Changing From a Lecture-Based Format to a Team Learning/Project-Driven Format: Lessons Learned

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ABSTRACT

In a number of courses in the School of Civil Engineering and Environmental Science (CEES) at the University of Oklahoma (OU), we are making a transition from the traditional lecture-based paradigm to a new paradigm that includes active, team-based learning, team teaching, and a project-driven syllabus. Based on our experience, we have identified five key measures to ease the transition and enhance the educational experience: 1) use "real-world" projects to motivate the learning process and introduce them at the beginning of the semester; 2) follow established keys to using groups successfully; 3) ensure sufficient "coverage" by having students learn basic material outside the classroom, which also fosters life-long learning; 4) team teach courses; and 5) use laboratory sessions for group-learning activities. While the concepts have been tested on upper-level courses (junior, senior, graduate), we feel they are appropriate for lower-division courses as well.

INTRODUCTION

Local and national surveys consistently point to several weaknesses in engineering education, including our graduates inability to communicate effectively, to interact with co-workers and management, and to think critically[4,5,7,8,13,15]. Among other problems, these weaknesses inhibit our graduates' ability to play an active role in team-oriented projects (which are becoming the norm in many consulting and industry organizations[11]) and their ability to present these results to management and the public. However, for reasons ranging from entrenched teaching strategies to lack of time, engineering education has been slow to respond to these needs. It has been our experience that the profession is dominated by the same learning paradigm that has educated engineers for the last several decades, namely, passive classroom lectures, individual homework assignments, and problem-solving exams. Group activities, if they are included at all, tend to be simplistic and ill-supervised. We in CEES are beginning to address these weaknesses via classroom reform. The paradigm centers on project-driven assignments, where students are organized into permanent teams and given a complex design question at the beginning of the semester *before* any substantive background material is delivered. In the remainder of the semester (or portion thereof, if several tasks are to be assigned), class activities, be they short lectures or class discussions or group exercises, are driven by student questions on how to complete the project. In essence, the syllabus for the course is an evolving document driven by student curiosity, thereby helping to prepare the students for life-long learning. Changing from the "traditional" paradigm to the new requires faculty commitment and administrative support. Still, even with proper support, the transition is not without pitfalls. This manuscript outlines some of the measures we have taken to smooth the transition.

LESSONS LEARNED

Problem 1 - Motivation.
Successful group learning requires students to be self-motivated. What "carrots" can be used to inspire them?

Solution - Project-driven syllabus.
At one of the first class meetings, we define a complex project and pose a list of questions, the academic equivalent of an RFP (request for proposal). Typically, the projects are drawn from our research or completed consulting projects. For example, in a junior-level design course, we present the students with a subdivision layout and charge them with developing the sanitary sewer, water, and storm water infrastructure; in a senior-level/graduate course, we use data from a contaminated aquifer at Hill Air Force Base in Ogden, Utah, and charge the students with evaluating innovative remediation approaches.

The basic task for the semester, then, is to answer all questions in the RFP and submit results to management, i.e., the instructors. We believe, as do our colleagues[3,8,12], that student interest and motivation, and hence learning, is increased when they can see the application behind the theory. Consequently, the key is to introduce the case study *early* in the semester, and then let the course be driven by the students' desire (and need in order to obtain a good grade!) to solve the proposed problem.

Complicated problems, like those used in the RFPs, require multiple "specialists" with various backgrounds. Students are responsible for dividing tasks amongst the specialists in their group; students must face the logistical problem of managing and coordinating all work. Recognizing that all students are motivated to some extent by grades, we have students prepare a timetable for completion of the project and base part of their grade on meeting posted deadlines.

If computer models are part of the course, another successful motivational technique is to distribute the code to the students at the time of the RFP. Students are encouraged to try and run the program without any background information. Typically, they stumble because of a lack of understanding. Much can be learned by the controlled failure, however, and the exercise captures the students' attention and provides motivation for the remainder of the course.

Problem 2 - Avoiding the group project stigma.
Common complaints from poorly structured group projects include: "I care about my grade more than the other members; thus I end up doing all the work."; "We have too much dead-weight."; "We cannot find time to meet."; "Cliques within the group prevent us from interacting as a whole."; and "The task cannot be divided into subparts to be worked on by various group members."

Solution - Permanent, heterogeneous groups and activities that promote interaction.
Group activities simulate the organizational structure used in professional practice when handling complex problems, viz, a project-oriented venue with work responsibilities allocated to

members of an interdisciplinary design team. In this educational scheme, the "senior" members (not necessarily seniors in college, and not necessarily the oldest, but rather team members who display natural leadership ability) of the team would act as "project managers" and technical experts (group leaders). By naturally introducing a teaching aspect into the overall structure, student learning is broadened. We make no attempt to assign group leaders; instead, roles evolve naturally through early group interactions.

To minimize the negative aspects of group learning while maximizing the positive aspects, we rely on a set of "group rules" that have evolved over the years. As summarized by Dr. Michaelsen, a nationally-recognized expert in team learning at the University of Oklahoma, the keys to using groups successfully are[10]:

1) Allow class time for group work.
2) Use group assignments that promote:
   - *individual* pre-class preparation for group work.
   - active discussion of course concepts.
   - team development.
3) Use a grading system that provides incentives for:
   - individual pre-class preparation for group work.
   - active participation in group discussions.
   - high-quality output.
4) Use a grading system that holds individuals accountable (peer evaluations).
5) Use a group formation process that ensures:
   - groups are permanent.
   - groups are maximally heterogeneous with respect to ethnicity, gender, age, experience, and discipline.
   - assets and liabilities spread across groups.
   - pre-existing cohesive subgroups are unlikely, i.e., best friends or boyfriend/girlfriend are not in the same group.

In Michaelsen et al[10], the authors address each of the above points; at the heart of it is the learning activity sequence described in Problem 3 below.

Problem 3 - The "coverage" problem.
Many instructors, particularly in engineering, feel compelled to "cover" a certain quantity of material in a given course, partly because of their own upbringing and partly because of externally-imposed ABET criteria. Thus, coverage becomes equated with lecturing on a topic x for y minutes, without regard to the depth or type of student learning. Two of our favorite quotes succinctly "cover" the coverage problem: "Coverage is the enemy of teaching[2]" and "...the challenge of college teaching is not covering the material for students, but uncovering it[6]."

Solution - RATs!
An extremely effective learning activity sequence, which avoids some of the pitfalls of team learning while increasing the educational experience (i.e., not just the amount of material covered, but the amount of in-depth learning), has been proposed by Dr. Michaelsen[9]. For each

major topic introduced during the course of the semester (as determined by the student's syllabus), we follow the sequence shown in Figure 1.

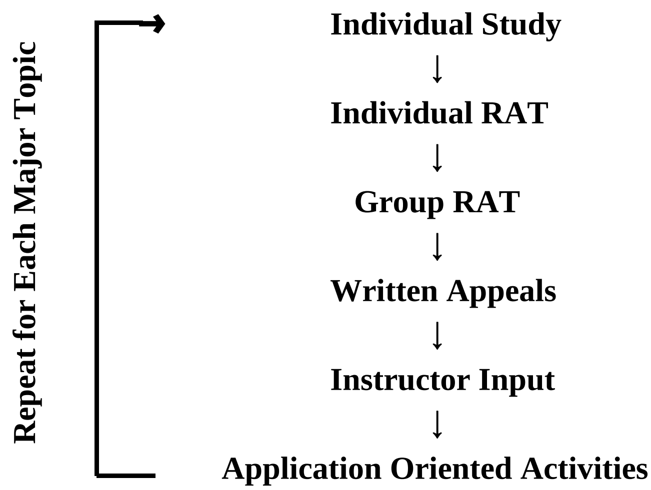

Figure 1. Instructional Activity Sequence[9]

Before any material is presented in class, students will have an announced quiz over a reading assignment. The quizzes, affectionately named RATs (Readiness Assessment Tests), are at the heart of the instructional activity sequence. RATs cover basic concepts from reading; they are taken first by each individual, and then the same RAT is taken by each permanent group. Such a setup addresses a number of pedagogical concerns *in addition* to the coverage issue. First, it forces students to learn on their own outside of class without having all the material "read" to them during a typical lecture. Second, since the RAT exercise emphasizes both individual performance and group performance, we can address the dead-weight problem. Third, the RATs help instructors identify difficult material. Fourth, since students learn the basic concepts and definitions on their own, valuable class time is freed up for explaining the more difficult concepts and for applications. Fifth, the group portion of the RATs promotes the students' communication skills. Sixth, the group portion also introduces a teaching component. As any instructor will testify, a true measure of understanding is being able to explain concepts to others. Furthermore, in preparing for the RATs, groups are encouraged to study together which further fosters these benefits.

Once concepts have been clarified, we then concentrate on applications. For some topics, particularly background-type material, the application can consist of a second quiz, which we term PSs ("p"roblem "s"olving quizzes, but the "post-script" interpretation of this acronym is also appropriate since it comes at the end of the activity sequence). PSs require students to apply principles learned during the activity sequence to open-ended problems; the same quizzes are given to both individuals and groups a la RATs so that the aforementioned benefits can be realized. For other topics, the application centers around a complex task related to the RFP, which requires the groups to divide the labor, carry out the work, and assemble the results as written and oral reports.

Problem 4 - How can an individual instructor serve as a model for the importance of groups?
All evidence points toward the importance of collaborative learning[1,14], yet the traditional single instructor mode is not a good model of group synergy, nor can it ever be.

Solution - Team teaching.
Team teaching does *not* mean tag-team. Rather, it means that both instructors are present in each class. Team teaching is synergistic; it provides a mechanism for alternative delivery techniques and enhanced group discussions. By observing and critiquing each other, instructors can improve their style and approach to educating students. Moreover, since all instructors have their own area of specialty, they can draw on each other's strengths to present a more complete picture of the problem. We have also found that team teaching enhances group discussion. Finally, we note that team teaching is funner (sic), which equates to high instructor enthusiasm.

On the other hand, we are not blind to the fact that most schools, including our own, do not have the resources to place two professors in every course. A possible solution, which we have just begun to implement, is to team teach with select Ph.D. candidates or post-doctoral students, especially those who wish to pursue academic careers. No additional funding is provided because we view it as part of their overall academic experience, not an extra service. A very positive aspect of this arrangement is that it helps us address a widely-recognized weakness in graduate education, viz, many recent graduates are ill-prepared to teach, even though they may be excellent researchers[2].

Problem 5 - We never have enough contact time!
Despite the effectiveness of the RATs in shifting much of the learning outside of the classroom, we still find ourselves short of time in the classroom, particularly when doing active, group learning exercises. This is not a surprising situation in that our entire University calendar has been optimized for the lecture paradigm, i.e., one credit hour of instruction equals just 50 minutes of contact time per week.

Solution - The lab session.
A temporary solution, until profound changes occur in the structure of the University calendar, is to take advantage of "lab" sessions that can be implemented for any engineering course. At OU, and at many other universities, one credit hour of lab instruction equals three hours of contact time per week. If one assumes a typical 16-hour credit load and if all courses implemented a lab session, then the total contact time per week would be less than 30 hours; hence, it could easily fit in the existing calendar. Moreover, with the expanded sessions, student groups would be required to meet less frequently outside of the classroom, which partially offsets the extra contact time. More importantly, this expanded time slot could be used to conduct group learning activities at a more relaxed pace, a pace that allows students to reflect on problems, explore and assess alternative solutions, and critique other group's solutions, all of which promote the higher level learning[1,6] that we are trying to achieve.

SUMMARY

In closing, we feel that our profession needs a change in engineering pedagogy; a change that produces graduates who are self-disciplined, responsible, curious, team-oriented, and effective communicators; a change that produces graduates who are not only prepared for their technical jobs as knowledgeable engineers, but for their places in the larger real world; a change that prepares students to be life-long learners; a change that integrates teaching and research; and a change that prepares graduates for multiple career paths. The course paradigm described herein is a step in this direction. By using an unstructured, project-driven, interdisciplinary team setting, we are developing the students' oral and written communication skills, preparing them to work in groups, and teaching them how to teach themselves. By centering the pedagogical steps around "real-world" projects, we are developing valuable technical skills as well. We feel that this methodology is an important contribution to re-engineering the engineering curriculum, both at OU and beyond.

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BIOGRAPHICAL INFORMATION

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