Journal of Industrial Microbiology & Biotechnology (2000) 25, 121–126

www.nature.com/jim

ORIGINAL PAPERS

The use of small groups in a large lecture microbiology course

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In the fall of 1997, we started using small groups in our large (100–200 students) junior level introductory microbiology course. Students form five-person groups early in the semester, and work on projects within these groups throughout the semester. These projects involve exploration of concepts such as metabolism, protein synthesis, and viral reproduction strategies and the submission of a poster describing a disease of their choice at the end of the semester. We have refined the use of the small groups during the last three semesters, and student acceptance and performance have improved steadily. In the fall semester of 1998, a comprehensive assessment of the effectiveness of these group projects was performed. Students were chosen at random to participate in student consultation groups to discuss group projects. Furthermore, we utilized a master teacher-in-residence from the Rocky Mountain Teachers Education Collaborative (RMTEC). This teacher-in-residence attended our classes, spoke with students, helped with student consultation groups, and provided observations of student responses to group work activities. RMTEC also provided funds to hire a research assistant to conduct student consultation groups, analyze student evaluations of our course, and compare evaluations from before and after the implementation of group examinations. Additionally, the Center for Teaching and Learning at Colorado State University assisted with mid-semester evaluations in each subsequent semester. The results of our analysis show that small groups in large lectures can be an effective learning tool provided students are given well-designed activities with clearly defined, obtainable goals and clearly articulated guidelines. Our experience also shows that the manner in which the instructor presents the process to students affects students' willingness to participate in the process. It must be clearly articulated to students why he has incorporated active learning strategies into the course, what he hopes students will gain from the experience, and how he expects students to participate in these activities. We recognize the increase in workload on ourselves as instructors, but the benefits seem worth the additional time and effort. This paper describes the group process that we use and provides an evaluation of the effort. *Journal of Industrial Microbiology & Biotechnology* (2000) **25,** 121–126.

Keywords: microbiology; education; active learning strategies; small groups; large lecture

Introduction

Colorado State University, like many universities, is coping with increased enrollment in the life sciences by enlarging lecture sections and decreasing the number of sections provided for lecture-only courses. In these large lecture courses, students often feel neglected, anonymous, and passive. Furthermore, although some students thrive in a traditional lecture course, many students possess learning styles that do not benefit maximally from the lecture and notetaking model of education [8]. Tobias [9], for example, described the loss of talented students from science because of their unhappiness with traditional instruction, preferring more cooperative structures. A series of reports from the Carnegie Commission on Higher Education [1,2,4] has called for innovations to address longstanding problems with undergraduate education, generally.

Cooperative or collaborative learning has a rich and growing base in both theory and practice. Johnson and Johnson [3] and Slavin [7] have been leaders in demonstrating the benefits of teamwork for active and experiential learning opportunities, bonding, critical and creative thinking, and more. While group work has its own set of additional challenges for students, from navigating different personalities to conflicts over heavy time demands outside of class, the benefits can far outweigh these and other difficulties.

We implemented small group activities after four faculty from our department engaged in undergraduate teaching met and discussed teaching strategies and approaches on an informal basis for an entire semester. Our decision to introduce small group activities was based on an assumption that we had done about all that we could to optimize our lecture presentations.

Materials and methods

Class characteristics

Our course is an introductory microbiology course in which 10% of the students is composed of microbiology majors. The balance of the class is from approximately 30 different science majors. Eighty percent of the class is composed of juniors or seniors, and the course is taught at a junior level. Prerequisites include general biology and, at least, concurrent registration in organic chemistry.

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Received 24 March 1999; accepted 23 November 1999

The course consists of three 1-h lectures per week, and 46 h are available in instruction, including a 2-h final examination. One senior faculty member is responsible for each section, and two sections of the course are taught each semester (section sizes range from 70 to 200).

Graduate teaching assistants are generally not assigned to this course, but up to three undergraduate teaching assistants (who register for supervised college teaching) are available each semester for each section. Students complete four examinations, including a comprehensive 2-h final exam.

Small group in-class examinations

The students are each given the in-class examinations 1 week before they are to meet. On the day of the in-class examination, groups meet to compile a common answer. During the class period, the instructor circulates to answer questions and observe progress. The instructor and undergraduate teaching assistants verify the attendance of each group's members by initializing the student's names on a common sheet. Groups compile a common answer to the in-class examination, and turn it in for credit. There are three graded in-class examinations, each worth 20 points for each student, and the lowest score for the three examinations is dropped. This eliminates the need to have make-up examinations for students who miss an examination.

In the third week of class, students are given a practice examination where they are asked to form temporary five-member groups and complete a non-graded in-class exercise. This exercise requires them to synthesize information from lectures and text to determine whether environmentally isolated organisms are prokaryotic or eukaryotic and to which kingdom they most likely belong by analyzing a given set of data. This exercise is not graded, and a general discussion (20 min) is conducted to summarize the class activity. The first graded in-class examination is given on the fifth week and covers metabolism. Students are asked to determine the type of metabolism organisms would have to possess in order to bioremediate different types of environmental contaminations. Students are still in temporary groups and can change groups for this exam if needed. The second graded in-class exam is given on the ninth week of class and covers transcription, translation and mutations. Students are given a short DNA sequence and asked to create the mRNA and protein using this DNA sequence. During the second examination, students form permanent five-member groups. The third in-class examination is given on the twelfth week of class and covers viral life cycles. Students are asked to design drugs to treat viral infections without killing the cell using viruses with RNA or DNA genomes.

Small group poster projects

On the ninth week of class during the second in-class exam, student groups are given a handout that describes the poster project. They are required to choose an infectious disease from a list of over 60 viral, bacterial, fungal and protozoal diseases of humans, animals and plants. Each group may select only one disease, and only one group within a section of the course may cover each disease. There are five sections to be covered on the poster—the disease, the microbe, epidemiology of the disease, treatment and prevention, and diagnosis. Each student in the group selects one section that is his responsibility. However, it is the group's responsibility to choose a format, and edit each member of the group's materials for writing style, references and accuracy of information. Students are provided general information about what is expected in each section of the poster, a suggested layout of the poster, and recommended reference styles. Students are required to provide all materials for their posters and are encouraged to use inexpensive, readily available supplies. The posters are turned in on the second to last week of class. During the thirteenth week of class, a class session is devoted to a mandatory exchange of draft materials, in which group members evaluate and provide guidance for each other's draft materials. Students are required to verify that they provided their group with materials to analyze by turning in a copy of these materials at this time, for credit. Completed posters are turned into the instructor on the fourteenth week of class, and are immediately hung in the halls of the microbiology building using inexpensive runners and large paper clasps. The instructors grade the posters on the basis of the quality of the input from each student and the appearance of the poster as a whole. The poster's appearance is generally dominated by a required three-dimensional model of the infectious agent. Posters remain on view for the rest of the semester. The instructors, with the help of the teaching assistants, generate a set of questions from the posters, and two class periods are dedicated to all students in the class viewing the posters and answering the questions posed by the instructor. Students are told that 10 of these questions will be chosen for the finals. Students are graded on the appearance and layout of the poster. At the end of the semester, each student grades his fellow groupmembers on the quality of their contribution to the groups efforts.

Grading

There are a total of 600 points a student can earn. They may earn up to 40 (6.66%) from in-class group exams, and 60 (10%) from the poster project for a total of up to 100 points (16.66%) from group work. Of the 60 possible poster points, 50 points are assigned by the instructor, five for full participation in the draft exchange, 35 for accuracy and completeness of individual contribution to the poster, and 10 for how well the group came together to produce an attractive and informative poster. The remaining 10 points are assigned to each student by the other members of the group, in that each student receives the average of the scores assigned him by the other members of the group. The remaining 500 points are composed of three examinations (100 points each) and a 200-point comprehensive final exam.

Evaluations

Two formal evaluations of each section are conducted each semester. During the eighth week, a member of the School of Education performs a mid-semester evaluation. This evaluation takes 20 min of class time, and generates a written student evaluation of the class to the midpoint of the course. Students are asked to write things they appreciate and things they would like to see improved. At the end of the semester, students are provided the university-wide form to complete. Instructor-asked questions are permitted, and are used to evaluate the group projects. During the fall 1998 semester, additional evaluation was provided by one of the authors (S.A.), a teacher-in-residence who attended class daily. She observed student participation, the pattern and frequency of student questions,

and circulated around the room to observe and listen to student concerns and comments. In addition, an undergraduate student majoring in math education was hired to conduct student consultation groups during the semester. Three groups were targeted: one involved students currently enrolled in the course and not planning a career in teaching; the second group consisted of students currently enrolled in the course who had identified their interest in K-12 or higher education; and students who had taken the course within the past 2 years comprised the third group. Between 7 and 10 students participated in each consultation group. Student consultation groups met outside of class, filled out a questionnaire designed by the instructors, and engaged in free-flowing conversation facilitated by the math education undergraduate student. Their discussions were recorded on tape or teaching assistants were present to transcribe student comments.

Results

Our reasons for incorporating group projects into this course were threefold. We wanted to make the large lecture setting seem smaller, allowing the students to get to know the instructor and other students better and differently. Second, we wanted to create a diverse learning environment that would foster learning and retention in students with different learning styles. Lastly, we wanted students to take a more active role in their own education and to encourage the development of teamwork skills that will be required in the workforce.

One of the most difficult tasks we encountered when using group projects was to lure students away from the comfort of passive learning. Many students resisted attempts to implement active learning, and some were even resentful. These students expected a course where they were told what to learn and how to learn it, and they did not wish to explore learning on their own. We will discuss some of the problems we encountered and the solutions we have developed to overcome these problems.

Working with other students is a new experience for many, so it is important to make them comfortable with their groups. For this reason, we ask students to choose their own groups. As mentioned, student groups can get bogged down in personality and work style differences [8]. Allowing students to create their own teams can overcome some of the problems associated with assigned membership, although clear directions and ongoing supervision are also important for keeping groups focused and efficient. Furthermore, we found less complaining about group members when we allowed students to "try a group on for size." We therefore allow students to change groups one time if they are unhappy with their initial group. Although this did not completely eliminate poorly functioning groups, it allowed students to leave groups they felt they could not work with. Another tactic we found useful was to form the permanent groups after the drop period was over, eliminating fragmented groups that result from students dropping course. To foster group formation, we asked students on the first day of class to fill out a card with information and then find other students in the class with the same major. This allows students to meet other students with whom they might want to form groups. Throughout the semester, we encouraged students to study with their groups on a regular basis. The report of Light [5] for Harvard University provides clear evidence for the value of study groups in enhancing student academic performance.

There will always to be a problem with differing commitment levels of group members. Many students complain that a few students are doing all of the work, but all of the students get the same grade. We address this problem by asking students to evaluate and assign grades to the other members of their group. Therefore, if a student is unhappy with the commitment level of other members of the group, his dissatisfaction is registered. The knowledge that other members of the group will be assigning a portion of each individual's grade also helps motivate students who might be tempted to allow other members to do all the work. Each member of the group is given the average of the numerical grade assigned by other group members. Additionally, we include questions from group projects on all standard examinations, and expect that active participation in group projects will lead to better performance on examinations.

During the first semester, we incorporated group work into our course and called them "in-class group projects". We found that students came to class unprepared to perform the duties asked of them in the allotted time. Consequently, we changed our procedure in the next semester and handed out projects a week before, with the understanding that students were to complete these assignments outside of class, and come to class on the day of the project prepared to discuss these projects with their group and to compile the best possible answer. However, we were still disappointed with

Table 1 Student course evaluations before and after the introduction of group work

Item	Instructor	Percent marking agree or strongly agree	Percent marking neutral	Percent marking disagree or strongly disagree
I would recommend this instructor to another student	A before group work[a]	90.6	4.4	5.0
I would recommend this instructor to another student	A after group work[b]	95.8	2.8	1.4
I would recommend this instructor to another student	B before group work[c]	95.2	2.3	2.5
I would recommend this instructor to another student	B after group work[d]	91.0	7.0	2.0

[a]136 students surveyed.
[b]217 students surveyed.
[c]531 students surveyed.
[d]363 students surveyed.

Table 2 Student course evaluations concerning group projects at the end of three consecutive semesters

Item	Semester	Percent marking agree or strongly agree	Percent marking neutral	Percent marking disagree or strongly disagree
The group projects were beneficial	First[a]	50.0	24.8	25.2
The group projects were beneficial	Second[b]	75.4	11.8	12.8
The group projects were beneficial	Third[c]	72.8	11.7	15.5
The group projects were beneficial	Average of all semesters[d]	67.8	15.0	17.2

[a]262 students surveyed.
[b]102 students surveyed.
[c]218 students surveyed.

the students' level of preparation on the day of the group project. We also encountered complaints about the lack of time to adequately answer the questions. So in the next semester, we changed the name of the activities from group projects to "in-class group examinations." The project assignments were handed out a week before they were to meet in class to formulate the group's answers. Now they were told that these were take-home exams to complete, and in a week, the group would meet to formulate a collective answer during an in-class group exam. The level of preparation went up dramatically, and complaints about time were almost completely eliminated.

When creating group projects, it is important to structure questions very carefully. Students are very good at finding answers in books and repeating what the book says. Students resist reporting what they think about a subject. Our first group project was very disappointing. We asked students to draw pictures of two types of cells, and discuss differences between the two cell types. The majority of the work that the students submitted were comprised of figures from the book copied verbatim. This caused us to re-evaluate the group projects we were developing. One of our main goals is to challenge students to think more for themselves. Our efforts have been guided by the model of cognitive development of Perry [6] which describes the shift in thinking from dichotomous (right–wrong) responses towards an increasing ability to handle complexity and ambiguity. However, when we examined our first project, it was obvious that we had simply asked students to report what the book was already telling them. Therefore, it is very important to decide what the goals are, to try to create projects that will meet those goals, and then to evaluate whether these goals were met.

In the fall semester of 1998, we began trying to assess the effectiveness of these group projects. Our first approach was to compare end-of-course student evaluations from before and after changing the course structure to determine whether there had been any dramatic changes in students' level of satisfaction with the course. To evaluate this question, we looked at students' responses to the statement "I would recommend this instructor to others?" We reasoned that if students felt the group exams were a highly negative experience, they would not recommend us, and likewise, the number of students responding "agree" or "strongly agree" would greatly decrease. We analyzed the responses of all responding students in the two semesters preceding and following the introduction of group projects in sections taught by instructors A and B. In the two semesters preceding the introduction of group projects, 95.2% and 90.6% of students agreed or strongly agreed that they would recommend instructors A and B, respectively (Table 1). This is virtually identical to the percentages of students agreeing or agreeing strongly with this statement in the two semesters following the introduction of group projects (91.0% and 95.8%) (Table 1). Therefore, adding group projects to the course did not dramatically affect student satisfaction as judged by students' willingness to recommend the instructor.

However, mid-semester student feedback sessions painted a more encouraging picture. One author facilitated 25-min inter-

Table 3 Student consultation group results evaluating group activities[a]

Question	Percent marking agree or strongly agree	Percent marking neutral	Percent marking disagree or strongly disagree
The group exams helped me understand the concepts	58.1	12.9	29.0
The group exams helped me learn how to work with people	48.4	16.1	35.5
I prefer to work alone, not in groups	38.7	25.8	35.5
The people in my group contributed equitably	51.6	16.1	32.3
I enjoyed the group projects	61.3	9.7	29.0

[a]31 students surveyed.

Table 4 Student consultation group results evaluating gender differences[a]

Question	Percent marking agree or strongly agree	Percent marking neutral	Percent marking disagree or strongly disagree
I prefer to work alone, not in groups: females[b]	50.0	12.5	37.5
I prefer to work alone, not in groups: males[c]	26.67	40.0	33.33

[a]31 students surveyed.
[b]Including 16 female students.
[c]Including 15 male students.

active whole class debriefing sessions and found clear evidence of growing student support for these group projects despite the challenges associated with this kind of graded teamwork [8]. Impressively, students were nearly unanimous and clear about the benefits of using microbiology content in creative ways on the posters. Moreover, the teacher-in-residence noted in her final analysis of our courses that most students she spoke with felt that group projects were a positive experience. Many noted the pride they felt when viewing their creative works displayed in the hallways of the Microbiology building and when they saw how professional the posters appeared. Admittedly, some students felt this was not college level work, most likely because they are not familiar with poster presentations at professional scientific meetings. Again, this may be a situation where the way we, as instructors, presented this project to students was inadequate. We may eliminate this feeling by discussing with students how scientists present information at meetings, and how this project will prepare them for this activity.

During the end-of-semester evaluations, students were asked again if they believed the group projects were beneficial. In the first semester in which we implemented group projects, only 50% of students agreed or strongly agreed that these projects were beneficial, 24.8% was neutral, and 25.2% believed they were not beneficial, as manifested by a disagree or strongly disagree response (Table 2). However, after making many of the changes noted above, by the second semester, 75% of students responded that they agreed or strongly agreed that the projects were beneficial and 13% thought they were not beneficial. The numbers in the third semester were very similar, with 73% agreeing or strongly agreeing and 16% disagreeing or strongly disagreeing. In conclusion, the majority of students feel that these projects are beneficial, even though they added a great deal of work.

Our next approach to evaluation was the formation of student consultation groups. A few interesting points arose from the consultation groups. Over half (58%) of consultation group members agreed or strongly agreed that group exams helped them understand the concepts (Table 3). However, 29% disagreed or strongly disagreed. When asked if the group exams helped them to learn to work with others, 49% was in agreement and 36% disagreed. When you consider that in the end-of-the-semester evaluations over 70% of students indicated they benefited from the group projects, it appears that students feel they are benefiting for different reasons. When asked if they enjoyed the group projects, 61% was in agreement, and 29% disagreed. When compared to the over 70% of students who felt that the group projects were beneficial at the end of the semesters, it appears that some students recognize the benefit even if they do not enjoy the process. Confirmation of this perception emerged from the mid-point semester student feedback sessions where students recognized the inevitability that effort and active involvement are required to make teamwork successful.

One interesting note is that nearly the same percentage of students indicated that they prefer to work alone and that they prefer to work in groups (39% alone, 36% in groups), while 26% marked neutral, which we assume means that they have no preference either way. We feel that because during the majority of the semester we have students working as individuals, we are addressing important goals and needs by providing group activities for the large percentage of students who prefer to work in groups [9]. Another interesting observation was made by the teacher-in-residence, who noted that she more often heard negative comments about the projects from male students. However, when we analyzed this same question for gender, it was females who noted most often that they prefer to work alone (Table 4). Fifteen men and 16 women were members of the student consultation groups. When the men were asked if they prefer to work alone, 27% of the 15 male participants marked agree or strongly agree and 33% marked strongly disagree or disagree. However, when the 16 female participants were asked the same question, 50% marked agree or strongly agree and 38% marked disagree or strongly disagree. Therefore, although the men may be more vocal about disliking group work, it was the women who felt more strongly about working alone.

Lastly, it appears that our efforts to ensure that students contribute equitably to their groups have been, for the most part, successful. This is due primarily to a great deal of planning, designed to ensure that all students participate. When consultation group participants were asked if people in their groups contributed equitably, 52% agreed, 16% marked neutral, and only 29% disagreed. This indicated that the majority of the students were comfortable with the contributions of other members of their group. We believe that the use of group exam questions on individual examinations, and the ability of students to evaluate the other members of their group also contributed to this general level of comfort.

Conclusions

We have learned that the most important portion of implementing innovative "group exams" (i.e. team-produced posters) is the time spent on instructional design. It is critical to convince students of the benefits of such activities to their learning. We were amazed at the major difference on student preparation and participation that followed by changing the name from group projects to group

exams. We found that we had to analyze what we want students to get out of these projects, and after each project, analyze whether our goals were met. We have made changes to these exams every semester, and hope to achieve our goals more completely in time. Due to the difficulty we experience in writing good critical thinking questions, we do not allow students to keep graded exams. However, correct answers are posted, and students can look at their exams during office hours.

From our analysis, (1) group activities have not decreased student satisfaction; (2) the majority of students found these projects beneficial, even if they did not enjoy them; and (3) we feel that we now ask questions on examinations that demand a greater level of critical analysis than we could before we added group examinations. However, we have not conducted any formal research in this area. In summary, we believe that while adding group projects to our course resulted in a dramatically increased workload for the faculty involved, it was worth the effort since student learning in our course has increased.

Acknowledgements

We acknowledge the financial support of the Rocky Mountains Teacher Education Collaborative and the Center For Science Mathematics and Technology Education at Colorado State University that allowed us to hire a research assistant to facilitate student consultation groups. We also acknowledge the financial support of The Center for Teaching and Learning, Colorado State University, that allowed William Timpson to facilitate mid-semester evaluations of our courses.

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