evaluators at a granting agency.
Web seminar (Hung & Der-Thanh, 2001; Shieh, 2006)	Extends the audience Employs up-to-date technology	Instructor as tech support – students unfamiliar with the technology Less personal Lack of audience participation	If available, use existing course management software that students are already familiar with. Do a trial run as part of formative assessment. Use as a follow-up to in-class presentations. Have follow-up discussions in class. Assign students the task of rating an assigned set of groups.

Whatever end product is selected, students will need ongoing feedback in the form of formative assessment as they work on long-term problems in order to feel that they are making progress and that their efforts are worth their time (McWilliams & Henderson, 2006). In large lecture sections, this can result in a lot of paper shuffling as students hand in outlines or progress reports for grading and the instructor hands them back. Course management software, if available, can ease the burden by allowing students a means of turning in brief project updates in electronic form, for electronic commentary and a quick turnaround. Another formative assessment is short, two-minute “elevator speeches” in class by each working group (which is to say, students imagine someone in an elevator asking, “So, what is your project about?” and must summarise before they hit the 20th floor). The entire class may benefit from hearing ideas from other groups during the early stages of the project. Voting for different proposed solutions via in-class ‘clickers’ systems (or ‘classroom response systems’) can also allow students some view into what other students think.

In planning how to assess the final product, the instructor needs to consider levels of accountability during the unit. When students work in formal groups, there needs to be some part of the end product that is a group effort and is assessed for the whole group. However,

students are often concerned when a group member does not contribute substantially, lest their individual grades be affected (Barrows & Tamblyn, 1980). This is a fair concern and if teamwork is an important learning outcome of the course, the instructor is justified in grading students on their ability to work in teams. If the learning outcomes are largely around content, instructors may want to consider how best to deal with groups where a member fails to participate fully or drops out entirely, without penalizing those who participate to the fullest. Alternatively, the instructor may want to rely primarily on individual accountability, based on knowledge gained, or an individual's participation in the group (or both). Groups themselves may rate their level of satisfaction with the group members' efforts, which can be a reliable measurement if groups are provided with clear criteria for doing so (Sluijsmans, 2001).

Rubrics are useful scoring guides that help ease the final grading task. A good rubric should provide a clear, written description of student expectations for components of the problem-solving task, and should describe what outcomes would fail to meet, meet, or exceed expectations. A rubric handed out at the start of the project helps students understand what they are to do by the end. Campus writing centers are often good resources for rubric development. The *Project Based Learning Handbook* (Markham *et al.*, 2003) has many useful examples

In planning the "Atkins or Fadkins?" and the Evolutionary Theory problems, in spite of the added grading load I chose to have students write short individual papers, of no more than two pages long. My reasons for this were twofold. First, the group work for these problems was informal. Groups were flexible and students sometimes chose to work with different people at different times. This suited classes where attendance was often patchy, but where I wanted students to benefit from social learning. Second, I was deliberately confronting common misconceptions in both of the problems, and wanted to track individual student thinking, which I could guide with feedback on formative questions that were handed in. Ongoing assessment during these units consisted of a few short sets of graded questions to be turned in by individuals and many ungraded "Daily Work" questions, which could be done by groups. Both allowed me to track changes in student thinking. The "Daily Work" was developed from classroom assessment ideas presented in Angelo & Cross (1993). Short written assessments such as one-minute papers, "muddiest idea", concept matrix, and others could be quickly scanned and sorted to see how many students were mastering a concept and how many were not.

The summative assignment for each problem was a short synthesis essay, no more than two pages, which addressed highly specific questions and thus reduced opportunities to plagiarise. With the help of the university's Writing Center, I developed rubrics specifically for each project, which were given to students before they began writing so that they would know how they were being graded. The rubrics reduced grading time by making the expectations clear, and by providing a point-based checklist which reduced time-consuming subjective decisions.

Launching the problem

As might be surmised at this point, most of the hard work involved in PBL happens long before the problem is presented to the class. If PBL is well-designed from the outset and most difficulties anticipated, units usually run smoothly. Trying to plan and administer PBL at the same time results in unclear directives leading to confusion and frustration for the students (Markham *et al.*, 2003).

To begin the unit, students will need to be introduced to the problem and provided with enough information to get started on solving it. Large lecture halls are set up for broadcasting information from the front of the room, and this setup can be used to advantage to introduce students to a problem. At the simplest level, a computer slideshow can present the problem in story form. To take full advantage of this visual medium, instructors can embed photos, illustrations, movies,

animations, and similar multimedia into the presentation in order to arouse student interest and engage them in the problem from the start (Markham *et al.*, 2003).

Students may gather into informal groups on the spot, or the instructor may pre-assign groups, depending on the logistics of the class and the formality of the groups. For most efficient functioning, group members should have specific roles, whether these are classic cooperative learning roles (leader, recorder, etc.) or group members dividing a set of stated tasks between them (Barrows & Tamblyn, 1980). Before they leave from the introductory session, students should be clear about what group they belong to (if formal groups are used), what work is expected from them, and when it is due.

Students should also be introduced to any online support materials if they are being used. Discussion boards on course management software, or a class Wiki can be employed to foster student collaboration, which in turn help foster higher levels of thinking (Hung & Der-Thanq, 2001; Shieh, 2006). Scanning online discussions allows the instructor an opportunity to spot misconceptions and decide how to address them. Individual groups will need their own space, such as their own threads or folders on a discussion board, to prevent mass confusion and to support collaboration.

It is essential to build in checkpoints into regular instruction so that necessary guidance or just-in-time instruction can be given to keep problem-solving on track. Infusing information relevant to the problem into multiple lectures and allowing class time to discuss the information keeps students involved in the problem, and allows them to re-think their solution in the light of new information. Additional information and useful website links can be added to any online support materials.

The “Atkins or Fadkins?” problem was launched using a PowerPoint presentation with the initial segment of the story involving students discussing diets. At the end of the story segment, the class was presented with a set of difficult questions that came out of the first story. Students needed to know basic facts about nutrients, including protein and carbohydrates, and understand what “calorie” and “energy” mean in a scientific sense. They were to critically analyse statements made by the characters in the story, such as, “If you eat way too much protein and not enough carbs you can ruin your kidneys forever.” After discussing their ideas, students used suggested resources to find answers to these questions at home, then discussed their responses in class. This cycle of story, discussion, seek information, discussion went through three iterations, before students wrote their final summary paper.

The Evolutionary Theory problem was also launched with PowerPoint, and with printed readings that were handed out in class. Students read and analyzed excerpts from writings of Buffon, Lamarck, and Darwin and Wallace (presented together), one reading per iteration of the learning cycle illustrated in Figure 1. With each reading, students critically analyzed the statements in the light of modern genetic knowledge and made judgments regarding strong points and weak points of each theory. By the end of the in-class sessions, students were able to summarise why the Darwin-Wallace theory of natural selection is supported by modern genetics.

One of the first things that the instructor will notice when launching the problem and beginning group discussions is that small group discussions in a large lecture hall create a great deal of noise. The large class also makes non-participation easy. Instructors find it difficult to oversee all conversations to be sure all groups are on-task and that all students are participating (Ebert-May *et al.*, 1997). Students who do not want to participate may find it easy to hide in the crowd by simply sitting near a group, unnoticed in all the activity. Table 2 summarises typical

problems that I have encountered when carrying out group discussions, and types of solutions that I have employed.

Table 2 *Issues that arose during discussion in the example PBL units, and solutions that were applied*

Problems	Potential solutions
Creating a safe discussion environment: students may find it hard to speak up in front of the whole class.	Think/Pair/Share or small group discussions allow students to voice ideas to a partner or small group and write them down. Instructor can pick pairs or groups to share written responses with the class.
Group vs. individual accountability: easier for students to hide non-participation in a large lecture section.	Group discussions can be followed by individual written questions or “one-minute” essays, which can be graded or ungraded. Group responses to questions can be marked for participation only, providing low-stakes group accountability.
Non-participation by individual students.	Individual writing assignments (graded or ungraded) can be collected before discussion at times and after at other times. If the collection time is unpredictable, students are more inclined to participate instead of copying down an answer after discussion.
Off-topic talking.	Provide focused discussion questions with a definitive product, such as a set of written answers or a group oral response. Set a time limit, providing just enough time to finish the question set.
Volume: poor acoustics, loud discussions.	Remind students as they start to keep their voices low. Short time limits and small question sets allow students to complete discussions before the volume rises out of control.
High post-discussion grading load for the instructor.	Small “daily work” assignments can be ungraded, marked only for participation and not returned. A quick scan of these papers can assess the whole-class grasp of a topic.

At the end

Whether the final product is a presentation, web seminar, poster session, or paper, scheduling the final production for the last day of class means there is no opportunity to reflect on what was learned. The problems presented as examples in this paper are problems requiring a few weeks to complete, and are finished before the end of the term. This gives students the opportunity to discuss what they have learned, give feedback to others if the format allows, and assess their own thinking. Feedback from the group or a final class discussion brings satisfactory closure to the problem. If students are working within a common web space, a final reflection can become a part of the assignment.

Conclusions

Working PBL into large lecture sections takes more time in planning, managing, and grading than lecture instructors are typically used to. However, employing class time for problem-solving frees the instructor from always being on stage, and allows the instructor to circulate among the students, getting to know them on a more personal level (Barrows & Tamblyn, 1980). Problems that span multiple topics help students recognize the connections between topics, and helps students retain content knowledge better because of the multiple links they create between concepts. With these benefits to be gained, it is worth an instructor’s time to infuse some degree of problem-solving into lectures, whether it is problems solved within a single class, or problems that span many weeks.

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