Proceedings of the National Science Foundation Workshop on the Role of Faculty from the Scientific Disciplines in the Undergraduate Education of Future Science and Mathematics Teachers

National Science Foundation
August 1993

From: Proceedings of the National Science Foundation Workshop on the Role of Faculty from the Scientific Disciplines in the Undergraduate Education of Future Science and Mathematics Teachers, August 1993.

Peer Interaction Formats Enhance Problem Solving in Science Classrooms

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Problem-solving skills are essential tools for learning, doing, and teaching science. Most people solve problems in different contexts in everyday life, for example whether to buy a 32- or a 64-oz. bottle of Tide to get the better buy or how to figure out what is wrong when the VCR suddenly stops working. Some important aspects of successful problem solving include (1) thinking about each problem with a flexible and fresh approach and relating what is new to what is already known, (2) assessing if sufficient information is available to solve the problem or how to go about obtaining additional information, and (3) dealing effectively with frustration or any other emotions so that the ability to think is not overwhelmed. In this paper, we review several collaborative formats that we have implemented to enhance problem solving for science students from middle school to college level. While the formats vary, they focus student attention on both cognitive and affective processes in problem solving. We comment on affective processes as they are related to doing cognitive tasks and offer examples of formats we have implemented in our classrooms.

Many current models for science courses at the postsecondary level emphasize mastery of factual content in passive learning contexts such as lectures (AAAS, 1989). Students are often presented with large amounts of material at the expense of opportunities to construct their own conceptual frameworks. This means that they often do not get time to discover for themselves what scientific inquiry involves, to reflect on what they are learning and how they are learning it, or to assess how the facts are relevant to their learning. Where students learn methods for problem solving, these are often goal-oriented at the expense of inquiry-based learning. Finally, in contrast to the extensive collaboration characteristic of modern science, it seems odd that students are still expected to learn in isolation.

In addition, affective processes are almost universally ignored in current classrooms. Yet students are often confronted with emotions and attitudes that arise for them concerning their abilities, concerning science, and concerning learning and classroom issues in general—feelings of boredom, of frustration, of being stupid, of math phobia, and so on. Further, teacher reactions to students' emotional responses in learning situations can make the difference between high achievement and dismal failure in science for minority students (Massey, 1992) and women (Widnall, 1988), as well as other students. Cognition and affect are interactive rather than mutually exclusive functions of intelligence; affect can influence access to cognitive processes (Piaget, 1981). Permitting the expressive aspect of affect in the classroom can remove blocks to flexible thinking by releasing stored emotional tension. Laughing, yawning, sweating (and, more rare in the classroom, shaking or crying) represent physical manifestations of releasing stored emotional tension, so that the ability to think is recovered rather than being overwhelmed by feelings (Jackins, 1964; Weissglass, 1990).

Collaborative learning formats of various kinds (Slavin, et al, 1985; Slavin, 1990; Sharan. 1990; Davidson, 1991) have been widely used in the nation's schools, but not in colleges. Peer interaction enhances science achievement (Slavin, 1990; Sharan, 1990; Light, 1990; Light, 1990/1991) and improves conceptualization where the task involves abstraction rather than memorization (Damon and Phelps, 1989). In addition, collaborative learning programs have had a positive impact on the achievement of minority and women students (Treisman, 1985; Webb, 1985; Kagan, 1985; Johnson, Johnson, and Maruyama, 1983). The success of these methods can be attributed to their creation of an environment where students can interact with science and, as importantly, with one another. Collaboration reduces isolation, increases engagement and participation, and encourages students to clarify and articulate their thinking.

We use collaborative formats for problem solving that are designed specifically to address the need for time not only to reflect and interact with the subject, but also to deal with emotional issues that may prevent problem solvers from thinking as clearly as they are able. This is most effectively accomplished in the company of an attentive listener. Consequently, we spend a little time at the beginning of each course training students to become effective peer listeners (Weissglass, 1990; Puttick and Chew, Unpublished; Chew, 1992). In pairs, students learn a few operating rules: (1) to share equal time, (2) to look attentive and approving, (3) not to interrupt, (4) not to give advice, and (5) to keep confidences. Emphasis in the formats is on thinking, not dwelling on feelings, but if the student gets stuck, he or she has the opportunity to deal with the feelings and then move on with the task at hand.

We have implemented three different formats for problem solving in a wide range of courses at the middle school, high school, and college undergraduate level. All three formats provide the chance to go back and forth between thinking and feeling to solve a problem. In practice, the formats require that students learn to listen and pay attention to each other before being asked to use them. With practice, students get better at listening, not interrupting or giving advice, and assisting each other in dealing with feelings. Students usually work in pairs (dyads) to use these formats, but we have also implemented some group adaptations that are mentioned later. The dyad formats are useful for several different types of problem solving. They are particularly useful for solving circumscribed problems. Examples include math problems; statistics problems; quantitative problems in genetics, population biology, etc.; and problems of estimation or of logic. Work in pairs can also be useful for defining more open-ended problems. Examples include developing an argument or searching for evidence to support or refute different hypotheses or interpretations.

Learning to Listen

We practice using dyads in our classes by using several kinds of short exercises that permit student reflection. First, we help students "wake up" (especially useful in early morning or evening classes) by asking them to take one minute each in separate turns answering "What's going well for you?". Each pair decides which student will talk first. The teacher keeps time—a lab timer is useful for this. When the timer goes off, the teacher prompts students to finish their sentences and switch roles. The teacher can participate as a member of a pair if there is an odd number of students. Groups of three also work but make time-keeping trickier. Tardiness has declined in every class where we have used these. When questioned, students say they do not want to miss the dyad.

Second, we can focus student attention on a new topic by enabling them to brainstorm about that topic and share what they already know. For example, at the start of an introductory ecology class, we ask students to recall what associations the word "ecology" brings up for them. Likewise, students can use these "focusing dyads" to review in preparing for further work on a topic. For example, for a discussion of population ecology of different plant groups we might ask students to take one to two minute turns to consider what they know about the factors affecting plant growth requirements. This serves to validate what students already know, get them thinking about the topic, articulate what they are interested in, and, if thinking is solicited by the teacher afterwards, provides a relevant starting point for the lecture or lab, etc. By taking turns, talkative students learn to listen and to be concise, while "shy" students learn they will have equal uninterrupted time to respond. This practice socializes students to share time more equally when nonstructured brainstorming (see below) is used.

Third, after a lecture segment, film, or presentation (15–45 minutes), we ask students to take two minute turns in pairs to think about what they have just heard, and then we ask for questions and comments after the dyads. We find that student questions are more thoughtful after a chance to reflect on content. For example, questions and comments such as "Would you say that again?" or "I don't understand!" are replaced by specific questions on some aspect of the material.

We find that these three short dyads help to socialize the class into a learning community. Although our evidence is only anecdotal, based on student self-report, we have found that these formats have noticeably increased student engagement with, participation in and enthusiasm for science. We get student feedback like "This class goes by real fast," "I'm learning more in this class than in any other," and "Feelings really *do* affect thinking." Students ask more thoughtful questions and pay better attention after having a chance to reflect on the material. They come to regard their peers as resources rather than focusing on the instructor as the sole source of effective assistance (Puttick and Chew, Unpublished; Chew, 1992). The dyads also help prepare students to listen effectively to their peers in the problem-solving formats described below.

Work Session

This format involves each student working individually on the same or different problem for a set time period (4–10 minutes, depending on the difficulty or complexity of the problem). Then the partners each take a 1–2 minute turn in a dyad to report on their progress or express how they feel or both. Each student then returns to working on his or her problem for an additional 4–10 minutes. The teacher keeps time and reminds students when it is time to switch.

Outside the classroom, students can use an extended version of the Work Session, working for 2–3 hours on problem sets, term papers, or studying for exams. Students work for an agreed-upon length of time, then take 5–10 minutes each to report on progress and feelings and to plan the next steps before resuming work.

Think and Listen

This format involves each student working on her or his problem while the other pays attention. Students each take a turn to think aloud about their problem for 5–10 minutes while the other student listens, pays attention, and takes notes if asked. The thinker uses the time in the way that is most useful to him or her—solving the problem or thinking aloud about what he or she knows about the problem and what is needed to solve it. If the thinker gets stuck, the listener encourages the thinker to express feelings. Short, nonverbal expressions such as gestures or noises are most effective. After a minute or so of nonverbal expression, the listener encourages the thinker to continue thinking aloud. Again, the teacher keeps time and reminds students when it is time to switch.

This format can be most effective with very challenging problems, but only after the class has practiced listening, so that students will be able to listen to each other for 5–10 minutes without interrupting or giving away the solution. Students will be able to build on one another's responses if they start work on the same problem from the same starting point. Alternatively, students still benefit if they work at different paces; each one will get a chance to confront a cognitively challenging situation with encouragement and an immediate chance to express feelings that may arise during the task. "High achievers" get a chance to learn patience and to let "lower achievers" come to their own conclusions. Since even "very high achievers" may have feelings about cognitively challenging situations, they often find that being listened to by a "lower achiever" provides assistance in problem solving, even though the latter provides no information about solving the problem. This may also be a rewarding experience for the "low achiever." Students have commented, "Two heads are definitely better than one" and "I can think better when I'm talking."

Work Session 2

This format has basically the same structure—students work in pairs and take turns—but here they collaborate together on the same problem. Students work together for a set time period up to about 10 minutes. Then the partners take turns in a dyad to express how they feel for a minute or so. Finally, they return to the problem for a further 10 minutes. This alternating between working together and breaking for dyads can continue for as many repetitions as are required to finish the task. Students may develop their own pattern of time spent in each part of the session—some may find 5 minutes on problem solving all they can handle while others may want to take 20 minutes. Likewise, students may only want to stop for dyads when they find they are stuck or when they notice that their feelings are overwhelming their ability to think clearly about the problem. Whatever timing they adopt, students need reminding that they should each have equal time when they stop for dyads. Students need to keep time for themselves in each pair. Students must work on the same problem simultaneously, and this format usually works best if students have prior practice at taking turns. Otherwise, as pointed out by Damon and Phelps (1989), students may not be mutually engaged.

Brainstorming

All three formats described above can also be effectively used for brainstorming about specified problems or topics. Brainstorming together often generates faster solutions and allows students explicitly to build on each other's thinking. On the other hand, taking turns in dyads will persuade "shy" or "underachieving" students to rely more and more confidently on their own thinking, especially if dyads are used consistently so students practice listening to each other. Having an uninterrupted turn gives them a chance to express some of the feelings and to speak without being interrupted by more vocal or less patient students. The teacher needs to say clearly whether the students should brainstorm together or brainstorm taking equal turns to contribute a thought. Likewise, group brainstorming proceeds with greater participation when students have had prior practice participating in pairs.

Work in Groups

Work sessions, brainstorming sessions, and think-and-listen sessions can also be used in groups of three or four students. (Social dynamics in groups larger than this tend to become unwieldy.) Groups are often suited to studying more complex issues or situations in which there is evidence to support many viewpoints or where there are arguments in favor of differing interpretations.

For example, we have had freshman and sophomore students in an introductory biology course consider the problem of tropical rainforest destruction. Interest groups include bankers, native forest dwellers, cattle ranchers, consumers of fast-food hamburgers, timber companies, etc. Each student group chooses an interest group to represent. They start by brainstorming to identify what they know about that group and what they need to know about the group or its concerns before they can speak for it. Students then do library research, using the work session format, to get the information they have identified as important. They prepare presentations using the Work Session 2 format. They present short oral presentations collaboratively. After each presentation in class, students take two minutes each in pairs to think about what they have heard and to formulate questions.

Conclusion

Rather than focusing student attention on mastery of factual content, these formats instead enable students to become active architects of their own scientific learning and experience. Their *interaction* with science and with others engaged in the same activity, rather than being *taught* science, is what gives science meaning. With encouragement to build on what they already know, to use diverse skills they have already mastered, to work together, and to deal effectively with their feelings about challenging tasks such as problem solving, science becomes more accessible to students.

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