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A VIEW FROM THE ACADEMY

Liberal Arts Professors on Excellent Teaching

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Peer Interaction Boosts Science Learning[1]

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College science requires facts, conceptualization, and critical thinking

Scientific inquiry challenges factual knowledge and conceptual understanding, both of which are required for the successful practice of science[2] and the critical thinking needed for general scientific literacy by non-scientists and scientists alike.

College-level science courses require that students (a) digest and sort large amounts of factual information, much of which is continually recontextualized or replaced by newer findings; (b) simultaneously assimilate current conceptual models; and (c) learn academic skills needed to manipulate information and concepts. In addition, students have feelings (knowingly or not, willingly or not) about their abilities, science tasks, and classroom situations. Our challenge as educators is to help students internalize cognitive skills needed for science, while also assisting them as they deal with emotional issues that can promote or deter persistence.[3] This paper reviews some classroom methods I have implemented to address both cognitive and affective issues.[4]

Peer interaction is a norm in scientific research

Most of the modern scientific world works collaboratively. Collaboration's prevalence testifies to the effectiveness of working together where problems are complex. Even where scientists do not specifically collaborate, assistance from colleagues is widely acknowledged; but collaboration and acknowledgment—useful and widespread practices in scientific research—are rarely used to teach science. Further, although various groupwork methods have been implemented in schools, college teaching has rarely incorporated collaborative formats.

Peer interaction significantly enhances science achievement, both for younger pupils[5] and at the college level.[6] While peer interaction is often not best for learning rote or mechanical tasks (e.g., memorization of terms, procedures, formulae), appropriate peer collaboration significantly improves participants' achievement in conceptualization[7] and manipulation of complex problems, which constitutes much college level science.

I have implemented methods modelled on the interaction of colleagues whose contributions are acknowledged, but who do not actually work together. Although I also assign collaborative projects, I focus here on the "acknowledgement" model because products are graded individually. Given our institutional preoccupation with individual evaluation [at all levels from freshman courses to dealing with jointly authored work in professorial tenure cases], this model embodies a more appropriate use of peer assistance than pure collaboration. Students take substantial individual responsibility for their own achievement levels, but peer interactions enhance their achievement by providing opportunities for reflection, assessment, informational feedback, and support.

Classroom example 1: Information overload

Lecturing is an efficient mode for communicating lots of information to lots of listeners within a relatively short timespan. However, compared with other oral modes (for example one-to-one conversation), lecture formats deprive listeners of the time for reflection needed to internalize the material.

On the other hand, student dyads address the questions "What have I just heard? What makes sense? What's one question I have?" In pairs, students take sequential turns to answer these questions for a minute while the other pays attention and gives non-verbal encouragement. The session is monitored by the instructor, who also calls out "time to switch" after one minute has elapsed, and "that's time" after two minutes. Students ask more thoughtful questions following such pauses for cognitive processing, and quickly realize if they have missed important information. This method is similar to the "one-minute paper"[8] because both methods use cognitive processing via writing or talking. The one-minute paper requires less time and promotes writing practice, but because talking is faster than writing, dyad participants process more information per unit time.

Classroom example 2: Focusing attention

Short dyads assist students to "wake up" in an eight o'clock class. Students take 2-minute turns to consider the question "How are things going for me right now?" I encourage them to stretch, yawn and giggle during dyad time. I observe that students pay better attention, and tardiness declines. To focus attention on a specific topic, such as island biogeography, I ask dyads to consider questions like "What do I know about islands? What associations do I have with islands?"

I may use student responses as a springboard for my lecture. A lecture on the genetics of cereal grasses may be prefaced by a dyad on "What do I think of when I hear the word 'grass'?" These dyads offer opportunity to reflect on knowledge and feelings and help students place new information in the context of what they already know.

Classroom example 3: Solving problems and critical thinking

Dyads can also be used for more complex tasks if one allows more time per turn. Here, students use each others' assistance to work on individual assignments, much as an individual scientist's work or manuscript is enhanced by consultation with another scientist whose contribution is acknowledged.

The reviewing scientist is not usually more expert in the topic than the writer; both writer and reviewer are often explorers of little-known territory.

Students use these interactions to think critically and write about unresolved scientific and policy issues. They must decide (a) what subject to write about; (b) how to construct their arguments; (c) how to present those arguments persuasively; and (d) what positive alternatives to propose to respond to criticisms.

Students use peer interactions extensively for support during the process of writing and revising successive drafts. Interactions focus on assessing one's own thinking and writing, with the attention and encouragement (but not advice) of a peer. Students report that peer encouragement keeps them focused on the task and enables them to deal constructively with feelings. Students use dyads to recognize when they are missing information, and when their thinking is strongly influenced by values and non-scientific agenda. Awareness of and distinction between reactions and thinking improves classroom discussion and enables students to construct arguments more persuasively.

Interactions create a learning community of peers

If used regularly, dyads socialize the classroom into a learning community. Students get acquainted with each other as peers. Formation of a learning community among course members shifts emphasis from the teacher to students. This shift facilitates students seeing each other as resources, and seeing their job as doing and assessing their own work, rather than (merely) figuring out what the instructor wants.

Within a few dyad sessions, students discover whether they are confused because they are missing important information; distracted by an immediate need such as hunger; or "daydreaming" because they are preoccupied with feelings about something. While remedies for the first two situations are relatively simple, the third is less easily dealt with in a classroom context. As long as a student's attention is occupied by feelings, cognitive processes will be blocked.[9] Access to cognitive functions can be restored by releasing or discharging the stored emotional tension through the expressive aspect of affect[10]—the physical laughing, yawning, sweating, shaking and crying that we do when we feel embarrassed, scared or sad. This non-verbal expression of feelings represents the physical manifestation of our natural ability to rid ourselves of emotional distress.[11] Rules are (a) equal time per student; (b) giggling, yawning, and other spontaneous behavior is fine; (c) no interruption or advice; (d) confidentiality.

After an opportunity to acknowledge and discharge feelings, students find they can better focus their attention on a cognitive task.[12]

Peer dyads promote autonomy in learning by providing students with opportunities to construct their own conceptual frameworks and to reflect on their progress. These formats also promote equality by structurally ensuring each peer has uninterrupted time to think or feel. Shy or less verbal students often realize they have something to say if they don't have to talk immediately. More assertive students learn to be succinct and to listen.

Students learn collaborative skills in the classroom

As emphasized by practitioners of many groupwork models, students must learn social skills in order to work together effectively. By the time they get to college, students have spent too many years working in isolation to work together without guidance. Instruction in collaborative skills consists principally of peers learning to listen attentively and confidentially to each other—without interruption, advice, or judgment— to provide a space to think out loud. I give student dyads the in-class assignment of taking turns listening silently for one minute and of being listened to for one minute without verbal feedback. It's actually a difficult task on both ends because we are socialized to give and receive immediate feedback in conversational interactions. But the point of taking turns is to do our own thinking aloud with an approving audience and without interruption, advice, or judgment, so we have the opportunity to really do our own thinking and to realize we have feelings.[13]

For more extended applications such as peer editing, there are helpful ways for peers to give feedback.[14] For example, in 20-minute turns, issues can be raised such as personal concerns (e.g., "I got confused here." "I wasn't sure where you were going with this thought.") or as questions (e.g., "Do you have a specific audience in mind?" "Would your audience benefit from an example?")

Peer interaction helps learners take charge of their own education

Implementation of these peer interactions reduces my lecture time 10-15%. However, students pay better attention and ask better questions, so I repeat myself less frequently. I find that student problem-solving, papers, and take-home exams are more thoughtful and well-written as a result of the interactions. Further, because students acknowledge each other's assistance, they are keenly aware of plagiarism. Best, students report a sense of autonomy, confidence, and awareness in their thinking and writing processes that goes well beyond my courses. Many say that they have improved confidence in their own abilities to tackle problems. Others report improved social skills, particularly in getting to know people who are quite different from themselves. Women in particular report they become more assertive.

Part of educating young scientists involves gradually giving them increased responsibility for figuring things out, whether the task involves simple procedures, complex problem solving, interpreting technical information, or finding outside expert help for one's project. The major challenge for me (as a teacher with substantial research and consulting responsibilities, as well as teaching duties) is to enable students to internalize cognitive skills in a supportive context that doesn't focus primarily on "expert" advice from me.[15]

When students finish their degrees they are suddenly expected (for doctoral level students) to oversee their own major projects, write their own grants, and negotiate their own collaborative arrangements. Because these undergraduate collaborative formats enable students to think productively without "expert" company, students gradually realize they can tackle problems with minimum expert help. To the extent that higher education focuses science education on the "expert" teacher, we seriously mislead students about the actual practice of science and complex problem solving. Autonomy and confidence, as well as the ability to listen to others, are critical in educating potential scientists and others who can successfully tackle the substantial global problems we currently face.

Ironically, giving up certain kinds of control and being willing to live with the appearance of chaos has generated a richness and a degree of independence, cooperation, affection, and creativity that I wouldn't have imagined. It has been exhilarating.

Notes

1. G. M. Puttick, a research biologist and educator at Technical Education Research Center, 2067 Massachusetts Ave., Cambridge, MA 02140, has co-developed and co-led our collaborative learning workshops and courses in academic and multicultural contexts since 1988. Jane Hill Detenber has helped me to think and write since 1984. E.D. va der Reijden, L. Flanagan, and G.M. Puttick read the manuscript. The Mary Ingraham Bunting Institute, Radcliffe College, provided encouragement to explore these ideas. The H. Dudley Wright Foundation supported some recent developments.
2. Empirical observations enhance construction of conceptual models; models enhance the ability to put data into patterns. See R.E. Cook (1977). Raymond Lindeman and the trophic-dynamic concept in ecology. *Science* 198:22-26; S. Toulmin and J. Goodfield (1965). *The Discovery of Time.* Chicago: Univ. of Chicago Press, 125ff.
3. For example, Ruskai, M.B., (1991). Comment: Are there innate cognitive gender differences? Some comments on the evidence in response to a letter from M. Levin. *American Journal of Physics* 59, 11-14.
4. I have implemented these methods in several intermediate courses with a heterogeneous mixture of undergraduates from biology and graduate students from several departments. I also teach an undergraduate course in leadership and multicultural awareness that makes extensive use of these methods for addressing diversity issues.
5. For review, see R.E. Slavin, editor (1990). *Cooperative Learning, theory, research and practice.* Englewood Cliffs, NJ: Prentice-Hall; and Sharan, S., editor (1990). *Cooperative Learning, theory and research.* New York: Praeger.
6. Light, R.J. (1990, 1991). The Harvard Assessment Seminars. Cambridge, MA: Harvard University.
7. Damon, W. and Phelps, E. (1989). Critical distinctions among three approaches to peer education. *International Journal of Educational Research* 13, 9-19; Phelps, E. and Damon, W. (1989). Problem solving with equals: peer collaboration as a context for learning mathematics and spatial concepts. *Journal of Educational Psychology. 81,* 639-646.
8. I have also implemented writing methods developed and taught at the Bard College Institute for Writing and Thinking along with these collaborative methods that emphasize talking. My students use writing when working alone but have found these talking formats more productive for cognitive processing, perhaps because there is more peer support.
9. Piaget, J. (1981). *Intelligence and affectivity: their relationship during child development.* Palo Alto, CA: Annual Reviews.
10. Ibid.
11. Jackins, H. (1964). *The human side of human beings.* Seattle, WA: Rational Island Press.
12. J. H. Detenber, a fifth grade teacher and A. Vhlahakis, a high school teacher, have adapted the "wake-up" exercise for non-dyad use in their classrooms in the morning or after lunch. Detenber instructs students to fake yawns and raise their hands when real yawns come, and when everyone's hands are up [usually two minutes], the exercise is over; Vhlahakis gives students two minutes to "yawn and

stretch," but they are not to talk or otherwise make much noise. Both report students' attention to cognitive tasks improves dramatically.

13. The difference between normal conversational interactions and really listening or being listened to needs to be experienced. Methods similar to these have been described as constructivist listening, see J. Weissglass (1990). Constructivist listening for empowerment and change. *Education Forum* 54, 352-370. To demonstrate the difference, I use the following short exercise: (i) one-minute fake listening and one minute trying to talk to a fake listener [during this exercise, the listener makes obvious attempts to ignore the talker, who tries to think aloud about a question such as "What's something I do well as a student/teacher that many of my peers don't know about?"]; (ii) one minute real listening and one minute thinking aloud with a real listener [during this exercise, listeners maintain eye contact, give non-verbal encouragement such as nodding the head, etc.]. If students observe most conversations, they discover that most participants aren't really listening. Each is waiting for a chance to contribute, and the urge to do so often results in interruptions at intervals of less than one minute. Satisfying conversations are those where participants really do listen to each other. Confidentiality is important to promote safety, and the injunction against interruption or advice gives the talker space to think about her or his own agenda; further, there are plenty of non-dyad times for students to give each other feedback, advice, etc., and dyads are a time for students to reflect without interruption. The approving listener approves of the talker's effort to think, even if the talker takes a temporary wrong turn in her/his reasoning. We all gain satisfaction and confidence from working through our confusions without being given the "correct" answer.

14. Peer editing and feedback do not substitute for feedback from an instructor, but instructors also are not sole proprietors of useful feedback.

15. For discussion of long term motivational effects, see A. Kohn (1991). Group grade grubbing versus cooperative

learning.; R.E. Slavin (1991). Group rewards make group-work work, response to Kohn; and A. Kohn (1991). Don't spoil the promise of cooperative learning, response to Slavin. *Educational Leadership*, Feb., 83–94.