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**Strength in Numbers. Making the Large Chemistry Lecture Course Work for You.**

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Why create another collection that assiduously reviews the literature on teaching large classes and provides yet more examples from actual classroom practice? What can anyone say about the large college course that has not been said a hundred times already? Within the usual assumptions about this topic, the answer may be very little, I expect. (Wait! Do not close the book. I am not giving up on the idea that there is something new to say.) For instance, if any reader of this volume enters any key word, phrase, or technique mentioned here into www.google.com (or pick your own favorite search engine), the result would be a high number of hits, all supporting the virtues of whatever idea was searched. The literature on large classes is there for the taking. All of the subject domains are represented. Highly credible educational research has been carried out and many of the recommendations are highly aligned. So what is the deal? What are we missing that we need to revisit this topic so often?

What assumptions can be examined in order to bring different insights to this topic? I would like to answer in two ways. First, I will begin this chapter with a brief framework for answering the question about large classes, and include some examples from my practice to illustrate the ideas. This is the traditional strategy; namely, I will share examples in a way that I hope others will be able to learn from. Yet, a large lecture class is not disembodied from its context, and my instructional setting and its parameters are as idiosyncratic as they would be for anyone else. So

I also mean to address the problem of instructional design and implementation from a systemic perspective. In my second answer, I will describe a future faculty development program designed to break higher education out of the decades-old cycle of rediscovery and reinvention that now occurs with each new generation of faculty.

As a matter of setting a context, the large course that I am involved with is a two-term introductory chemistry course called *Structure and Reactivity*. In 1989, my colleagues and I instituted a large-scale curricular change to introductory chemistry instruction at the University of Michigan (Ege, Coppola, and Lawton, 1997; Coppola, Ege, and Lawton, 1997). The *Structure and Reactivity* courses use organic chemistry to introduce students to the fundamental concepts of chemistry instead of using the physical chemistry approach traditional to *General Chemistry* courses. In the Fall term, there are ca. 1000 students who elect the first term of *Structure and Reactivity*, 55% of whom are first-term, first-year students. There are 3 large lecture sections taught by 3 different faculty members, one of whom is the course coordinator. Students groups of 18-24 meet for recitation sections, and these same groups comprise the laboratory sections.

We give common examinations that are assembled by the 3 faculty instructors. The examples used on the exams are generally drawn from the primary literature (Coppola, 2001). We do not use low-level questions (multiple choice, matching, definition, or ranking the order) in favor of problems where students must draw chemical structures and provide explanations for unfamiliar phenomena. We assign grades on a historically determined absolute scale. Finally, we also provide a number of different opportunities for students from the large, impersonal lecture setting to form small peer-led study groups that are led by undergraduates experienced in the course (Coppola, 1995). Beginning in 1994, we used this model of peer-led instruction as the

basis for the Honors option, called Structured Study Groups (Coppola, Daniels, and Pontrello, 2001).

**Wulff, Nyquist, and Abbott**

From among hundreds of articles written about large course instruction, I have selected just one to frame the first part of my discussion. In 1987, Wulff, Nyquist, and Abbott (1987) suggested three dimensions about teaching that are particularly useful for thinking about large courses. First, they remind us that teaching is a complex process, and effective teaching more so. And, increasing the scale of teaching and learning from 1-on-1 to 1-on-500 further increases the complexity by expanding the number of choices and decisions that need to be made.

Second, Wulff, Nyquist and Abbott say that good teaching follows from understanding. Although they do not use the term, they mean pedagogical content knowledge or PCK (Gess-Newsome and Lederman, 1999). PCK acknowledges that content and process are not on opposites ends of a linear spectrum, but rather interact with each other (Ege, Coppola, and Lawton, 1997). A forthcoming reformulation of Bloom's taxonomy is predicated on this idea (Pintrich, 2001). Understanding, as encouraged by Wulff *et al* includes both subject matter knowledge (one's expertise in the content) and its intersection with the range of pedagogical choices that one might make in deciding what would constitute effective instruction (student learning). PCK is that set of skills, or understanding, by which an instructor can use disciplinary expertise and pedagogical knowledge in order to decide how to deploy a classroom methodology that is linked to the desired instructional outcome. There are many variables that need to be taken into account in order to make effective PCK-based decisions, including balancing conflicting criteria in what are surely instructional dilemmas. For example, effective use of the large lecture classroom pits the economy of scale against the benefits of personal interaction. In their survey

work with students, the benefits from the large class setting are (1) that lots of other students are present with many different perspectives, (2) a low-pressure environment, (3) a sense of independence, and (4) a variety of attendance options. On the down side, the students report (1) lessened individual responsibility, (2) the impersonal nature of the instructional setting, and (3) noise and distraction. These are choppy waters for an instructor to navigate.

Third, Wulff *et al* encourage instructors to understand how students perceive the instruction they receive. I add to this the idea that instruction always involved human subjects, not just when we are funded to do pedagogical experiments, and that our subjects (our students) deserve a kind of informed consent when they enter our classes. The unstated corollary is that students, like anyone, will create attribution for why something is being done to them. If you are explicit with your instructional goals, and your plan to get there, then this can frame the way students see the course. If you do not let them in on your thinking, they will still have an opinion or explanation for why you are doing what you are doing, but it might not match your reasons at all. This third point, then, recommends that we do a better job at giving out the rules of the game we are playing, and to be sensitive to the messages that are being received in addition to those being sent.

**A Plurality of Goals**

A plurality of instructional needs and objectives creates a familiar tension in formal education between training students in the technical content of the disciplines and more overarching liberal arts values. Large courses also tend to be "service" oriented, meaning that most of the students are there in order to fulfill some sort of requirement imposed by their academic program or professional objective (such as medical school). In our program, we have found value in creating a taxonomy of goals in order to remember that there are many things we

are trying to accomplish in our teaching, and that these goals can sometimes be in conflict. At the liberal arts level, we want students to leave our courses better able (1) to recognize recurring elements and common themes, (2) to see relationships between things that may seem different, (3) to combine familiar elements into new forms, (4) to arrange their thoughts in logical order, to write and speak clearly and economically, (5) to tolerate ambiguity, (6) to become accustomed to a relatively unstructured and unsupervised research and discovery process, and feel comfortable with nonconformity, and (7) to learn about the kind of creativity that leads to visionary solutions (Ege, Coppola, and Lawton, 1997). Such values describe *general intellectual* goals for education. *Professional intellectual* goals are the overarching values for a more specific literacy at the disciplinary level (e.g., "chemistry," "biology," or "science"). Instructors need to attend explicitly to the connection between the *professional* and *general intellectual* objectives, namely, to answer how learning science is connected to a liberal education. Lastly, individual courses are embedded within the richness of *professional technical* goals: the factual subject matter that typically comprises a written syllabus or table of contents. Technological progress in the disciplines and the detailed articulation of the *professional technical* subject matter should be exploited in order to make clear connections between the facts and the overarching lessons. Instructors need to think explicitly about how learning triple integrals, solving a problem in chemical synthesis, and translating Goethe are not only representative of *professional intellectual* objectives, but also addresses *general intellectual* ones. This connection, which is often simply left up to the student without even a direction to do so, is the greatest step towards making learning relevant for students, namely, to let them know why they are there.

**Teaching and Learning Strategies in the Classroom**

A critical aspect of my teaching philosophy for large classes is that not all strategies are equally important for all students. My students are required to do one thing: take my examinations. I prefer to offer a menu of different learning options to my students in order for them to succeed at this task. This does not mean that the infrastructure of the course is not tightly managed; when it is, it does not guarantee success, but when it is not, then there is inevitably trouble.

Five principles have guided my thinking. A detailed discussion of classroom activities organized by these categories is published (Coppola, 1995).

***Give out the implicit rules.*** Every discipline creates linguistic and symbolic representations for concepts in order to facilitate communication. In professional associations, we share critical assumptions about representations and rules of operation used by our disciplines, including how these are connected to one other. Beginning learners in any area strive to build a picture based on necessarily incomplete information, and their understanding lacks the sophistication that allows experts to make judgments based on the information which is only implied and not at all apparent in the surface features of any word, symbol, or action. Like the fundamental lessons in semiotics provided by the surrealist painter Magritte, "H-O-H" is not water, but only its representation (Hoffmann and Coppola, 1996).

***Socratic Instruction.*** Anything that turns a passive listener into an active participant is a good thing. Unlike others who advocate dismantling the lecture classroom, I claim that what you do with your class time is the key. Certainly, a lecture to a group of novice learners cannot be like a professional seminar because the audience lacks all of the prior knowledge, shared assumptions and understandings. On the other hand, it may not be necessary to demand individual accountability on the part of every student when a question is asked, as is the benefit

in small group work, but rather the opportunity to respond out loud to questions along with hundreds of others. I regularly teach in a 400-seat lecture hall. I do not need to hear every answer as I count to ten after asking a question, but instead I want all of my students to understand that I want them thinking in their seats about the hour's topics, and that I intend for all of them to participate. Some instructors make the error of only acknowledging the expected response from the noisy clamor, affirming the efforts of those who 'got it right' without considering how and why other attentive learners could come to the 'wrong' answer. Exploring the range of possible solutions allows me to demonstrate the kind of reasoning skills I want the students to emulate. I ask open questions nearly every time I judge that I am making an informed decision, which makes the questions very brief, concrete and focused rather than broadly philosophical. The opportunities to ask questions arise spontaneously, so they might occur three times in one minute, or after a ten minute monologue, but the effect is a kind of conversation between me and the class. Training a classroom of first-year students how to have this conversation is a PCK-based strategy that must be mastered.

***Creating alternative metaphors for learning.*** When instructors say "study, learn, and do problems," we do not account for the variety of ways studying, learning, and doing problems might be interpreted by our students. I might memorize and recite lists of items as one way to learn, if I judge that to be an appropriate strategy. But as an expert learner, I have developed a toolbox of techniques, and I readily create new tools as I need them, refining and discarding them according to the tenets of self-regulation. What do we mean when we say "do problems?" How can I express the difference to students who beat on every problem they face with the same wooden club, and who might just as soon look at one of my sophisticated, refined tools, pick it up and start to hammer away with it? One strategy, perhaps the most powerful, is through

metaphor because, when done effectively, it anchors understanding in prior knowledge in its comparison.

***Make examinations reflect your goals.*** A set of examinations outlines the expectations of a course much better than a syllabus. If these goals also include higher order learning and thinking skills, then care must be taken in order to actively preclude unwanted skills. In other words, if I do not want memorization and recitation to be successful, then I must (1) design tasks that do not reinforce these skills, and (2) include explicit instruction for alternative strategies.

***Education is not a neutral activity.*** Mentoring is not an activity that can be turned on and off at will. Faculty members are role models for intellectual citizenship through all of their words and actions when they take on the public trust of education. Faculty members influence directly how the next generation of intellectuals will behave. One of my colleagues, Ralph Williams, uses the wonderful phrase "full human presence" to describe the combined professional and personal obligations of a faculty member to the responsibilities of guiding the development of students (Coppola, 2001a). “Full human presence” represents an ideal. It charges us to be honest and fully realized people in our interactions with those whom we mentor and educate. Ultimately, “full human presence” may be a particularly poignant idea in mentoring and educating undergraduate science students because the research literature indicates such a strong dis-identification of young people from the scientists they see (Seymour and Hewitt, 1997).

**The skill, the will, and the thrill**

It is not enough to want to do something, but one must also know how to do it (McKeachie, 1994). The question of professional development frames the second half of my discussion about large classes. Commitment to good teaching, regardless of its venue, is like any other activity: it requires more than the decision to do so in order for it to happen; it requires the knowledge, and

in particular, pedagogical content knowledge (PCK). Scott Paris, a psychologist at the University of Michigan, has nicely capsulated two distinct interactions, namely the "skill" and the "will" for what is called strategic learning, and I think these apply quite well to faculty members in their teaching (Paris, Lipson, and Wixson, 1983; Paris and Cross, 1983). These ideas about teaching and learning (as change) are generically useful. In addition to the intellectual (skill) and behavioral (will) dimensions, one of Paris' colleagues has also suggested that reward (thrill) should be included, too (Paris, 1997).

Educational psychologists have used *skill*, *will* and *thrill* to remind educators that motivational issues and learning skills play a significant role in student success; I suggest these work equally well when the 'student' is a faculty member learning to be a more effective instructor. Many instructors are motivated to do well (that is, they have the will), and reward structures are a common topic in conversations about institutional structure. I now turn to the root question behind the development of PCK: where does the skill come from? The traditional answer is inadequate: attend workshops on campus and read chapters in books such as this one! The answer, to me, follows from recognizing that effective teaching is at least as demanding as carrying out effective research. Where can a faculty member learn and practice the diversity of pedagogical strategies and how to align them with instructional goals, assessments (Heady, Coppola, and Titterington. 2001), all the while drawing from the core strength of the Ph.D. training? The same place, I contend, where they learn to design, implement, assess and document their research skills: during their formal education.

**Developing the Scholarship of Teaching and Learning: Chemical Sciences at the Interface of Education**.

New faculty members face incredible challenges when they begin their careers. Joining the professoriate means taking on a set of responsibilities and obligations for which the new Ph.D. is basically unprepared.

For over a decade, the Carnegie Foundation for the Advancement of Teaching has advocated a broader understanding of scholarship and its relationship to faculty work. In *Scholarship Reconsidered* (Boyer, 1990), the Foundation's then-president Ernest L. Boyer reminds us that scholarship is a mode of thought and a way of practice that can be applied to all aspects of faculty work. Boyer (p. 14) put it this way: "We believe the time has come to move beyond the tired old 'teaching versus research' debate and give the familiar and honorable term 'scholarship' a broader, more capacious meaning, one that brings legitimacy to the full scope of academic work.... Specifically, we conclude that the work of the professoriate might be thought of as having four separate, yet overlapping, functions. These are: the scholarship of discovery; the scholarship of integration; the scholarship of application; and the scholarship of teaching."

In his proposition, Boyer implies that research, teaching, and service can be done in more or less scholarly ways. The scholarship of discovery (research) has been continually refined in order to minimize non-scholarly work. Over the long term, this has been a core feature of intellectual progress in the scholarship of discovery. Unfortunately, this type of winnowing has never been applied to teaching or service. Instead, teaching and service have not benefited from scholarly development because they have been deliberately moved outside the realm of scholarship.

Inasmuch as *Scholarship Reconsidered* provides a broadened answer to "What is Scholarship?," its follow-up, *Scholarship Assessed*, answers the next implicit question, "What tools do we use to distinguish the more scholarly from the less scholarly?" (Glassick, Huber, and Maeroff, 1997) In the strength of its persuasive argument, *Scholarship Assessed* also provokes a

new question, and that is: "How does scholarship arise?" If research is not the exclusive domain of scholarship, then understanding how we develop our research scholarship becomes a model for how we develop scholarship in general. Scholarship arises through a deliberately constructed infrastructure of professional development in which mentoring relationships play a large role. Through formal and informal work, undergraduates are identified for their scholarly potential and, in the majority of institutions today, provided with opportunities for increasing autonomy and responsibility through independent study and research. These same principles apply to graduate students, with some variation in the balance between formal course requirements, tasks such as proposals and seminars, and research. Research has become the focus of scholarship, and scholarship's infrastructure has become synonymous with the development of research skills. This development continues through the post-doctoral level and provides a momentum for a faculty member's professional career.

What would it look like to broaden the infrastructure of professional development to include the broadened notion of scholarship? In my work, I have been creating the pieces of the infrastructure that are devoted to the scholarship of teaching, beginning at the undergraduate level and extending to the faculty level. CSIE: Chemical Sciences at the Interface of Education (http://www.umich.edu/~csie) is a project devoted to creating and documenting exemplars within the professional development infrastructure that supports the scholarship of teaching in chemistry. We are exploring undergraduate curriculum design that allows students to have a mentored experience in examining their potential for teaching. Junior and senior students can move into more independent work in design, implementation, and assessment. In the graduate program, first-year chemistry Ph.D. students can take their cognate courses in education science or educational psychology and then work with experienced faculty in designing, implementing,

and assessing curriculum ideas in our department. As in the department's research program, graduate students are playing a significant role in the teaching program. In their third and fourth years, these students participate in weeklong mentored teaching internships at nearby institutions that are quite unlike our own. This solution to the problem of improving teaching, including managing the intellectual problem of the large lecture course, is to take the intrinsic strengths of our existing program of scholarly development in research and broaden it to include all aspects of future faculty development. The current faculty get to work with informed, enthusiastic undergraduate and graduate students, and the next generation of faculty gets an education quite unlike their predecessors.

The CSIE argument underlies some recent recommendations for improving precollege education. At the end of "Some Features of a Flawed Educational System," an article in *Daedalus*, Seymour Sarason (Sarason, 1998) points out that blaming teachers for the inadequacies of education is blaming "the well-meaning victims of an educational system that they did not design." Ken Wilson and Constance Barsky (Wilson and Barsky, 1998), in the same issue, propose that only by studying and understanding the success of continuous change in our existing "sociotechnological systems" will we be able to bring lasting reform to education. They conclude that education is the system most in need of learning from applied research and development. Until we provide mentoring for a broadened notion of scholarship, we will not break free from repeating cycles of reinventing reform in each generation. What we call curriculum reform is more often than not faculty re-education because the informed professional development of faculty for instruction is lacking. Larry Cuban asserts that the process of reform is itself unexamined (Cuban, 1990). In his essay, "Reforming Again, Again, and Again," Cuban concludes that "waves [of reform] occur on the surface [of formal education] and, in some

instances, programs, like the skeletons of long-dead sea animals, get deposited on the coral reef of schooling...[yet reform itself goes critically unexamined]. … I end with a plea for rationality...If we do not heed the plea, we will continue to mindlessly speculate, and as Gide observed: Everything has been said before, but since nobody listens, we have to keep going back and begin again."

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