AC 2001-885: The Role of the Lecturer in the New Learning Strategies

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Recent trends in education have included learning strategies that employ complex, often multi-disciplinary, problems as centerpieces. They are then employed as beacons toward which course topics, concepts, or solution methods are directed. Generally, the learning strategies can be categorized as case-based, problem-based, or inquiry-based. These three new approaches tend to rely on the use of technical papers or briefs, whether electronic or printed, to support and drive the discussion of the topic. As a result, the traditional role of the lecturer, moving sequentially through chapters in a textbook, has been challenged. However, the qualities that make for an effective traditional lecture are also present in these new approaches.

I. Learning strategies and their use in engineering courses

Case-based learning uses previously solved problems to understand and investigate the decisions and methodologies that were employed to arrive at the solution. For engineering courses, cases may come from industrial projects or previous design projects. They include enough details about the problem statement and the variety of solutions under consideration so that advantages and disadvantages can be discussed. Depending on the course and topic, the case may draw attention to the technical issues, economical aspects, and societal impact.

Consider an introductory engineering design course, where students get their first exposure to the design process by solving an industrial problem. Prior to tackling the problem, the instructor may choose to introduce students to the design approach by reviewing how students from previous semesters addressed a different industry-sponsored project. In this instance, the 'case' would focus on how the students organized their work, gathered information, dealt with highly technical information, made decisions, and presented their solution. The instructor's role is to present the students with the proper background information to the problem and solution approach, craft sessions to dissect and discuss the information, and provide an opportunity for students to reflect or get feedback on their understanding of the design process.

Problem-based learning is similar to case-based learning in that it features a problem statement; however with this method, the solution will be determined by the students and the learning occurs while solving the problem. An additional outcome of the method is that students develop their problem solving skills and continue to enhance those skills as they encounter different problem types. This method tends to be familiar to engineering instructors, particularly those who are responsible for capstone design projects. It requires students understand and tap their prior knowledge as well as fill in the gaps in their knowledge–all in the context of solving a particular problem.

For engineering students, the process of interlocking various knowledge pieces to solve a problem is very difficult because it usually involves integrating seemingly disparate subjects. While capstone projects are most closely associated with this technique, engineering instruction at lower-level courses can benefit from this approach. For example, consider a pedestrian bridge project in a fundamental mechanics course. Students will employ knowledge about mechanical loads, internal stresses, material properties, manufacturing, assembly, engineering codes, and economics. The instructor must structure the mechanics topics sequence so students can apply their newfound knowledge directly to the project as the course progresses. With regard to topics outside the scope of the course, such as engineering codes, the instructor must raise student awareness and cite references for the students to explore. Finally, the instructor should provide an opportunity for students to assess and get feedback on their understanding of the knowledge throughout the project solution stages.

Inquiry-based learning is differentiated from the other two strategies in that it is driven by specific questions for which the students must present answers that are grounded on investigation, research, experimentation, or discovery. While step-by-step laboratory experiments are good activities for illustrating the practice of experimental methods, they are grossly inadequate for allowing students to develop the critical thinking skills necessary to determine what experiments are needed, how to assess existing evidence, and how to show sufficient arguments to support the answer. In fact, such experiments accomplish the opposite goal. They assure the student that everything will work out okay if they just carefully follow directions. Thus, successful implementation of an inquiry-based learning experience requires focused, persistent attention by the instructor.

Consider the point in a fundamental mechanics course when the relationship between axial deformation and axial load is being presented. The instructor could ask “How do specimen length, stiffness and cross-sectional area affect axial deformation for a constant axial load?” Students would have to support their answers with sound evidence and reasoning, such as analysis of experimental data, a derivation, or a set of observations. A single equation or sentence from the textbook would be inadequate. The instructor's role when applying this strategy is to pose an answerable question and depending on the depth of response expected, provide a breadth of resources for the students. For the axial deformation example, a wide assortment of rubber bands may be sufficient.

In summary, these three learning strategies increase the student's involvement during class. Does this mean the lecturer role is reduced? No, but it is changed. In some instances, an entire course may be revised based on one of these strategies, but more likely, the instructor will choose the specific method that fits a particular topic in a course.

II. Course Structure - Ground rules for student engagement

Successful implementation of any of these three learning strategies begins with discussing expectations with the students. They must know what you expect and what to expect from you. For example, with each of the three strategies there will always be classes in which discussions dominate. In those instances, student and instructor preparation is essential. Just as 'winging' a lecture is poor practice, so is 'winging' an open discussion session.

The importance of student preparedness is perhaps one of the most significant differences between the traditional lecture and those learning vehicles that require discussion. For traditional lectures the 'assigned' reading may occur only if the student is stumped while attempting the homework problems. Lecture notes are often believed to define the topic coverage for which the student is accountable–not the assigned reading.Thus, students used to attending class, taking careful notes, asking or answering an occasional question are likely to be uncomfortable with their new role. Fortunately, techniques, such as Readiness Assurance Process[1] and peer instruction[2], have been developed and used successfully in conjunction with problem-based and case-based learning and can easily be applied to inquiry-based learning. These techniques require students articulate, as discussants in a group, their understanding of specific material.

Discussion generation is the product of a focused technique. Rich interactions will be sure to occur when the questions posed by the instructor are challenging and well organized so that students can respond thoughtfully with sound reasoning and evidence. Students must be faced with discussion questions that demand salient points to emerge, common mistakes to be addressed, and topics to be summarized. If instructors pose such questions, students will see the benefits of being prepared because their individual and collective responses will affect the breadth and depth of coverage.

Another technique similar to using case study readings, but more likely encountered with inquiry-based learning is the critical review of technical briefs, reports, or journal papers. The collection of papers spans the intended topic coverage and the readings are assigned to progressively build on the concepts. With each assigned reading, the students receive a list of questions, which forms the basis of class discussion. For higher level courses, students identify appropriate readings for a particular topic, justify their choices, and even prepare the list of questions that will support the ensuing discussion.

III. Course Preparation – The library connection

Integrating library resources and research skills in the classroom provides another link to engineering practice. A number of studies suggest that engineers have a tendency to use personal resources and colleague expertise before utilizing library resources. While this is adequate in some situations, the revisions in standards, updates in regulations and progress in research indicate a need to go beyond what most engineers can collect or know. In addition, the increasing interdisciplinary nature of engineering and science necessitates breadth and depth of information resources. These needs can best be met with judicial use of the library and the library component must be totally integrated into the course, a seamless component rather than an evident add-on. Any obvious add-on assignment is seen as busy-work which forces the student to use the library with no evident relationship between the activity and the class.

Like all disciplines, engineering must face the new information environment. Skills that are crucial include recognition of the resources available, identification of the most appropriate resources for the need, and then effective utilization of those resources. Identification of resources has become more difficult as resources proliferate. Resources include databases that index journals, conferences, reports and books such as *Compendex, NTIS, Aerospace Database*, etc., online catalogs, full text books, journals, standards and handbooks, datasets, graphics, videos, and more. Narrowing the field of information appropriately is the first challenge. There are several ways to address this proliferation of resources. The traditional handout or a short talk/demonstration will focus attention on the most appropriate resources; however, utilizing the web is fast, highly adaptable and popular with students. For course specific or assignment specific as in case-based or problem-based activities, customized web pages with annotations can be created to direct students to the most appropriate sites, lowering frustration levels and increasing efficiency.

Once a list of appropriate sites is devised, students need a basic primer on how to navigate the resources. The goal is efficient searching with appropriate results. After the student has a listing of citations the critical research of evaluating the resources begins. The criteria may include accuracy, authority, objectivity, currency and depth of coverage. There is no all-encompassing checklist that works for all examples. These five criteria take on varying importance by the individual need, the subject and the research environment. Authority and objectivity are somewhat moot in a database such as *Compendex*, which indexes the better journals and conferences in engineering. However, these are absolutely critical when evaluating web documents where anyone can create a professional looking site and present inaccurate information as evaluated reliable data. Currency is another flexible criterion. For most research, the most recent information is considered crucial, but historical data can provide interesting classroom perspective for a discussion. Another area that is often a stumbling block for students is the tendency to develop extensive bibliographies of information that is beyond their current comprehension or need. Thus, there are times when the appropriate database is *Applied Science and Technology*, not *Compendex*.

To illustrate the point, return to the assignment of designing a pedestrian bridge. The area is marshy, the environmental groups are very concerned about its impact on endangered rookeries, and the local community wants handicapped access. Of course, safety is a primary factor and the budget is tight. A resource list could be developed which includes engineering databases, design handbooks, online catalogs to locate primary sources, environmental databases to present real life scenarios, and Environmental Protection Agency and American With Disabilities Act web sites.

Current cost estimating guides and construction codes are a necessity. Pulling together information from a number of resources allows the students to develop a realistic design, which considers all the factors. Evaluation of the resources for objectivity, currency, accuracy and authority will be paramount and the result is a project that integrates the factors that exist in real life design.

For specific assignments the appropriate research tool, i.e., database, web site, or search engine can be introduced and the requisite evaluation skills can be developed. Thus, the somewhat confusing process to obtain resources, either at the local university, through interlibrary loans, web documents, etc. can be developed naturally when working with the students rather than artificially introduced in a library tour. Whether case, problem, or inquiry-based learning, students must become familiar with gathering meaningful information and assessing, to some degree, the level of authority.

IV. Illustrative Examples - Preparation and class structure

Not all courses or course material can be neatly packaged to fit one learning strategy, but the range of courses and topics where case, problem or inquiry-based learning is applicable is vast. The following examples demonstrate the approaches and describe the instructor and student preparation as well as the class activity. Do not underestimate the time to identify, review and select appropriate materials. Guide the discussion by carefully wording questions that will ultimately lead to addressing the desired learning objective, and give students ample time to reflect on what they have learned.

a. Case-based learning in an engineering ethics course

<u>Topic and case:</u> Whistle blowing is perhaps best demonstrated by widely covered accounts of negligence, such as in the case of the space shuttle Challenger explosion.
<u>Prior to class:</u> Select and make available to students a concise but broad range of readings to expose them to the technical and management issues. This case may include the following sources: *Newsweek* interview with the CEO of the booster rocket manufacturer, *Physics Today* article that summarizes the investigating committee’s findings, and videotape (or transcript) of the famed whistle blower, Roger Boisjoly, lecture to MIT students. Specific questions should be provided with the readings in the event that a student needs to dig for additional information. Identify the particular learning objective and develop a plan for drawing out of the students observations that will meet that objective.
<u>During class:</u> Begin with discussing the position and perspective from the different sources and what motivated the creation of each document. Guide the discussion to hit the key points you feel are important. Summarize with a list the points either as a wrap up or at intermediate points in the discussion.

b. Problem-based learning in a mass transport course

<u>Topic and problem:</u> Diffusive transport is a topic common to many mass transport situations. Although the general transport equations are available, there are many twists to the initial and

boundary conditions that cause havoc with students when it is time to model a specific situation. Electrochemical applications such as plating, ion selective electrodes or corrosion are excellent candidates for a problem-based learning experience.
Prior to class: Select and make available to students readings to expose them to the redox vocabulary. In this situation, referral to the topic chapter in a first year chemistry book will certainly do the trick. Provide specific questions that direct students to the task of reviewing the mathematical techniques or transforms they will need to solve the problem. Break the problem to be presented in class into manageable segments so that a group or possible team approach will have boundaries that limit the chances of the collective problem solving experience drifting out of control.
During class: Begin with a discussion of the physical image needed to begin to match the mathematical statement of initial and boundary conditions to the stated problem. Do not define these conditions, but leave that as part of the problem solving discussion activity. Direct the class discussion toward the distinction between developing the problem's equations and applying physical translations to the initial boundary conditions. When the time is right, review the steps the students took to reach the successful mathematical statement of the problem.

c. Inquiry-based learning to understand the application of scientific findings
Topic and case: The Challenger disaster is well known for the ensuing investigations to uncover the cause of the disaster. The question 'What scientific findings changed or refined engineering design practice as a result of those investigations?' can be posed during the discussion session.
Prior to class: Select and make available to students a copy of the commissioned investigative report and background on thermal effects on materials. Assign one group of students to collect and present a summary of the relevant science at the time of the disaster and another group of students to collect and summarize the subsequent research that discovered the flaw in the design. One of the more difficult but important research databases, *Science Citation Index*, can be introduced. It is a unique source that allows the researcher to follow a relevant journal article forward in time.
During class: Begin by having each student group present the state of the relevant science at the time of the incident. Direct the discussion to investigate how the disaster advanced the understanding of the science and or the engineering design practice. Close attention to accuracy, authority, and objectivity in these instances could generate interesting discussion. Currency also becomes an issue as the two groups must pay close attention to research dates.

V. Evaluating Student Participation - Documenting student preparedness and learning

Evaluation of student participation in case, problem, or inquiry-based learning situations is critical if an instructor expects these strategies to be viable instructional methods. Not only is evaluation of performance and/or the extent of learning important to determine a grade for students enrolled in a course, it must also be considered in light of the ABET assessment criteria. The driving concern is to determine if the students are achieving the stated objectives of the topic, course, or curricula.

The assessment of student mastery of course content is straightforward. The assessment tools used can certainly be the exact same instruments currently used in your program. The fundamental goal is to determine and document if the students have accomplished the stated course objectives. The choice and use of case, problem, or inquiry-based learning strategies merely offers an alternative route to the desired outcome. Traditional assessment techniques will, therefore, continue to confirm any course content objectives.

The three learning strategies provide a means to achieve the course content objectives. However, these learning strategies themselves require that additional skills be developed and matured. These include, at a minimum, teamwork skills, information gathering skills, and the variety of communication skills required to actively and effectively participate in group discussions (listen attentively, ask pertinent and possible probing questions). Students' observation, synthesis, and analytical thinking skills may be isolated as educational objectives in these learning environments. If desired, the educational unit may choose to assess student maturation in these cognitive areas. The particulars of such assessment tools will certainly depend on the extent of use of the alternative learning strategies in a course and the level of the course. Regardless, use of case-based, inquiry-based, and/or problem-based learning strategies offers significant opportunities to assess the less tangible goals of an ABET curriculum. Their successful use also demonstrates horizontal and vertical integration throughout the curriculum.

Possible evaluation tools of student participation and oral communication skills include pre and post experience essays and activity journal. For the essays, students are directed to outline their initial reactions to the posed situation and how they would proceed with the case or problem. The exercise is repeated after the learning experience. The instructor then uses a developed tool to isolate the particular skills pertinent to the material or activity. Similarly, a journal for the extent of the learning activity can be used.

If the instructor and/or the educational unit chooses to assess the non-content aspects of a students education during case-based, inquiry-based or problem-based learning activities, they can use the spirit of ABET to fine-tune the entire exercise. The development and use of any effective assessment tool requires that the topic, teaching materials, and teaching methodology be evaluated in light of the desired learning outcomes and objectives. Thus evaluation of objectives in light of the assessment tools should allow for fine-tuning of the assessment process itself. For sure, this approach increases the time and energy spent by the instructor and in return, it also maximizes the possibility of students meeting with success in all the educational goals associated with these learning strategies.

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