The Delta Cooperative Model: a Dynamic and Innovative Team-Work Activity to Develop Research Skills in Microbiology

CARLOS RIOS-VELAZQUEZ,* REYNALDO ROBLES-SUAREZ,[†]
ALBERTO J. GONZALEZ-NEGRON,^{††} AND IVAN BAEZ-SANTOS^{††}

Department of Biology, University of Puerto Rico at Mayagüez, Mayagüez, Puerto Rico 00681-9012.

The Delta Cooperative Model (DCM) is a dynamic and innovative teamwork design created to develop fundamentals in research skills. High school students in the DCM belong to the Upward Bound Science and Math (UBSM) program at the Inter American University, Ponce Campus. After workshops on using the scientific method, students were organized into groups of three students with similar research interests. Each student had to take on a role within the group as either a researcher, data analyst, or research editor. Initially, each research team developed hypothesis-driven ideas on their proposed project. In intrateam research meetings, they emphasized team-specific tasks. Next, interteam meetings were held to present ideas and receive critical input. Finally, oral and poster research presentations were conducted at the UBSM science fair. Several team research projects covered topics in medical, environmental, and general microbiology. The three major assessment areas for the workshop and DCM included: (i) student's perception of the workshops' effectiveness in developing skills, content, and values; (ii) research team self- and group participation evaluation, and (iii) oral and poster presentation during the science fair. More than 91% of the students considered the workshops effective in the presentation of scientific method fundamentals. The combination of the workshop and the DCM increased student's knowledge by 55% from pre- to posttests. Two rubrics were designed to assess the oral presentation and poster set-up. The poster and oral presentation scores averaged 83% and 75% respectively. Finally, we present a team assessment instrument that allows the self- and group evaluation of each research team. While the DCM has educational plasticity and versatility, here we document how this model has been successfully incorporated in training and engaging students in scientific research in microbiology.

As educators and scientists all over the world accept the challenge of teaching students how to engage in scientific projects and investigations, it has become of central importance not only to give them the right tools for becoming proficient researchers, but also to teach them how scientists communicate and work together. Given that creativity, communication, critical thinking, and self-evaluation are all essential for scientific work, it becomes obvious that science students need to develop these skills to be successful. Furthermore, it is highly desirable that students become metacognitive; that is, they are self-conscious of their quest for becoming good scientists.

Several lines of evidence support the philosophy that teaching these skills significantly improves science education. The Biological Science Curriculum Studies and Scientific Inquiry programs (<http://www.bsccs.org/>) are teaching models that stress the importance of learning

science through activities that emulate real scientists and the processes of scientific inquiry. Suchman et al. (7) have postulated that success in microbiological studies using small group activities requires clearly articulated guidelines and well-designed goals. In addition, inquiry-based cooperative learning creates favorable relationships among peers, promotes a relaxed and positive educational environment, improves peer communication and acceptance, and increases the likelihood of educational success. Inquiry-based cooperative learning has been used extensively by Trempey (6) in her microbiology courses. Review of her studies suggests that an approach combining scientific inquiry and cooperative learning enhances scientific literacy and retention, even among students that dislike science (6).

The Cooperative Learning Center at the University of Minnesota outlined numerous benefits of a cooperative learning culture in helping students' academic achievement and even become better citizens. Among the collateral benefits stressed by Johnson and Johnson (2, 3) were that students: (i) became "peacemakers" (which contributes to less violence in schools), (ii) developed in communicating knowledge, and (iii) committed to producing high quality work. Johnson and Johnson were also convinced that those students engaged in cooperative learning processes develop higher self-esteem and self-efficacy.

A recent investigation using cooperative learning conducted by McInerney (5) shows that the introduction of

*Corresponding author. Mailing address: Department of Biology, P.O. Box 9012, University of Puerto Rico at Mayagüez, Mayagüez, PR 00681-9012. Phone: (787) 832-4040 ext. 2874. Fax: (787) 834-3673. E-mail: crios@uprm.edu.

[†]Present address: School of Math, Science and Technology, Ana G. Méndez University System at Yauco, PR 00698

^{††}Present address: Upward Bound Math and Science Program, Inter American University of Puerto Rico, Ponce Campus, PR 00715

team-based projects in an undergraduate Microbial Physiology course significantly improved final examination scores as compared to the previous year when a more traditional lecture-based approach of teaching was used. All teams showed significant increases in learning outcomes such as: (i) creativity, (ii) ability to transfer acquired knowledge to new contexts, (iii) serving as trained scientists, (iv) critically analyzing and interpreting the literature, and (v) inferring and deducing.

Here we present an innovative team-based cooperative learning strategy to allow students to actively learn how to do research. We wanted to determine if students emulating scientific roles in a teamwork learning environment could develop research skills, knowledge, and values while actively participating in a research project. The Delta Cooperative Model (DCM) is a dynamic and innovative teamwork activity intended to develop fundamental research skills such as experimental design, data analysis, and oral and written communication. It was designed by implementing a modern constructivist educational approach, where the students establish among themselves by trial and error (with faculty providing guidance) the best strategy to generate and answer the scientific question. The DCM focuses on three of the essential components of scientific research in assigning students roles as researcher (R), data analyst (DA), and research editor (RE) (Fig. 1A).

The students participating in this study were from the Upward Bound Science and Math program (UBSM). The UBSM is one of the TRIO Federal Grant programs designed to help secondary school students overcome class, social, and cultural barriers to higher education. Specifically, the UBSM aims to help first-generation university students from low-income families to strengthen their math and science skills. In addition, students learn computer technology as well as Spanish and English communication skills. The students in the UBSM take science and math courses during

the semester and also participate in a summer program where research is the basic and cohesive element. Students at our institution belong to the UBSM at the Inter American University at Ponce Campus. A total of 80 sophomore and junior students (40 students per year in a 2-year study) from secondary schools in south Puerto Rico participated in the DCM during the summers of 2004 and 2005.

METHODS

The Intensive Research Method workshop. The students participating in the UBSM summer camp began taking a 3-day (8 hour/day) intensive research method workshop that included topics in: the scientific method (8 h), biostatistics (2 h), scientific writing and literature search (2 h), basic instrumentation (6 h), ethics (1 h), science fair (1 h), oral and poster preparation and presentation (2 h), and the basics of the DCM (2 h). A module for the intensive workshop was prepared by the authors and included theory, examples, hands-on activities, and practical problems. By using teamwork and the scientific method as the framework, the workshop's major objectives were to have students identify a problem and generate a hypothesis by inquiring, develop critical thinking and experimental design skills, and illustrate and describe a research investigation using an oral and poster presentation.

The Delta Cooperative model. After the intensive research method workshop was completed, a team was developed and students were organized into groups of three based on having similar interests. Students took on roles as either a researcher (R), data analyst (DA), or research editor (RE). The R was in charge of the research experimental design and data collection, the DA was accountable for the analysis and organization of data, and the RE was responsible for the manuscript generation and organization of the entire research project. The specific roles in each team were chosen by the students. It is important to point out that this structure

FIG. 1. Delta Cooperative Model diagrams. (A) The organization of the DCM research team required the interaction between three students with specific roles: the Researcher (R), the Data Analyst (DA), and the Research Editor (RE). (B) Besides the intrateam interaction (A), the DCM participants also exchanged ideas by holding interteam meetings.

allowed for three students with different roles to work together on each project and for each student to become a leader at different stages of the research.

The problems chosen for DCM research projects were in the field of microbiology and were generated either by the students or by the faculty participating in the project. As part of the complementary activities during the intensive workshop and the DCM development, the students were given short talks and trainings on basic microbiology. For example, instructors presented the use of aseptic techniques and methods for the isolation and characterization of microorganisms. The DCM microbiology research topics selected by the students during the 2-year study ranged from microbial community analysis to microbes producing antimicrobial agents. Examples of the research projects done by the students include: Isolation and Characterization of Aquatic Fungi from two Rivers in Puerto Rico, Microbial Flora in the Pitcher's Fluids of the Carnivorous Plant (*Nepenthes* sp.), Detection of Bacterial Contaminants in Fast Food versus Commercial Hamburgers, Microbial Communities Present in Spring Water from Two Municipalities in Puerto Rico, Detection of Bioluminescent Bacteria from Puerto Rico's Satellite Island Caja de Muertos, and Isolation of Antimicrobial-Producing Microbes from Soils in Three Municipalities in Puerto Rico.

Research meetings: scientific round tables. In order to encourage idea exchange, critical review, and project follow-up, "scientific round tables" were organized at least twice in the summer. There were two types of meetings. First, the intrateam research meetings were held to allow each DCM team to recapitulate and redirect efforts or approaches. Second, the interteam research meetings allowed all of the DCM individual roles (e.g., all of the researchers [$R_{\text{project 1}} + R_{\text{project 2}} + R_{\text{...}}$]) to discuss their research (Fig. 1B). The purpose of interteam research meetings was to give input to and receive input from fellow students in the UBSM doing different DCM research projects.

UBSM science fair. At the end of the 6-week summer participation (45 hours dedicated to research by DCM), those students engaged in the DCM presented their research as poster and oral presentations at a UBSM science fair. Scientists and graduate students (mostly university students) from several educational institutions in Puerto Rico served as judges. The oral and poster presentations were evaluated using a scale ranging from 5 (excellent) to 1 (poor). Specifically, the research performance criteria used to evaluate the presentations included topics such as: applicability, poster set-up, and poster presentation as a team. The 15-minute oral presentations were evaluated based on criteria such as organization, critical thinking, clarity, and the use of visual aids, among others. The rubric used in the assessment of the oral presentations is shown in Fig. 4. A similar rubric system was used to assess poster set-up, and categories used included: appearance and display, research elements and organization, diagrams, and grammar. The criteria used to assess the students oral and poster presentations were

the same as those used at the Department of Education of Puerto Rico science fairs. The categories for evaluation included: creative ability, critical thinking, dexterity, and clarity. Students were required to clearly state the problem, objectives, and hypothesis in both their oral and poster research presentations.

Assessment of student learning. A pre- and posttest were used to assess the effectiveness of the DCM in increasing students' understanding of the scientific method and improving the ability of students to apply the scientific method. Biostatistics knowledge, scientific writing, DCM definition and main objective, and poster set-up and presentation were also assessed on the pre- and posttests. For the scientific method, emphasis was given to problem identification and hypothesis generation, recognition of dependent and independent variables, and determination of control and experimental groups. This was accomplished by including a set of open-ended statements that served as a starting point for the students to generate a question, formulate a tentative answer, and set up an experimental design. Some of the information in the statements was designed for the students to calculate statistical parameters such as dispersion and central tendency measurements. Also, students were asked to illustrate and identify their research using a poster. The pretest was administered to students before the workshop, and the same test was given once the workshop was concluded and after the science fair. The test was not announced in advance nor were students aware of how often the test was going to be administered. A paired t test with alpha value of $P = 0.05$ was used to determine significant differences between the pre- and posttest results.

Assessment of the intensive workshop and the DCM. A student perception questionnaire was used to assess the students' receptiveness to and awareness of the intensive research method workshop objectives. The questionnaire assessed 14 areas including which skills were developed and what content and values were gained through the project (Table 1). This assessment was administered to the students at the end of the workshop and was used to determine those areas that needed to be reinforced during the DCM participation.

The student's general perception of group performance and self- and team research participation was assessed by asking students to assign a value from 5 (excellent) to 1 (poor) to seven specific collaborative and teamwork criteria: active participation, effective role playing, effective communication, integration, team work, reasonable time dedicated to research project, and support from and to cohorts. This assessment was administered to the students one week after the DCM started and again after the science fair. Along with this instrument, a question regarding the student's research setting preference (lab, field, both, or none) was asked after the UBSM science fair. A nonparametrical analysis of variance (ANOVA) was used to determine statistical significance of the general perception of the team performance, with an alpha level of $P = 0.05$.

TABLE 1. Criteria used to determine students' perception of the intense workshop: effectiveness in developing skills, content, and values

Criteria	Description
1	Helped me clarify general concepts related to the scientific method procedure
2	Familiarized me with using a literature search to find scientific articles related to my research topic of interest
3	Taught me how to generate questions about research issues
4	Showed me how to generate a hypothesis
5	Helped me identify variables (e.g., dependent and independent)
6	Helped me define the control and experimental groups and their importance in the experimental design
7	Helped me identify and define the components of figures and tables and how to organize and present them
8	Helped me recognize basic errors in scientific writing as well as become aware of research article components
9	Helped me define biostatistics, its importance, and how to calculate the central tendency and dispersion measurements
10	Familiarized me with poster components and how PowerPoint is used to prepare them
11	Helped me identify research proposal components and their preparation
12	Exposed me to different laboratory equipment and techniques used in research
13	Exposed me to field and laboratory research
14	Described the requirements and categories to participate in scientific fairs

RESULTS

The Intensive Research Method workshop. (i) Students' perception of the intensive workshop. Using a scale of 1 to 5, where 5 was excellent, students were asked to rate the intensive workshop. Seventy-seven percent of students gave a rating of excellent (5) to the workshop, while 94% of students rated the workshop as either excellent or good (5 or 4) (Fig. 2). Students gave biostatistics and its importance in research the lowest rating. By contrast, criteria with the highest scores included clarification of concepts, such as scientific method, questions generation, and tables and figures identification. Finally, the scientific posters, oral presentations, and science fair requirements and categories were perceived as positive outcomes from students' participation in the workshops.

(ii) Pre- and posttests. The pretest results showed that students participating in the program had little (15%) previous knowledge of the workshop content. After the 3-

day intensive workshop, the mean score of students' knowledge increased to approximately 55% (posttest 1). The paired *t* test analyses demonstrated that these improvements were statistically significant ($P < 0.0001$). Finally, after completing the DCM, the students achieved a mean score of 70% (posttest 2).

Delta Cooperative Model, (i) General perception of team performance. Figure 3A shows the evaluation used by students to assess team performance. There were also two evaluation forms in each category, the general (per group) evaluation and the specific (each member) evaluation. Our results showed that the general student perception of the team's performance was variable when compared among research projects. This type of evaluation helped determine how each member of the DCM perceived the overall team performance. Figure 3A shows an example of the general perception of team performance for one of the microbiology DCM team research projects. Student's general perception

FIG. 2. Student's perception of the intensive workshop: effectiveness in developing skills, content, and values. After the 3-day intensive research method workshop, the students assessed 14 criteria based on skills, content, and values using a scale that ranged from Excellent to Poor.

mean score ranged from 4.43 to 4.86 and 3.86 to 4.57 out of a maximum score of five, during the first and second assessments respectively. As determined by a nonparametric ANOVA ($P = 0.0488$), there were significant differences between the assessment administered at the beginning and at the end of the DCM project, but not among the individual components of each DCM research team (data not shown).

(ii) Specific perception of team performance. Figure 3B-D provides examples of a specific evaluation by team members after the first of the two stages of the DCM research experience. This evaluation allowed students to assess their (self-) performance and the performance of other members of the DCM (team). This information could be used by students to determine areas in which they needed improvement.

Evaluation of poster and oral presentations at the science fair. **(i) Science fair.** The judge's average evaluation of the team's performance in poster set-up, poster presentation as a team, and oral presentation averaged 79%, 83%, and 75% respectively.

(ii) Research preference. Student's indication of preferred research setting in the DCM project showed that 71% of the students preferred to work in both field and laboratory research settings. Twenty-six percent of the students preferred only the laboratory research setting, while 1.5% of the student population preferred just the field work

setting. Finally, only 1.5% of the students reported complete dislike of research.

DISCUSSION

Here we have presented the DCM as a pedagogical strategy to teach microbiology and develop research skills by combining the key educational instruments of intensive research training and a cooperative learning structure. By allowing students to role play one of the three specific jobs of a researcher on a "scientific stage," they were able to construct and learn by doing while dealing with events and circumstances in research that emerge from making inquiries and working in a team.

The students had the opportunity to participate in a research project from three different roles or perspectives, knowing that at a given time, each of them would become the leader in charge. As part of the process, they were able to discuss their progress with their cohorts at both intra- and interteam levels. Scientific roundtables allowed exchange of details about experimental design, data collections and analysis, and the interpretation and dissemination of scientific findings. These are all essential skills for a successful scientist. Furthermore, it is important to mention that in some cases the structure of the DCM team varied from three to four or even five students where two research projects were done per team, and some of the roles were shared by

FIG. 3. Assessment of the Delta Cooperative Model self- and team performance. (A) General perception of team performance at the beginning (R1, DA1, and RE1) and at the end (R2, DA2, and RE2) of the DCM research project. (B–D) These graphs represent specific perceptions of team performance at the beginning of the DCM research project. All the figures show collaborative and teamwork criteria (numbered 1–7) used in the self- (e.g., researcher self-evaluation annotated as R-R) and team assessment (e.g., researcher evaluating data analyst annotated as R-DA). The scale used ranged from 1 (poor) to 5 (excellent).

two students. The DCM variants were proposed by students themselves. This educational event promotes and strengthens the constructivist aspect of the DCM, where the students had the opportunity to build educational and learning schemes, while the faculty acted as facilitators in the process. These variants and the drop of one participant explain why we were able to maintain the DCM original role team structure after starting with an even number of students.

Results of the three assessment tests administered to the students demonstrated that combining the intensive scientific workshop with the hands-on experience allowed for an improvement in student content understanding. Areas improved after participating in the DCM project include biostatistics, scientific writing, poster set-up, and ability to search for scientific literature.

The assessment instrument used to evaluate team performance allowed students to give input at different levels. In general terms, the students could compare their individual perceptions of the team accomplishment, evaluate their participation as part of the team, and specifically identify those areas to be improved, based on the DCM teamwork assessment criteria. The DCM team assessment instrument provided the student an opportunity for reflection and for

comparison of their performance and perception in achieving the team's scientific goals with their peers' evaluations. While the student's perceptions of team performance in the DCM research project presented in Fig. 3A decreased from the pre- to the posttest, this is an intrinsic project-specific experience, and we consider it should not be taken as a rule or generalization. Each participant in each DCM research project will be unique, and how well they can adjust in the team will determine their view of success in the self- and team performance assessment. We plan to administer this instrument also between the pre- and posttest, in order to follow DCM students' self- and team assessment progress.

The self- and team performance assessment concept is similar to the auto-rating and peer-rating method developed by Brown (1) and used extensively by Kaufman et al. (4) as a tool to maximize group and individual performance. By choosing and participating in a DCM research project with a specific scientific role (e.g., R, DA, or RE), the students had an opportunity to develop an inner consciousness of their particular learning style. For example, those students that decided to participate in the DCM as an RE for two consecutive years indicated that they had a particular learning style mostly devoted to developing skills in scientific

Category	Values				
	1	2	3	4	5
Organization	Audience cannot understand presentation.	Audience has difficulty following presentation.	Student presents information in a creative sequence which audience can follow.	Student presents information in a logical and creative sequence which audience can follow.	Student presents information in a logical, creative, and interesting sequence which audience can follow.
Critical thinking	Student's thinking shows no logic or decision-making process, very ambiguous.	Student's thinking remains ambiguous, without decision making, but shows some logic.	Student's thinking lacks adequate decision making with ambiguity and little analysis, but shows some logic.	Decision making and analysis are made with no ambiguity and student's thinking shows some coherence and logic.	Decision making and analysis are clearly made, with no ambiguity, student's thinking shows impeccable coherence and logic.
Clarity	Inadequate voice tone and frequent mispronunciation. No scientific vocabulary used. The student read during the entire presentation.	Correct voice tone, but frequent mispronunciation. Some scientific vocabulary used. The student read during the presentation.	Correct voice tone and pronunciation. Speaks clearly all the time. Some scientific vocabulary used. The student read during the presentation.	Correct voice tone, pronunciation, and scientific vocabulary used. Speaks clearly and distinctly all the time. The student read during the presentation.	Correct voice tone, pronunciation, and scientific vocabulary used. Speaks clearly and distinctly all the time. The student did not read during the presentation.
Objectives	All action verbs are irrelevant to research, and the objectives are incoherent.	Most action verbs are irrelevant to research. All objectives are incoherent.	Most action verbs are relevant to research. Most objectives are coherent.	Most action verbs are relevant to research. All objectives are coherent.	All action verbs are relevant to research. All objectives are coherent.
Hypothesis	The project lacks a hypothesis, and there are not defined variables.	Hypothesis is not clearly stated, and some of the variables are not clearly defined.	Hypothesis is stated but not substantiated. Dependent and independent variables are clearly identified.	Hypothesis is well stated and somewhat substantiated. Dependent and independent variables are clearly identified.	Hypothesis is well stated and substantiated. Dependent and independent variables are clearly identified.
Method	Procedures are not clearly outlined in a step-by-step fashion. The control and experimental groups are not defined.	Procedures are outlined in a step-by-step fashion. Control and experimental groups are not defined.	Procedures are outlined in a step-by-step fashion. Control or experimental groups are not clearly defined.	Procedures are outlined in a step-by-step fashion but do not show reproducibility. Control and experimental groups are clearly defined.	Procedures are outlined in a step-by-step fashion and show reproducibility. Control and experimental groups are clearly defined.
Visual aids	Student uses superfluous diagrams and/or graphs or no visual aids.	Diagrams and/or graphs relate to the research project but are not correctly labeled.	Diagrams and/or graphs explain the research project but are not correctly labeled.	Diagrams and/or graphs explain and reinforce the research project and are correctly labeled.	Diagrams and/or graphs explain and reinforce the research project and are neatly and correctly labeled.

FIG. 4. Oral presentation rubric used in the UBSM program science fair. The student's 15-minute oral presentation was assessed by the judges using a rubric with seven categories and a scale that ranged from 1 (poor) to 5 (excellent).

reading and interpretation. On the other hand, participating as an R or DA, could imply learning styles associated with developing skills in problem solving and analysis respectively. The fact that the students made a decision regarding staying or changing the DCM role from one year

to the next highly suggested an inner consciousness or awareness of the student's own learning process. In general, the skills and values gained and developed during the DCM experience could also play a relevant role in the students' individual progress and in their future educational and

professional decision making and performance. As previously described, the students' research setting preference was for both lab and field. However, the research projects selected by the students revealed a preference towards applied microbiology and lab research settings. It is possible that because the research project has a field sampling component, students assumed this activity as a field research setting too. We plan to assess the student's research setting preference after the intensive workshop and along the DCM experience in order to determine how the research setting preference changes or evolves. Conclusive information on how the DCM experience has impacted the participants in these aspects is still unavailable due to the fact that the students are currently juniors or seniors in high school. We plan to follow-up with the participants after high school in order to relate academic progress in science and the field of study chosen at college with the DCM experience.

We have described the DCM as a novel pedagogical approach to develop scientific skills in microbiology which also incorporates some constructivist concepts. The basic scientific fundamentals and microbiological foundations have been taught to the students in the intensive research method workshop so they can generate a model based on individual assumptions. By interacting in the DCM during the intra- and interteam round tables, the students actively constructed and reevaluated their microbiology research project scientific design and knowledge, developing adequate and assertive schemes. Social context is central to constructivism. This implies that students organize their base of constructed knowledge in order to recognize patterns and apply them to new contexts. The newly constructed schemes will serve as thinking tools which will guide the students to solve new scientific research problems. As in all constructivist approaches, the role of the faculty participating in this process is not one of direct involvement but rather as a facilitator, giving the students the chance to develop their own and versatile repertoire of learning tools.

We have shown a three-student team activity, based on scientific role playing that besides pretraining the students in the scientific method also allows around 45 hours during the summer for DCM implementation. Some of the outcomes achieved by the participant students included: (i) the ability to disseminate science (microbiology) in various formats (orally, written, and as a poster), (ii) the development of research skills that ranged from experimental design to data analysis, and (iii) the ability to critically discuss research one-on-one with their cohorts (young science colleagues) through round tables, role playing, and team interaction.

To incorporate this activity as part of a class in a regular semester, a DCM prototype at the college level can be incorporated by assigning a research paper to a class similarly organized into students assigned to each scientific-role and asking them, after group discussions and analysis, to present a paper from the three DCM perspectives. The RE will show how the research was done and explain the scientific question and the experimental design. The DA will present how the data obtained was organized and presented, and

the RE will display the entire research project as a poster. Since the scientific method is usually the starting point in almost any science text, the DCM can be used as a trigger educational instrument or starting point to introduce several of the research concepts and develop scientific investigation and dissemination fundamentals. In a basic undergraduate research course, the DCM can be incorporated at the beginning of the class with a general problem (new or already solved) and generate scientific round tables (intra- or interteams) in order to analyze hypotheses and strategies, looking for the best approach.

ACKNOWLEDGMENTS

We would like to thank the academic and administrative personnel and students from the UBSM program at the Inter American University-Ponce. This work was previously presented at the 105th Annual Meeting of the American Society for Microbiology in Atlanta, Georgia. We also thank Dr. Vivian Navas for her comments and suggestions on the manuscript and Ilianet Morales for helping with the statistical analysis.

REFERENCES

1. **Brown, R. W.** 1995. Autorating: getting individual marks from team marks and enhancing teamwork. *In* D. Budny and R. Herrick (ed.), 1995 ASEE/IEEE Frontiers in Education Conference Proceedings. [Online.] <http://fie.engrng.pitt.edu/fie95/3c2/3c24/3c24.htm>.
2. **Johnson, D. W., and R. Johnson.** 2000. Teaching students to be peacemakers: results of twelve years of research. [Online.]. <http://www.co-operation.org>.
3. **Johnson, D. W., and R. Johnson.** 1989. Cooperation and competition: theory and research. Interaction Book Company, Edina, Minn.
4. **Kaufman, D. B., R. M. Felder, and H. Fuller.** 2000. Accounting for individual effort in cooperative learning teams. *J. Eng. Educ.* **89**:133–140.
5. **McInerney, M.** 2003. Team-based learning enhances long-term retention and critical thinking in an undergraduate microbial physiology course. *Microbiol. Educ.* **4**:3–12.
6. **Trempey, J. E., M. M. Skinner, and W. A. Siebold.** 2002. Learning microbiology through cooperation: designing cooperative learning activities that promote interdependence, interaction, and accountability. *Microbiol. Educ.* **3**:26–36.
7. **Suchman, E., R. Smith, S. Ahernae, K. McDowell, and W. Timpson.** 2000. The use of small groups in a large lecture microbiology course. *J. Ind. Microbiol. Biotechnol.* **25**:121–126.

Save the Date!
14th ASM's Conference for
Undergraduate Educators

May 19 - 21, 2007
Toronto, Canada

ASM cue.org