Expanding a Learner-Centered Environment Using Group Reports and Constructivist Portfolios

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A study was performed in the Microbial Physiology course to increase students' self-awareness of their misconceptions, promote sound research techniques, develop written and oral communication skills, stimulate metacognition, and improve teamwork and interpersonal relationship skills. The transformation in the teaching methodology included using cooperative learning, field trips, and portfolios that targeted diverse learning styles to challenge students in creative ways and to help prepare them for future careers. The entire structure of the class was modified by introducing in-class portfolios to form a constructivist environment in which the discussion and lecture topic of the day were built on prior student knowledge. Based on evaluations, students were very pleased with the new teaching and learning process and learned more content than in the more traditional class. They also felt better able to reflect on their learning.

Undergraduate science education has seen many recent reforms. The traditional classroom scenario characterized by professors giving lectures using only blackboard and chalk has given way to a new field of ideas (15). We have learned that interactions, both student-faculty and student-student, affect students' learning (2). For example, students benefit substantially from cooperative learning experiences in the classroom (11).

Simply putting students in groups does not get at the heart of the intended reform. Constructivism studies have indicated that students build on their prior experiences (7, 19). Some studies consider new material meaningful to a student only if it can be appropriately linked within the student's existing cognitive network (3). In fact, literature on undergraduate biology education supports the idea that meaningful learning is related to experience (14, 16). Besides bringing a unique set of experiences to a group, each student brings his or her own personal learning style preferences (8). To maximize learning, students should be made aware of their learning style preferences and those of their group members (13). To succeed in the classroom setting, either cooperatively or individually, students should also be aware of their existing cognitive network; or in other words, the content base (or lack thereof) that they bring with them to class.

Professors are currently being asked to have students work together, while recognizing that each student brings a unique set of experiences to the class and will build upon them using a learning style that might differ greatly from those of other students in the class. Moreover, building on student prior knowledge is not performed on or performed for the student, but rather is something in which the student should be actively engaged (10). Hence, professors are also challenged to help students become involved in their learn-

ing, realize how they learn, and monitor their learning experience (12). This process is often called metacognition.

Students must receive opportunities for self-awareness of their misconceptions and gaps in their knowledge, benefit from working with other students, and monitor their own learning. In order to rise to the challenge of creating a student-centered classroom, guided-discovery and cooperative learning were integrated into the teaching and learning approach described in this paper.

This study addresses the evolution of a curricular transformation initiated in a General Microbiology course (4) and then expanded to a Microbial Physiology course. The teaching methods evolved to create a student-centered atmosphere. The professor used cooperative learning, mentoring, and field trips to better prepare students for research and for the interpersonal and teamwork skills that they will need to work in industry (1, 5). This article explores additional techniques used to improve students' research and teamwork skills using group reports and explains how to use in-class portfolios to restructure the course so that every topic is built on prior student knowledge.

THE MICROBIAL PHYSIOLOGY COURSE

The Microbial Physiology class in this study consisted of 52 junior and senior students. The course is required for students majoring in Biotechnology or Industrial Microbiology and is optional for other biology majors. The three-credit course was taught twice a week allowing for longer class periods at each meeting.

On the first day of class, the Index of Learning Styles Questionnaire was administered to all students by using the Felder and Silverman Learning Style Model (9). The student learning profile was used to establish formal, cooperative student teams of five to six members. The groups were formal because they remained intact during the entire semester, only the assigned student roles changed. The professor required periodic peer evaluation of students' individual participation within their cooperative groups, allow-

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ing the instructor to intervene as needed. Students were given a miniworkshop on requirements to function properly as a team, such as positive interdependence, individual accountability, and interpersonal skills with emphasis on conflict resolution. Teams were also given individual learning style information to generate a team profile so that they could understand how their diverse learning styles might affect team performance and how they could capitalize on the different perspectives that each team member brought to the group. Based on Solomon and Felder's learning style inventory (8, 9), the students were found to be 55% active (45% reflective), 77% sensorial (28% intuitive), 78% visual (22% verbal), and 61% sequential (39% global). This information was used by the student groups and by the instructor to develop activities during the semester. The entire process has been used repeatedly by the professor, and its effectiveness is documented in earlier publications (4, 5).

IMPROVING TEAMWORK, COMMUNICATION, AND RESEARCH SKILLS

In order to improve written and oral communication skills and the ability to conduct literature reviews, the following process of group reports was incorporated into the classroom setting. To achieve microbial diversity within the class, each student group was assigned one microorganism (eubacteria, archaebacteria, mold, yeast, or protozoa) and eventually gave written and oral reports on their assigned microorganism. The reports included the importance, structural characteristics, metabolism, and genetic features of the microorganism. After four weeks each student, using a list of peer-reviewed journals, identified two papers about his or her group's microorganism. Each student was required to submit an assignment with complete reference citations, a summary of the paper in the student's words, an explanation of how the article could contribute to the reports on the microorganism, and the reason why that particular article was selected. Two weeks after the individual submissions, the student groups submitted a team summary that integrated the individual contributions of its members. The integrated summary was then reviewed by a different peer group. The entire literature search and review process was then repeated for a second round after each student had submitted two new papers. In the end, each student made four submissions, participated in two synthesizing processes to create two integrated group reports, and participated twice in the peer-review process with his or her team.

At the end of the semester, student teams were required to give an oral report on their microorganism. The oral reports were given by the entire team and were evaluated based on organization, clarity and accuracy of information, ability to answer questions, and presentation skills such as use of time, eye contact, and voice tone. Each student then had to submit his or her own written report which was eventually evaluated in a manner similar to the group reports with more emphasis on the documentation of the related literature.

To improve computer research skills, students were required to find information on the Internet as a part of their homework assignments. Since the Internet information was placed in the students' portfolios, this process is described more fully in the section below.

IMPLEMENTING A CONSTRUCTIVIST PORTFOLIO

In order to enhance the learning process, another course goal was to facilitate students' awareness of their misconceptions so that they could correct them through guided discussions and discovery learning. This resulted in a major transformation in the teaching of the course. In-class portfolios were used in a pretest-posttest sequence to let students see which misconceptions they held and which areas of knowledge they lacked. Students were asked in class to write or draw about a predetermined issue that became the topic of the day. This quick, usually five-minute, activity became the first in a series of three portfolio entries. The information they supplied in the first portfolio entry was from the prerequisite General Microbiology course. This information was used as a springboard to the topic of the day. Besides helping students identify gaps in their knowledge base, this activity helped students see how Microbial Physiology links to and uses information from General Microbiology. During the activity, the professor walked among the students to determine the most prevalent ideas. After five minutes, student volunteers shared their information with others, while the professor verified that the most commonly held misconceptions were dispelled. This was followed by a guided discussion and the lecture topic of the day. Besides sharing new information, the discussion and lecture session was aimed at helping students clarify their erroneous ideas and fill in their missing gaps. At the end of the class, students had the opportunity to do the same five-minute assignment in their portfolios in order to assess their enhancement of knowledge and their clarification of prior misconceptions. This was the second in the series of portfolio entries on the topic. As a homework assignment, students were required to go to the Internet to find and download visual information on the same concept to include in their portfolios before the next class as the third entry in the series. An example of this process follows.

In microbial physiology, the structural components of the cell provide the students with the framework for understanding cellular processes such as transport and metabolism. So, at the beginning of the class during which the bacterial cell wall was to be taught, the professor asked the students to draw the peptidoglycan and identify its components as their first portfolio entry. This information should have come from the General Microbiology course. See Fig. 1A for an example of a student entry which indicates that the student can localize the cell wall above the membrane but cannot identify cell wall components. The professor allowed several students to share their entries with the class. The shared information resulted in the complete peptidoglycan struc-

ture. This information served as the framework for discussing the topic of the day, antibiotic effects on cell walls. At the end of the class, the students were asked to repeat the first portfolio entry correcting any misconceptions. In this second entry, students assessed their own learning and corrected prior gaps in knowledge and previously held misconceptions. In this second entry (Fig. 1B), the student was able to identify the components of the peptidoglycan such as *N*-acetyl glucosamine, *N*-acetyl muramic acid, and tetrapeptide, and establish the relations among the components. This entry is similar to the preprinted transparency used by the instructor during the lecture (17). Finally, in order to familiarize the students with Internet resources, they were required to download a figure that complemented the previous portfolio entries as their third entry on the given topic.

To thoroughly explain this teaching method and demonstrate how the different learning styles were accommodated, it is necessary to give specific examples. Assignments followed by an asterisk (*) were discussed in the cooperative groups before each student wrote in his or her portfolio. The Microbial Physiology course was divided into three modules—*structure*, *transport*, and *metabolism*—with genetics and regulation embedded in each module.

Some of the portfolio assignments related to *structure* were: (i) draw a ribosome, (ii) state the function of the ribosome, (iii) mention the different types of RNA, (iv) state the function and draw the components of the plasma membrane, (v) state the functions and mention the components of the bacterial cell wall, (vi) identify and name the functions of the outer membrane components, and (vii) list flagellar components.

A.

B.

FIG. 1. Example of a student portfolio entries concerning the bacterial cell wall. (A) First entry on the cellular wall; (B) second entry. (Words in diagram are in Spanish.)

Portfolio activities related to *transport* asked students to: (i) identify structures responsible for transport, (ii) define transport, (iii) list transport systems, (iv) develop a strategy to transport hydrophobic and hydrophilic compounds in a gram-negative bacterium, (v) design an experiment to separate outer membranes from the plasma membrane of gram-negative bacteria*, (vi) design an experiment to separate proteins from a bacterial membrane*, (vii) use experimental data from different conditions in which lactose was transported and not transported to identify the energy and structural requirements for lactose transportation*, (viii) state whether lactose is transported in the absence of glucose in mutants lacking EII, EIIC, and HPr for the PTS transport system*, and (ix) document the visit to the electron microscope facilities and explain how the electron microscope is useful for microbial physiology studies.

Portfolio activities related to *metabolism* asked students to: (i) draw the Embden-Meyerhof pathway, (ii) define substrate phosphorylation, (iii) establish the metabolic reaction intermediate between glycolysis and the Krebs cycle, (iv) draw the Krebs cycle, (v) identify energy release steps in the Krebs cycle, and (vi) define fermentation and respiration.

Portfolio activities varied to target all learning styles. Group work helped active learners; individual assignments that required thinking or reflection on a concept helped reflective learners. The field trip was targeted at sensorial learners, while theory given in lectures benefited intuitive learners. Drawings and flowcharts targeted visual learners whereas written explanations and definitions were aimed at verbal learners. Flowcharts were used for sequential learners, while explanations that required connections between concepts were assigned for the benefit of global learners. Portfolios were also designed to help students form links building on material from other classes. For example, lactose utilization by *E. coli* served as a capstone topic to link structure (permease in the cell membrane), transport (symport mechanism), regulation by glucose, genetics by the lactose operon, and biphasic growth in the presence of glucose and lactose.

Finally, the portfolios were used to help bring about a self-awareness in students permitting them to grasp the extent of their misconceptions and gaps in knowledge. The self-evaluation and comparison allowed for an evaluation much richer and more meaningful than a single letter grade ever could. By doing side-by-side entries in their portfolios before and after the discussion and lecture session, students were able to see the corrections and changes in their ideas. In this respect, the portfolios empowered the students by putting them in charge of their learning process and letting them learn how to learn. Students examined their own misconceptions, received and interpreted the immediate feedback given in the discussion and lecture sessions, were responsible for correcting their mistakes, and compared information found on the Internet. Students monitored their intellectual growth and became active members in their own evaluation process. This led to a fascinating environment

that stimulated metacognition. In this environment, the professor often witnessed students questioning how they thought, how they were learning, and why they had “learned” a concept incorrectly. Students became more than active learners, they acquired a self-monitoring aspect to direct their learning.

COMMON MISCONCEPTIONS

The use of portfolios helped bring to light some common and surprising student misconceptions. Table 1 lists selected portfolio assignments with the percentage of students who completed each activity correctly before the topic was discussed; hence, lower numbers in the table indicate fewer students could do the activity. (Note that the table only includes topics with which students struggled; topics that over

80% of the students understood well, as evidenced by their first portfolio entry, were not included in the table.) The learning styles that may be favored are listed in the third column of the table.

RESULTS

The portfolios made a strong and lasting impression on the students. Although many students initially lacked necessary information, as evidenced in Table 1, 90% of the final exam questions that asked directly about a concept covered in a portfolio activity were answered correctly. When this modified class was compared with a traditional section taught by a different professor during the same semester, the biggest difference noted was that 37% of the class using group reports and portfolios received a grade of A, while only 19%

TABLE 1. Common misconceptions discovered during the portfolio activities^a

Portfolio activity	Students able to do activity (%)	Learning style(s) favored
Structure		
Mention the subunits of the 70S ribosome	58	reflective
Draw a model of the cell wall in a gram-positive bacteria	16	visual, global
Draw and identify the 3 components of the lipopolysaccharide in a gram-negative bacteria	11	visual, global
Explain the function of an outer membrane in a gram-negative bacteria	51	sensorial, global
Identify from a given figure the components of the lipopolysaccharide:		
lipid A	9	visual
core	4	visual
antigen	9	visual
Transport		
Design an experiment that separates the plasma membrane and outer membrane using structural differences	11	reflective, intuitive
Same as above but in teams	70	active, intuitive
Design an experiment that separates the proteins from the plasma membrane	58	active, intuitive
Define transport	76	intuitive
List transport systems in the cells ^b	73	sensorial
Metabolism		
Prepare a flowchart of the Embden-Meyerhof pathway ^c	25	visual, sequential
Establish connection between Embden-Meyerhof intermediate and other metabolic pathways	33	global
Define substrate level phosphorylation	51	reflective
Prepare a flowchart of the Krebs cycle ^d	11	visual, sequential

^a Lower percentages in the second column mean fewer students are able to successfully complete the first portfolio entry for the concept listed in the corresponding first column.

^b All of the students answering this correctly only listed two of the many transport systems—active and diffusion.

^c 25% of the students could start with glucose and end with pyruvate but had difficulty with the intermediate steps. Only 10% could go from glyceraldehyde to pyruvate; 29% could convert glyceraldehyde 3-phosphate to dihydroxyacetone phosphate and vice versa.

^d Only 42% of the students could establish the step from acetyl COA + oxaloacetate to citrate while only 2% could determine the substrate level phosphorylation step.

TABLE 2. End of semester questionnaire results^a

Statement on the questionnaire	Response avg
The portfolio . . .	
helped me visualize the material.	3.80
allowed me to clarify misconceptions.	3.78
allowed me to integrate new information with previous material.	3.77
gave me an opportunity to reflect on my learning.	3.70
allowed for an opportunity for creativity in science.	3.64
helped me develop critical thinking skills.	3.52
The portfolios were a waste of time.	1.19
I consider that the time invested in the portfolio was justified.	3.54
The use of the Internet for the portfolios enriched the course.	3.62
The use of the Internet for the portfolios enriched my research skills.	3.63
I would recommend these types of activities for other courses.	3.65

^a The following scale was used: 4, strongly agree; 3, agree; 2, disagree; 1, strongly disagree.

of the other class received the same grade. When this modified class was compared with the same class taught by the same professor one semester before incorporating group reports and portfolios, the biggest noted change was again in the percentage of students receiving a grade of A which went from 24% to 37%.

All students seemed to recognize the benefits of the portfolios (Table 2). The table contains the results of an anonymous end-of-the-semester evaluation. The evaluation also had an open-ended comment section. Fourteen students wrote in this section, and all of their comments were positive. The following comments (translated from Spanish) seem to summarize the attitude of the students: *it (the course) was a success; it helped me understand how I learned and helped me to improve my grades; the portfolio was a good idea, it helped me measure my learning; the course was designed for learning; excellent class, teamwork should be used in other courses; the portfolio helped me visualize the information.*

CONCLUSIONS

The modified course format was well-accepted by students. They felt that the activities really helped them, and they left the course with a positive attitude. This is echoed by the high final examination scores, which suggest that students learned the basic concepts of the course. These findings agree with Tombulak and Sheldon who reported that upper-division biology students who completed journal assignments obtained significantly higher test scores (18).

One of the most interesting aspects of this study was the information that the professor obtained about the knowledge base the students had when they entered the course. While the benefits of constant feedback for students and professors have been recorded in journals (6), it was still surprising how beneficial the daily feedback from the portfolios was for the professor. The portfolio data indicated that students had strong content knowledge of the cell membrane and its functions. However, there were weaknesses in their

FIG. 2. Student is unable to establish links between layers of the cell wall. (Words in diagram are in Spanish.)

FIG. 3. Student is unable to complete a drawing of the Embden-Meyerhof pathway before the topic is discussed in class. (Words in diagram are in Spanish.)

understanding of the cell wall and the outer membrane structure of bacteria (Fig. 2).

Students often limit their idea of transport to only one type—active transport. In design activities, students were capable of identifying the problem but were limited in providing alternatives to solve it. Two things were alarming in students' understanding of metabolism: (i) the high percentage of students (90%) who had difficulty establishing the Embden-Meyerhof pathway—the step from glyceraldehyde 3-phosphate to pyruvate—even though they were capable of determining the first part of the pathway (Fig. 3) and (ii) the high percentage of students (89%) who had difficulty with the Krebs cycle, the step from citrate toward oxaloacetate. However, students did very well defining the concepts of fermentation and respiration. These results suggest a need to reevaluate the curriculum with regard to central topics such as glycolysis and the Krebs cycle, which are present in almost every class taken by a biology major.

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