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WHEN IS THERE STRENGTH IN NUMBERS?

A STUDY OF UNDERGRADUATE TASK GROUPS

Diane F. Baker and Connie M. Campbell

Abstract. Undergraduate college students in an advanced math class were videotaped as they worked on three mathematical proofs. Findings indicated that both ability and self-efficacy were needed for group success. Members with high levels of self-efficacy served the group by encouraging others to continue working. Groups tended to use a trial-and-error methodology that was not always effective or efficient. Many group members did not have an accurate perception of their own abilities or the group's performance. Implications for using groups in the classroom are discussed.

One of the more robust findings in educational research is that cooperative learning—having students work together to learn concepts and problem-solving skills—leads to higher levels of learning and academic achievement than other instructional methods. Johnson and Johnson (1998) reviewed more than 305 studies that compared cooperative, competitive, and individualistic learning at the college and adult levels and found that cooperative learning significantly improved individual achievement. Researchers have found that cooperative learning has numerous other positive outcomes as well, including increased confidence in one's ability to achieve, enhanced interpersonal relationships among peers, increased effort, improved morale of teachers and students, increased willingness to attempt challenging tasks, and decreased stress (Tien, Roth, and Kampmeier 2002; Onwuegbuzie, Collins, and Elbedour 2003; Morgan 2003; Zimbardo, Butler, and Wolfe 2003; Johnson and Johnson 1998; Strom and Strom 2002).

Several theories have been suggested to explain why cooperative learning works. Walker and Angelo (1998) used Karau and Williams's Collective Effort Model (Karau and Williams 1993) to explain the effectiveness of cooperative learning. Karau and Williams proposed that individuals are willing to exert effort when they believe it will lead to successful performance and valued outcomes. When members identify with their group, one of the valued outcomes is group success. However, members must believe that their efforts are instrumental to group performance; otherwise, social loafing occurs. Johnson and Johnson (1998) suggested that when confronted with ideas that differ from their own, students are forced to reconsider their assumptions and review relevant information. This process leads to clarity of thought and a more carefully developed conclusion. According to Johnson and Johnson, behavioral theory may also be used to understand the positive outcomes of cooperative learning. Instructors can provide meaningful extrinsic rewards to encourage students to participate in the group efforts to reach certain levels of performance.

Given the advantages, one might wonder why many college professors resist using cooperative learning. However, as most instructors who have used various forms of cooperative learning can attest, using groups in the classroom clearly has challenges. The mechanisms that often lead to greater student learning can actually reinforce wrong thinking when group members misunderstand concepts or procedures. Perceptions of unfairness can occur if the lowest performing members of each group are given the same

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grade as the highest performing members. Some students prefer working alone and actually experience more stress when they have to work in a group (Morgan 2003). In the college setting, students become frustrated when an assignment requires meeting outside of class, but the group is unable to find a suitable time when all of the members can attend. Groups may take longer to make decisions. In the absence of feedback about their performance, group members may become overconfident, discount important information, and make poor decisions (Janis 1972). Harmful behaviors by members can cause frustration within the group, such as domination by one member or a subgroup of members, social loafing, self-censorship, or prematurely rejecting ideas.

The challenges are not insurmountable. Instructors have influence over many of the variables that affect the extent to which cooperative learning is successful, such as group membership, task assignments, performance feedback, and grading methods. The more instructors know about how student groups work (that is, group process), the more they will be able to manage the variables in a way that enhances the experiences of students in a cooperative learning environment.

Research Process

Although the literature is filled with information about outcomes associated with cooperative learning, less is known about the specific group processes that lead to those outcomes. One way to learn more about group process is to watch group members as they work together on a task. We designed a study that involved videotaping groups of students as they worked on a set of complex tasks. We randomly assigned students in an undergraduate advanced math class to groups of three and asked each group to construct three mathematical proofs on a chalkboard or flipchart paper. The task—constructing proofs—was ideal for this type of study. Based on Gagne, Briggs, and Wager's typology (1992), proof construction is an intellectual skill; it requires analyzing a mathematical statement, selecting an appropriate proof method from memory, and determining how to use the method for a given hypothesis and conclusion. It is, therefore, a challenging cognitive task that requires analysis and creativity. Although several different solutions are possible for each of the mathematical statements that we assigned, a proof can be objectively evaluated as either right or wrong.

Fifteen groups with three students each were videotaped. All students received the same amount of class credit for participating; credit was not dependent on success or effort. The researcher who conducted the videotaping came from outside the mathematics department and did not know how to solve the problems.

Before we gave each group the three problem statements, we asked the students to complete a pretest, which assessed the prerequisite skills needed to construct proofs, and a survey, which measured self-efficacy and collective efficacy. Self-efficacy is an individual's belief about his or her ability to achieve a desired outcome (Bandura 1986). Collective efficacy is a group member's belief about the group's ability to achieve a desired outcome (Bandura 2000; Riggs and Knight 1994). Subjects with higher levels of self-efficacy and collective efficacy tend to set higher goals, give forth greater effort and persist longer on tasks (Bandura 2000). Self-efficacy was measured by evaluating six items on a seven-point scale adapted from the work of Riggs and Knight (1994). The measure included statements such as, "I have all the skills needed to construct proofs well" and "I have confidence in my ability to do proofs." Collective efficacy was assessed using three items on a ten-point scale adapted from a self-efficacy measure described by Gist and Mitchell (1992): "How confident are you that your group will correctly complete at least one proof? Two out of three proofs? All three proofs?" After the groups were finished with the problems, we asked them to estimate how well the group did on the problems using a similar format.

Results and Observations

The videotapes and statistical analyses revealed some interesting results regarding member characteristics, group processes, and group performance. We analyzed how member abilities and beliefs affected persistence and performance. In addition, we studied the way in which groups tried to solve problems. In some cases, our observations clarify how groups aid or impede learning. Other observations are more neutral in nature but help us understand the relationship among beliefs, abilities, and performance.

Member Characteristics

Ability versus efficacy. The presence of group synergy did not eliminate the need for prerequisite knowledge. Successful groups had members who had stronger proof-related math skills than the members of unsuccessful groups. Members of the six groups that correctly constructed all three proofs scored, on average, 14.5 percent higher on the pretest than members of the nine groups that constructed one or more proofs incorrectly. This was a statistically significant difference ($t = 2.6$; $p < .01$).

We found a linear relationship between self-efficacy and ability, as measured by performance on the pretest ($r = .33$, $p < .05$). The size of this correlation coefficient is very close to what Stajkovic and Luthans (1998) found in their meta-analysis of 114 studies (r = .38). We also tested the relationship between self-efficacy and the course exams in the advanced math course that covered material on proof construction. As one might expect, the lowest performers in the class had the lowest self-efficacy. Surprisingly, how-ever, the average performers had higher self-efficacy than the strongest performers in the class (quadratic equation was significant: $p < .05$, $R^2 = .148$). In two-thirds of the groups, the highest performer on the pretest was not the person with the highest self-efficacy rating. These findings suggest that the average performers were most susceptible to a self-enhancing bias, perhaps because they did not fully understand the nature and challenge of the task.

Nevertheless, those with a high self-efficacy were important to the team, even when they did not know the material as well as others in the group. This was especially evident on the third proof, which was by far the most difficult of the three. A discriminant analysis revealed that a combination of ability, self-efficacy, and collective efficacy predicted success on the third proof for fourteen out of the fifteen groups ($p < .01$). All of the groups experienced initial intimidation or cognitive difficulty at some point during their efforts to construct the proof. Six groups considered giving up on the problem, although only three actually did give up. Often, it was the member with the highest level of self-efficacy who encouraged the group to keep working. Consider the following dialogue between two members of a group that successfully constructed the third proof after fifty-two minutes. Names are used for simplicity but have been changed to protect confidentiality. Sally had the lowest self-efficacy score in the group but the highest pretest score. Ned had the highest self-efficacy score in the group and was tied with two others for the highest self-efficacy score in the sample ($n = 45$), but he scored twenty percentage points below Sally on the pretest.

> *After 31 minutes:*
>
> SALLY: I'm stumped.
> NED: No, you're not.
> SALLY: Yes, I am.
> NED: No, you're not. We've just got to think of the right trick.
>
> *After 41 minutes:*
>
> SALLY: I'm ready to throw in the towel.
> NED: No, hold on, we might be the only group that doesn't—
> SALLY: We've been doing this for an hour.
> NED: No, we've been doing it for about forty minutes.
> SALLY: I can't think about it anymore. All I think about is the same stuff. I can't think of anything different.
> NED: Change your thoughts.

People with high self-efficacy played a key role in keeping members motivated until the proofs were fully constructed. Those who had both ability and high self-efficacy could keep members working either by offering encouraging words or providing new ideas directly related to task completion. Those without much ability had to rely most heavily on socio-emotional support. However, a regular flow of new ideas was imperative for group success; even the most encouraging words rang hollow when the group could not make any meaningful progress.

The people with low self-efficacy were more easily distracted. In groups that struggled with the task without a major breakthrough, most members eventually showed signs of fatigue. However, nonverbal clues indicated that those with lower self-efficacy were more likely to lose interest in the task before anyone else; they looked at their watch, looked out the window, yawned, or sighed. The member with the lowest self-efficacy was the first to suggest giving up in five out of the six groups that talked about quitting before completing the third proof.

Preserving one's image. Ned's comment from the dialogue above—"We might be the only group that doesn't [solve the problem]"—revealed that one of the main motivations for achieving success was to avoid embarrassment among one's peers. Members of other groups expressed similar concerns. Consider, for example, the remarks made by people in two other groups:

> JOHN: (to the person running the video, who did not respond) What did everyone else do on this one?
> EDDY: Can't give up. Feel pressure [to work it out].

Ned, John, and Eddy had the three highest self-efficacy scores in the sample. These group members valued group outcomes, probably because they believed that group failure would reflect poorly on them. Based on their self-efficacy scores, they had a high opinion of their abilities. To sustain this image, their group needed to succeed. Ned's, John's, and Eddy's groups worked longer on the third problem than the sample average (fifty-two minutes, forty-two minutes, and thirty-three minutes, respectively; sample mean was thirty minutes for fifteen groups). All three groups completed the problem, although the proof constructed by John's group contained errors.

Perceptions about group performance. Members did not always have an accurate perception about how well their groups performed. After finishing, students were asked to rate how well they thought their group did on the three proofs using three items on a ten-point scale. T-tests indicated that members whose groups completed all three proofs successfully had, on average, higher performance ratings than groups that were not successful on one or more proofs ($t = 3.2$, $p < .01$). Interestingly, however, 22 percent of the students were overly optimistic; they had an average rating of nine or higher on the three items, despite the fact that their groups did not complete one or more proofs correctly.

A critical danger is that students will learn a concept, theory, or procedure from team members that is flawed or based on a misunderstanding. Confidence in one's group can lead to confidence in the concept or technique that was learned within the group. In one group from our study, for example, students developed their own technique to prove one of the mathematical statements. Although creative, it was seriously flawed. Later in the semester, individuals from that group used that same flawed technique again on an exam. For better or for worse, ideas learned within the group context can have a lasting effect.

Problematic Group Processes

Trial-and-error methodology. Students generally did not approach their task using a rational problem-solving model. For example, they frequently tried to solve the problem before they fully understood the problem or its constraints. In some cases, a better understanding of the problem emerged as students considered various approaches. In other cases, students never did fully understand the problem, making a correct solution virtually impossible.

Students typically began their search for solutions using methods with which they were most familiar or comfortable. Although this was not a very efficient approach to solving the problem, it did give students the opportunity to explore when and how each method could be appropriately applied. In a learning environment, this was not a bad result. In other settings, when time is an expensive resource, a more systematic approach to problem solving is needed.

Unfortunately, the group environment may have reinforced an inefficient and often ineffective method of problem solving. Students practiced solving problems using a rather haphazard trial-and-error methodology that sometimes worked. Without feedback suggesting that they were using a flawed approach, they are likely to use the same approach in the future. Thus, not only can groups lead their members astray with respect to ideas or theories, but they also can reinforce bad habits among their members.

Communication breakdown. Students frequently were unable to communicate in writing what they had discussed orally. Discussion on the videotape sometimes indicated that students understood the key issues and how to apply methods. Once they began transferring their ideas to the chalkboard or flipchart paper, however, a clear connection between ideas and writing was lost. This was especially true as groups composed the written argument that served as their final answer. Problems included using improper terminology, leaving out key arguments, not developing their arguments enough to prove the validity of their logic, and not organizing their ideas. Frequently, the students simply were too impatient to take enough time to write their arguments in an organized and precise way. One would think that a group setting would be ideal for ensuring that the statements forming the final argument were accurate and logical. Watchful members could make suggestions or look for errors. In the successful groups, members did participate in this way. Members in other groups were less diligent, either because they did not understand the importance of the final written argument or because they were anxious to finish.

Summary of Results: Better Odds for Success

Despite some of the inherent difficulties, groups can be incredibly effective at solving problems. The key advantage of working in groups, as opposed to individually, is that members have access to more resources that can help them accomplish tasks. After her group figured out how to construct the third proof, Sally noted, “I would never have been able to figure it out for myself.” What did Sally have in a group that she did not have working alone? She had access to more knowledge, of course. She also had more reasons to be successful; Ned reminded her of those reasons. Failure meant failure for three people, not just one. Group members helped each other refocus on the task after becoming distracted. In several groups, someone provided humor to help relieve frustration. Others provided positive reinforcement for good ideas or breakthroughs, thereby motivating members to continue. When working alone, individuals must rely on their own knowledge, generate their own motivation, and draw on their own self-discipline to achieve goals.

Implication for Enhancing Group Performance

The positive outcomes of cooperative learning are impressive but not automatic. Only six of the fifteen groups successfully constructed all three proofs. Although the final product may not be the only measure of success, it does indicate that groups need guidance and feedback from the instructor. One group only spent six minutes on the third proof, twenty-four minutes below the sample mean. This signals possible apathy on the part of group members; evidently there was no one in the group pushing for success. A closer investigation reveals that the group’s average pretest score and self-efficacy rating were well below the sample averages. In other words, they had fewer resources from which to draw compared to their peers. For optimal learning, instructors need to be sensitive to these types of issues.

Groups must be managed effectively. The instructor must play an active role at all stages of group formation and development. The following suggestions, although not exhaustive, are based on the findings from this study.

Assign Groups

Instructors, not students, should decide the membership of each group. If possible, instructors should include high ability and high self-efficacy in every group. This may mean having groups with as many as five or six members to ensure that both ability and self-efficacy are represented. Information about ability can come from tests, grade point averages, grades in previous classes in a related area, and other such factors. A brief student survey can measure self-efficacy (see Riggs and Knight 1994; Gist and Mitchell 1992).

Teach Problem-Solving Skills

The instructor’s role is to create an environment in which students can learn the skills that allow them and their groups to be successful. These skills should include problem-solving methodology. Several models of problem solving exist (for example, Dean 1996; Polya 1973; Whetten and Cameron 2002). The instructor should identify the steps in the problem-solving process, model the process, and give students plenty of opportunities to practice using it. For example, a classic problem-solving model includes defining the problem, generating alternative solutions, selecting an alternative, and implementing and evaluating the solution. In addition to understanding the overall problem-solving process, students can become aware of some common pitfalls that can short-circuit the process, such as defining the problem too narrowly or focusing on familiar solutions instead of exploring other possibilities. Tools for overcoming pitfalls can also be taught, such as brainstorming, using analogies, asking questions, breaking a problem into parts, and so on. The particular model and tools used depends on the type of problem that students are asked to solve.

Provide Immediate Feedback

Clearly, students do not always have accurate perceptions about their knowledge, abilities, or performance. Some students overestimate their abilities, and others underestimate their abilities. This is true for group performance as well. Instructors therefore need to provide feedback about individual and group performance to keep students from spending a lot of time and effort learning erroneous information or misapplying concepts. Feedback helps students develop a deeper level of self-awareness and an appreciation of others; they learn when to trust their abilities and when to rely on the abilities of their peers.

To give feedback, an instructor must find a way to get regular information about individual and group performance. Information can come from individual and group assignments, class discussion, and listening in on small group discussions. We do not recommend assigning a large group project that is due weeks later without any instructor evaluation of individual or group progress. Our findings indicate that groups can make critical errors and yet be quite confident in their decisions. The member who is the most vocal and confident may not be the most talented in the group. Frequent feedback is vital to ensuring that the group work enhances learning rather than impeding it.

Monitor Group Process and Reward Performance

The most important variable predicting group success is ability. Groups that have talented members tend to do well. Onwuegbuzie, Collins, and Elbedour (2003) referred to this as the "Matthew effect." However, group processes must work effectively to ensure that members' skills and expertise are used properly. For example, a talented member who is silent will not improve a group's chances for success. Similarly, a talented member who gives up after experiencing initial failure will be of little benefit to the group on challenging tasks. This is why groups need individuals who are able to facilitate group meetings, keep members focused on the task, and motivate members to put forth effort and persist when faced with obstacles to success. Our research indicated that people with high self-efficacy, whether or not they have the most ability in the group, tend to value group success and encourage others to keep going until the task has been accomplished.

When group processes are not working, an instructor may have to intervene. There are several approaches an instructor can take, depending on the course goals and the nature of the project(s). The most drastic course of action is to break up the group, either sending members to other groups or reassigning all of the groups in the class. This can be frustrating for other groups that have established rapport and are working well together. It also allows problem group members to avoid confronting and developing their deficient group skills. Another approach is to tutor group members about group dynamics and provide feedback about their group skills. It is useful to devote some time for groups to discuss how well members are working together. Members can give each other feedback about strengths and weaknesses.

Another factor that affects group process is the reward system in the class. Both individual and group performance must be rewarded in some way to avoid social loafing and to enhance motivation to achieve group goals. For maximum motivation, individuals must see the connection between their effort, group performance, and individual rewards. Rewards include grades, recognition and positive feedback. Both individuals and groups must be held accountable for their work.

Conclusion

We studied fifteen groups of students as they worked on three challenging tasks. We were impressed at the amount of time and effort that many students were willing to spend without any extra credit; the credit they received for participating was not based on correctness of answers or time spent working the problems. We watched as peers motivated others to keep working despite perceptions of insurmountable obstacles. Members served as tutors for other members, suggesting or critiquing approaches. Students benefited from articulating ideas and receiving feedback from their peers. When members believed that they had correctly accomplished their assignment, many were visibly excited, indicating that their success was rewarding. These are some of the benefits of cooperative learning.

We also witnessed some of the challenges associated with cooperative learning. The most confident person was not always the most skilled; this becomes a problem when the most confident person is not open to others' ideas. Several groups began searching through solutions before fully understanding the problem and its constraints. There was a trial-and-error approach to problem solving that was usually inefficient. Some members were confident in their group's performance, despite the fact that their answers contained flaws. Without immediate feedback, group processes may actually reinforce erroneous thinking or methodology. Despite these problems, the advantages we found far exceeded the disadvantages of group work. It is clearly possible for the instructor to manage the classroom experience in a way that ensures that students will benefit from cooperative learning.

Key words: cooperative learning, groups, self-efficacy

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