

Fig. 2. Linear sucrose gradient (10% to 60%), made with the apparatus, in total volume of 50 ml. Neutral red dye was added to 60% sucrose solution. Dye concentration was determined at 500 nm (nanometers) with a spectrophotometer.

one end and connected to a variable-speed lab motor, is introduced into chamber B, and the effluent and connector pinchcocks are removed. As the chambers drain, the speed of the motor is reduced to prevent excessive cavitation.

The shape of the gradient made by the apparatus can be determined by mixing a dye with one of the sucrose solutions. Fig. 2 shows the shape of the gradient obtained by using 10% sucrose in chamber A and 60% sucrose with neutral red in chamber B. Obviously, linear gradients can be made with quite dense solutions by means of this simple apparatus.

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INQUIRY ROLES IN COLLEGE

Having become aware of five naturally occurring cleavages in the junior-college classroom—sex, color, marital status, scholarship, and freshman or sophomore standing—I decided to break up these cliques. My hypothesis was that students will choose to work with one another on the basis of personal worth when social barriers of prejudice and class are broken down and when they know each other personally. I also wanted to increase the lines and quality of

communication: if students can learn to work together efficiently and can learn to communicate effectively, it will help them in every phase of life, not just in the science classroom. A further aim was to increase speed in learning scientific content, both quantitatively and qualitatively.

To attack the problem of cliques I chose the small-group method of togetherness. Teams of three students were placed together by the aid of sociometric techniques. Sociograms help pinpoint existing cliques (fig. 1). The sociogram of any class clearly shows cleavages: boys together, girls together, Mexican-American students together, and so on. Also, immediately evident are the isolates and potential isolates—the students with whom no one or almost no one chooses to work and the students who choose to work alone or nearly so. (This semester a girl wrote her own name down three times as her choices of partners, and one boy simply said, “I don’t want to work with anybody.” By the end of the semester both students had made choices and were no longer reluctant to work with others.)

Using the sociogram data, the teacher forms the first groups, who are to work together for four to six weeks (fig. 2). Each group consists of one leader, one isolate, and one “average” person, if possible. Grouping is done so that each student has in his group one person from his list of choices. Naturally, you have to let the students form their own whole groups at times, or they see no value in the sociograms. Usually, after roles are learned, teacher-formed teams are alternated with student-chosen teams. Teams are regrouped two to four times a month, depending on class activities. Students are grouped so that they mix thoroughly and with as much variety as possible. Teams composed of two to 10 students are used, depending on the complexity of the task at hand; the average team has three members.

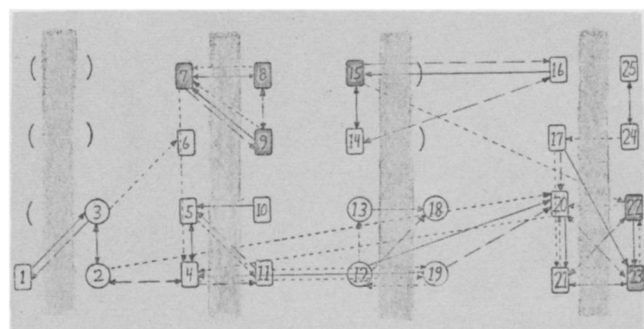


Fig. 1. Sociogram of initial, free-choice seating in the classroom. Dark strips are aisles; crescents are unoccupied desks. Oblongs are boys, circles are girls; darkened figures are Mexican-American students. Students were given choices as to associates; solid arrow is first choice, long-dashed arrow is second choice, and short-dashed arrow is third choice. From the choices the teacher could categorize the students as “obvious social leaders” (many choices: students 20, 21, 4, and 23); “obvious isolates” (one choice or none: students 10, 6, 25, 1, 12, 13, and 17); “potential isolates” (average of two choices: students 8, 9, 11, 14, 5, 16, 18 and 19); and “average” (three choices: students 2, 3, 7, 5, and 22).

Three different roles are assigned, with definite listings of responsibilities. Each student must learn to function efficiently in each of the three roles. After this is accomplished, squad or team members are shuffled to form new groupings. Eventually each student will work with every other class member. At first the team members may wear badges identifying the roles they are to fill in the cooperative enterprise.

Each team of three students chooses its members for the following roles: (i) a moderator, who leads the discussion, oversees group progress, sets the discussion pace, provides each team member with the opportunity to speak, and sees to it that each member understands and does his job; (ii) a secretary, who records data and makes notes of all work, on carbons, so each member has a record of his own, and also sees to it that charts, tables, and graphs are accurate and correctly made; and (iii) a librarian, who looks up resource material on debatable points and confirms all answers from textbook read-

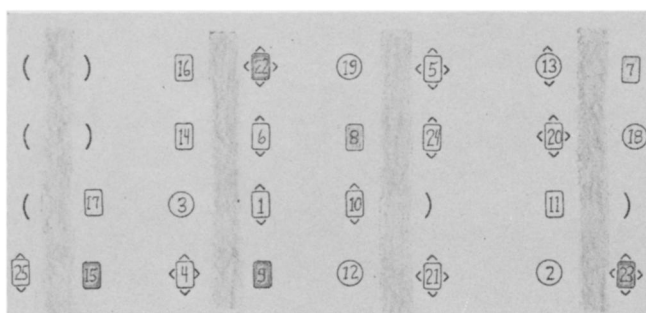


Fig. 2. Seating of students, by the teacher, to break up cliques. This sociogram is based on the findings in fig. 1 (see, for symbols). Academic and social leaders are designated by four carets; isolates, by two carets. One leader, one isolate, and one average student have been placed together. Due to the spread of students in one class, two potential isolates may have to be substituted for an average student or an isolate, depending on availability.

ings or laboratory investigations and also prepares the references-cited list for written assignments.

Teams compete against each other. They invent team names or symbols. The teams are charted by name or symbol on a large posterboard, so everyone can see just how each team is progressing. Each team keeps an accurate, cumulative record of laboratory investigations, study guides, cooperative quiz scores, and any other form of teamwork that is evaluated and competitive. Teams know where they stand in relation to their own class and to other sections of the course. Teams may do extra projects, labs, or exercises to raise team scores. Competition is keen and team spirit is high. Extra work and projects are submitted routinely.

After each team endeavor the top team in each class is recognized. This always brings a rousing round of cheers and applause. Because team performance is rewarded and individual performance is played down, the development of a cooperative team-effort becomes necessary. The biggest and most cov-

eted reward requested for top team-performance by the students is extra-credit A grades or a day off while the rest of the class is traditionally tested over the material they, the top team, already know.

Unless team members assume definite roles of responsibility, the effort may not be a team effort. It may instead end up being the work of one person while two people sit by and observe. With definite roles each student plays a vital part in the team effort.

To increase diligence in reading I have prepared study guides, which are written to stimulate thought and competition. Each guide consists of a "stem," which states a problem or proposition and is followed by five or more statements that can be answered "true," "false," or "both true and false." If true-and-false, both sides of the debatable question must be presented. Every true or false statement must be given with supporting evidence and is not acceptable without such reasonable evidence.

Cumulative test-results show groups of three students usually make perfect scores or miss one or two test items. Groups of two students miss three or four test items. Students working alone tend to miss four to eight test items.

Emphasis is put on thinking, not on memory and regurgitation. Concepts are learned and understood as the student takes part in a group learning-process.

The teacher becomes a resource person and can help groups of students who need help. He may also enter discussion and debate with the groups.

One rewarding result of this kind of inquiry, which mixes and intermingles students and ideas, is evidenced when the shy student from a minority group forgets his shyness and enters into or even initiates a discussion—to find that his ideas are not only acceptable but valuable to the group and the entire class. This small-team method allows a maximum of inquiry and discovery in the lab as well as in textbook study.

Before these methods are initiated, lab work usually shows majority participation and interest by students, but there always are some who fail to enter into the book-study and discussion exercises. Now, students find themselves deeply involved in thorough discussions of scientific information and concepts. After topics are discussed freely in small groups the problem is opened to class discussion, during which each group may express its ideas and thus share its findings with the whole class.

Test results have shown much higher scores and a complete lack of failures on the part of those who attend. Attendance problems are cut down as interest soars. The enthusiasm is catching, and it spreads rapidly through the classroom. Students find they can achieve—some of them for the first time in their lives. Those who have difficulty in reading and comprehension are not embarrassed; instead, they learn basic truths from their peers during deep scientific discussions. Because of a happy experience

in science, many students then will pursue other science courses, for they are no longer afraid of a "hard" course of study.

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STUDENT INVOLVEMENT IN THE "SYSTEMS APPROACH TO BIOLOGY"

How do high-school students spend their time while assigned to a 55-minute classroom period five times a week in a course using the principles of *A Systems Approach to Biology* (Bush *et al.*, 1971)? The Systems Approach to Biology, a program of individualized instruction designed and implemented by the undersigned, who are the biology teachers of West Lafayette (Ind.) High School, has been in operation in that school (Smiley *et al.*, 1972). This paper is a report on the students' use of their time in the program.

The program, which is self-pacing, allows students the freedom to determine when to study, when to take quizzes, when to perform inquiries or laboratory exercises, and when to attend issue, or "value," discussions, within a weekly schedule. Students who neglect to complete the weekly oral and written quizzes are restricted in their freedom only until they complete the tests successfully.

The Systems Approach to Biology places the students on their own for grades of A and B. Once the weekly oral and written quizzes have been successfully completed, the student earns a grade of C. The grade of A or B can be earned by accumulating points, which are awarded for performing inquiries, attending value sessions, teaching other students, and taking an A-B test. The grade each student receives is entirely up to him. All competition between students is eliminated. No student ever receives a grade lower than C. If he does not complete his weekly quizzes, an incomplete is recorded until he does complete the quiz or quizzes that he did not master. Sometimes, however, he must return next year to complete a particular unit.

The Systems Approach to Biology is an instructional innovation that combines performance objectives, mastery, the use of students to teach other students, and the freedom for students to decide when and how to study.

One of the advantages of the Systems Approach to Biology is its foundation on performance objectives. These objectives tell the student exactly what he is to do on quizzes and tests.

Another advantage of the system is the concept of learning for mastery at a preset level. This mastery-learning permits students to recycle through the lessons or modules until they have sufficient command of the cognitive material to complete all quizzes with at least 80% accuracy. Because students do not com-

pete with each other for a grade, it is theoretically possible for all students to achieve the letter grade of A. A spirit of cooperation is fostered. The minimum standards for each grade have been arbitrarily established by the instructors.

The system also features students teaching students. Students who have successfully completed the weekly oral and written quizzes are encouraged to teach students who find the material more difficult.

Performance objectives are established for each module, and quizzes are written directly from the objectives; therefore students actually have several options as to how they can learn the cognitive material. After satisfying the objectives by whatever route they have taken, students can request their written and oral quizzes.

Instruction, then, can take several pathways. Students may listen to taped lessons in carrels, which are provided with cassette players; may read assignments from textbooks; may receive instruction from other students; or may get help from an instructor. Each student normally uses the combination of these options that suits him. Instructors help each student to establish his learning pattern.

A survey was conducted during a three-week unit on the cell to determine how 157 students spent their time when given the freedom to study as they wished. At the end of each daily class the students recorded how they spent their time for the 55-minute class period. Each student recorded his progress on charts kept in folders in the classroom. (If a student failed to record his daily progress, he was reminded to do so before he left the classroom at the end of the period.) The following are the data obtained:

What was the time needed for students to complete a unit? The average unit-completion time for the three-week period was 13.7 days. Some students completed the unit in 12 days; a few required 16 days.

38.8% of the students' time was spent on cognitive material. This included 24.7% of their time listening to tapes, 2.0% reading, and 12.1% studying for quizzes. So less than 50% of their time was spent in acquiring the cognitive skills needed for the written and oral quizzes.

25.2% of the students' time was spent on open-ended activities. This included 14.7% performing inquiries or laboratories, 5.3% discussing and writing up "values" (position papers on current, controversial topics), and 5.2% teaching other students as performance instructors. The 5.0% for values includes a minimum of reference research; most research is normally completed outside the 55-minute classroom period.

14.2% of the student's time was spent taking the oral and written quizzes. The inclusion of the concept of mastery into the system means that some students may take certain quizzes two or three times before they complete the quizzes at the 80% level.

4.4% of the students' time was "teacher time." This included the distribution of duplicated Study Guide