MAKING ROOM FOR GROUP WORK

Teaching Engineering in a Modern Classroom Setting

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The traditional lecture format of engineering courses has many drawbacks. A 50- to 90-minute lecture period exceeds the typical 20-minute attention span of a college student.[1] Hartley and Cameron[2] present data showing a decline in note taking after the first ten minutes of lecture. When questioned about their lack of notes, the students said that they would fill in the gaps on personal time. For the case presented, not only did they *not* follow up on their intention to complete the notes, but 19 out of 22 also did not even read through their notes.

While resources are available for improving note-taking skills,[3] the passive structure of lecture does not encourage teamwork or lifelong learning skills, and some students leave lecture-oriented courses confident that they can solve the in-class examples and little else. A number of group-learning approaches have been suggested to augment lecture courses. These include small- and large-group student-led discussions and in-class assignments. A nice review of what to expect is given by Felder and Brent.[4] These strategies can improve a student's ability to handle ambiguity and complexity, to recognize assumptions, to improve their communication skills, and to help them feel connected to a topic.[5] Additionally, shifting material from a lecture to a student-led discussion format increases student confidence that they can learn on their own, a prerequisite for lifelong learning.

Discussion-format classes have to be carefully structured if they are to cover the same amount of material as a lecture-format course. This paper will describe the use of creative group-learning structures in an experimental methods course. Specifically, these structures were employed during the summer of 2000 offering of the course *Experimental Methods in Chemical Engineering*. According to the *University of Dayton Bulletin*, the objective of this course serves as an "Introduction to experimental methods, instrumentation, digital data acquisition, data analysis, and report writing. Use of digital computer is emphasized." The course is taught to second-semester sophomores who are majoring in chemical engineering. It is their second course in the major. While having a stated objective of introducing the students to the engineering way of experimentation and to engineering instrumentation, it also serves the objective of maintaining student involvement in the department until they have completed the necessary mathematical background for the more advanced topics.

Historically, this course, when taught in a standard classroom using a conventional lecture format, has received poor student reviews. The course theme—how to conduct experiments as a chemical engineer—leads to many varied topics, from uncertainty analysis and probability to instrumentation principles of operation to computer programming for data

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acquisition. Students had difficulty seeing the common theme and tended to experience the course as a hodgepodge of information with no common thread.

Bligh[6] reviewed and summarized hundreds of studies regarding the effectiveness of a straight lecture to alternative methods. He found that the lecture is statistically equivalent to other methods when the purpose is to transmit information, but if the purpose is to promote thought (necessary for problem-solving skills) or inspire interest (much needed for this course), then discussion is significantly more effective than a lecture. If the goal is to teach a skill (the computer programming portion of the course), then practice of the skill is superior to a lecture.

A special offering of the course was taught in an ideal classroom for group work—the Studio in the Ryan C. Harris Learning Teaching Center at the University of Dayton. As part of an innovative approach to encourage faculty members to explore new pedagogical styles, the University of Dayton established the Ryan C. Harris Learning Teaching Center. In the Learning Teaching Center, a classroom called the "Studio" was erected that incorporates classroom flexibility and the latest technology. University faculty members use this top-notch teaching facility for pedagogical exploration and to test new technology on a small scale before implementing it in larger settings. The Studio, custom designed to foster classroom discussion and groupwork, was the best place to develop an improved pedagogical style for this course.

THE CLASSROOM

The classroom is designed to handle up to 24 students. The room and the desks evoke memories of a kindergarten classroom—only with bigger seats. The floor is carpeted, and instead of desks, the students sit at specially designed tables that can be moved around as necessary. An open closet runs along one wall where coats and excess baggage can be placed. Portable whiteboards and corkboards can be placed along any wall or can be hung in the middle of the room by what can best be described as a tic-tac-toe railing system overhead. In one corner closet there is a combination TV/VCR along with a standard overhead projection unit, and in the other corner closet there is a notebook computer with wireless connection to the Internet and a computer data projection unit. This system is coupled with a SMART Board, which is much like a giant touch screen for the computer. Notebook computers are available for the classroom upon request. These also have wireless connections to the Internet along with standard network ports.

Other unique aspects of this classroom involve its physical setting—appointments both inside and outside of the Studio are exquisite. Just outside of the room is a coffee bar. In addition, one of the most promising aspects is that the Learning Teaching Center is in the basement of the library.

Discussion-format classes have to be carefully structured if they are to cover the same amount of material as a lecture-format course. This paper will describe the use of creative group-learning structures in an experimental methods course.

TABLE 1
Summary of Comments About the LTC Studio

Keep	***Change***
• Interaction room (sufficient space to get in among the students) • Extremely helpful LTC staff • Availability of multimedia • Wireless network • Portability of whiteboards (they could be physically moved) • SMART Board use excites students • Students began showing up progressively earlier	• Tables don't move as easily as designed • Whiteboards hanging on a track allows them to swing when writing (requires additional hand) • Whiteboards should be able to cross tracks (they cannot cross intersecting support tracks) • Whiteboards should be able to rotate • Needed to arrive early to set up seating • SMART Board screen must be calibrated to use as a touch screen—a slight bump during the lecture gets it out of calibration

Studio Evaluation

Notes about the Studio and its technology were collected from the instructor, the students, and communications with other instructors who were using the classroom. These notes have been summarized in Table 1. Although certain aspects of the Studio could be improved upon, most were considered to be a step in the right direction.

GROUP-DISCUSSION STRUCTURES

Brookfield and Preskill,[5] McKeachie,[7] and Aronson and Patnoe,[8] among others, have discussed ways to promote classroom discussion. Five are particularly useful for engineering education

- *Small-group discussion followed by large-group discussion, then a lecture*
- *Lecture with individual in-class practice (with instructor's help)*
- *Snowball followed by lecture*
- *Modified jigsaw with no lecture*
- *Straight lecture but open to questions*

As previously mentioned, this was an off term (summer) with 14 students. Thus, observations may be tainted by the small class size or by the fact that all of the students had just returned from their first cooperative education experience.

All techniques were either immediately followed or immediately preceded by an appropriate homework assignment. Also, each technique was followed by a large-group discussion (entire class) to evaluate the style's effectiveness.

Small Groups

For the small-group discussion technique, the students were first asked to read selected sections from the text about a new topic prior to the next meeting. At the next meeting, the students were asked to reflect on aspects of the reading that they understood well and aspects that they found to be confusing. The students were then divided into groups of three or four and asked to create a group list. Finally, all of the lists were summarized on a board in the front of the room and a large-group discussion ensued.

What the students found was that, in general, they were all confused about the same things. This was followed by a lecture where additional focus and example problems were applied to the difficult material. All material was still covered for completeness. Knowledge of their limitations helped the students to focus on these parts of the notes.

As an added benefit, topics that were not well understood by the minority were often cleared through the initial discussion. As with all techniques, when finished the approach was discussed in a large group to judge the effectiveness.

In-class Practice

While presenting aspects of computer programming, it was decided that it was best to program live along with lecture. The Studio provided a notebook PC to each student and one for the instructor, which projected onto a SMART Board. The programming had some lecture, a handout, and plenty of in-class practice where the instructor and the teaching assistant went from student to student to help them over the simpler hurdles that so often stop programming in its tracks. This structure was employed over a period of several weeks.

Snowball

Snowballing is much like the small-group discussion as applied to this course. After reading, students progressively get into larger groups until eventually the entire class is involved in the discussion. Lecture still follows the discussion, with focus on the areas of concern. What distinguished Snowball from Small Group was the addition of more group layers, much like a growing snowball.

Jigsaw

A jigsaw is an approach where groups are formed to discuss one topic. Then they form new groups with one topic expert in each (works best with a squared number of students $2^2 = 4$, $3^2 = 9$, 16, 25, 36, *etc.*). For this implementation, all students were first asked to read the entire chapter (temperature instrumentation). Next, four groups were created and each assigned to establish an area of topical expertise: thermal expansion techniques, thermocouple techniques, electrical resistance techniques, or radiation techniques. They met for one period in-class and then had until the next class period to create a set of notes. They were also provided with references to additional resources. At the following class, four new groups were formed that included a topical expert from each area. The students then gave lectures and examples to each other using the portable whiteboards. This only took one class period (1.5 hours) to present the information.

TABLE 2
Summary of End-of-Term Anonymous Student Evaluations of Modified Course
(Select Questions)

Question	*Agree*	*Neutral*	*Disagree*	*N/A*
You like the required text	0	3	11	0
The book was a useful reference	3	9	2	0
The instructor is boring	3	8	3	0
You would recommend instructor to a friend	11	2	1	0
The course objective was clear	13	1	0	0
The course met the stated objective	13	1	0	0
As experienced co-ops, you feel that you've learned tools that will be useful to your future	13	1	0	0
The instructor is clear about the subject area	9	1	0	0
The instructor understands the material	14	0	0	0
The instructor is well prepared for class	14	0	0	0

TABLE 3
Summary of End-of-Term Anonymous Student Evaluations for Previous Term *(Select Questions)*

Question	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*Not Applicable*
The textbook was an asset to the course	1	6	8	10	10	0
Instructor enthusiasm inspired interest	0	9	12	14	1	0
You would recommend this instructor to another student	4	9	15	5	3	0
The instructor clearly communicated the course objectives	3	25	5	3	0	0
You learned a great deal from this course	3	20	9	1	2	0
Class discussion contributed to your understanding	1	10	12	4	4	5
Instructor encouraged classroom participation	2	11	15	5	2	1

Despite requests from the students, no lecture from the instructor accompanied the jigsaw notes (as a way to help assess the improvement). A specialized homework assignment was created to test how deep of an understanding was formed in each area. The homework was assigned to each of the new teams (*i.e.*, not to individuals) to be turned in collectively.

Lecture and Other

Other teaching styles were used as necessary, but they were not evaluated. The straight (traditional) lecture style was used, primarily as a basis for comparison. All lectures included examples, and students were encouraged to ask questions when they needed clarification.

Another teaching format that was used but not evaluated involved meeting in the chemical engineering laboratory and collecting data. This was used at the end of the term to bring all of the aspects of the course together with a case study.

STUDENT EVALUATION

Formal university evaluations are not required for courses taught in the Studio, but the instructor created a special evaluation form to help determine the success of the course. Table 2 summarizes the statements and responses. For comparison, related questions from two previous sections are reported in Table 3 (same instructor).

The responses to most of the questions reflected well on the course. This is in stark contrast to evaluations received for the previous instruction of this course. The response to the question about the book is the same as previous; the students did not like the text. It is also apparent that the instructor is not too exciting (before and after).

The most pertinent questions to the course modifications are the next four. For these questions, 90% of the student responses are at the highest level and 98% of the responses are favorable. This marked a significant improvement to whether or not the students would recommend the instructor to someone else. The other areas marked a slight increase.

TABLE 4
Rank of Techniques Used in Classroom

Technique	*Topic*	*Points*
1. Lecture with individual in-class practice (with instructor's help)	computers	66
2. Small-group discussion followed by large-group discussion, then lecture	introduction, basic concepts data analysis	57
3. Straight lecture but open to questions	electrical measurement, flow measurement, data acquisition	33
4. Snowball followed by lecture	pressure measurement	32
5. Modified jigsaw with no lecture	temperature measurement	16
6. Other		6

In the evaluation, the students were also asked to rank the techniques used in the classroom. Five points are given for the technique that the student liked best, four points for the second, *etc.*, with zero points given for the least-favorite method. The total points received by all students are summarized in Table 4.

The top-ranked technique was the one applied to computer programming where the lecture was followed with in-class practice such as examples or homework. The second-ranked technique was small-group discussion followed by large-group discussion and then lecture. The lowest-rated technique was the modified jigsaw with no lecture.

The evaluation also contained several open-ended questions. One question asked the students to summarize topics covered in the course about which they felt confident and topics about which they felt confused. The topics about which the most students indicated confusion were electrical measurement, temperature measurement, and data acquisition (straight lecture and jigsaw). The topics about which the most students indicated confidence were computers, data analysis, pressure measurement, and flow measurement (each a different technique). Ironically, the students did best on the jigsaw-taught topics as judged by homework and test scores.

The students were also asked to list the positive and negative aspects about the homework. Most agreed that while it was difficult, it was quite relevant. During the course, assignments were alternated between being due before the topic was covered in class and afterward. When asked which was better, 1 preferred before, 8 preferred after, and 5 indicated that they would like to alternate between the two scenarios. Adjusting the timing of notes and homework can lead to an increased student interest.

When asked what modified methods they might propose, they responded with the following ideas:

- ► *Emphasize important topics to be covered in jigsaw*
- ► *Add 1 lecture to the jigsaw*
- ► *Variety*
- ► *Lecture followed by working on problems in groups*
- ► *Conduct class as a meeting*

These ideas are certainly worth future exploration. Another is to take the structure used for computer programming and apply it to problem solving with the other material.

INSTRUCTOR COMMENTS

Throughout the semester, notes were made about the progress of the class in a journal fashion. Notes were made prior to, during, and immediately following each class period.

Notes prior to each class included a summary of announcements along with a proposed list of topics and objectives for the day. Occasionally, the objectives were written on a side whiteboard in the classroom for the students to consider for the entire period. As a way to ensure equal participation among the students, a list of students to "pick on" was also created prior to the class. The instructor first called upon two of these students to attempt to answer each question, for the entire period, before asking the other students to answer. During the course of the term, all of the students had their opportunity to be "picked on." Note that the term "pick on" was harsher than the implementation.

Notes made during each class included how the lecture notes could be improved, who was late or missing from class, observations of the students, and summaries of student comments about the course topics and formats (including a summary of large-group discussions).

Notes generated after the class period included an evaluation of the period, what was covered (or not covered), and ideas for future classes.

Table 5 summarizes the notes that are of general interest; course-specific notes were deleted. This information establishes timelines and reinforces key concepts for the term. It also helped to keep track of smaller observations such as best seating arrangement (U-shape) for lecture or large-group discussion.

TABLE 5
General Interest Notes (Roughly Chronological Order)

- Students were slow to use whiteboards in the room
- Term started quietly
- Small-group discussion
  - Covered comparable material
  - Students happy to know that others were confused
  - Maybe assign review questions prior to reading assignment
  - Nice to have peers explain topics
- Some students are already beginning to dominate conversation
- U-shape of desk arrangement works well for large group discussion and for lecture
- It would be nice to set aside discussion time for such topics as the impostor phenomenon[9]
- Students requested more practice problems
- Could try an e-mail discussion to kick off the topic
- Students are less likely to be shy in small-group discussion
- In the future, let small groups solve example problems
- Midway through the course, students speak out; still reluctant about moving desks
- During snowball approach, the four board writers were the students who tended to dominate large-group discussion
- Students enjoyed working through computer assignment in class (independently, but with instructor help)
- The jigsaw
  - I should have videotaped this
  - Approach would not work well without seat mobility
  - Having students discussing same topics simultaneously makes instructor's evaluation job easier
  - The students did additional research, but they did not make it apparent in presentations
  - Students recommend that I do this (jigsaw) "to" the next class also
- In future, try role reversal (student - professor)
- Attendance is exceptional

CONCLUSIONS

A classroom designed for group work with notebook PC's for each student, a SMART Board, and movable tables, whiteboards, and corkboards made an excellent location for exploring different cooperative-learning methods. The classroom was used as a setting to evaluate (a) the effectiveness of small-group discussions, in-class practices, snowballing, and jigsaw discussions, (b) how these techniques were received by students, and (c) the effect these techniques had on student confidence.

Small-group discussions and in-class practices were well received by the students. Small-group discussions were well suited to the subject matter, and in-class practices gave the students the most confidence about their abilities. Although students developed the deepest understanding of the material covered by the jigsaw method, they did not enjoy it and, paradoxically, did not feel confident of their understanding of the material. This matches the observations of Felder and Brent,[4] ". . . cooperatively taught students tend to exhibit higher academic achievement . . . [with] deeper understanding of learned material." If increased student confidence is desired then it would benefit the instructor to follow with a brief lecture.

Overall, a well-designed classroom can facilitate cooperative learning methods, but preparing students for group work remains essential. Part II of this work[10] will compare these results to those in a traditional classroom setting.

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