

Investigative Labs in Biology

The Importance of Attending to Team Dynamics

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Facilitating team interactions is crucial to investigative labs. We discuss how to minimize problems from the start and how to address problems that typically arise.

The use of investigative labs is quite common these days—and rightfully so. As early as 1969 the Commission on Undergraduate Education in the Biological Sciences claimed that “the best use of the laboratory in undergraduate instruction is to engage the student in the process of active investigation” (Holt et al. 1969, p. 1104). Holt and his colleagues emphasized the importance of investigative labs in “communicating the nature of biology as a branch of thought” (p. 1105), not just as a collection of facts. This approach not only familiarizes students with the scientific method, but also gives them experience with other aspects of the process of science, such as creativity, critical thinking, troubleshooting, collaborative work, and ownership of the experience.

At the College of St. Catherine we began using an investigative ap-

proach in our General Biology labs in the early 1990s (see Norton et al. 1997; Tweeten et al. 2006). In the first semester, we use semester-long open-ended inquiry where the problem and method of inquiry are student directed (although within the theme of reproduction). In the second semester we use several shorter rounds of more bounded inquiry to work on data-analysis skills, followed by an eight-week long research project. We turned to investigative labs because we wanted students to develop an understanding of the process of science, and thus a better understanding of the nature of scientific knowledge—its strengths and its limitations. We also wanted to improve the retention of students in the biology major since evidence suggests that students become more interested and motivated if they are actively involved in the process of doing science (AAAS

1990; Project Kaleidoscope 1991; Tobias 1991). Helping students develop basic research skills in their very first biology courses allows us to incorporate more demanding, developmentally appropriate learning experiences in our sophomore and upper-level courses (Tweeten et al. 2006). We believe this increased curricular vertical integration is critical in preparing students for careers in science.

Our pedagogical goals are being met by the use of investigative labs, but as lab mentors we have found that supervising the science is only half the job. The other half is facilitating interactions among students working together in teams. Few articles on the use of investigative labs address team-dynamic issues, yet attention to team process is a critical factor in successfully using an investigative approach in a large class where

projects must be done in teams. The fact that our research teams must operate over a whole semester adds to the likelihood of team difficulties. We have invested a great deal of time and energy learning to facilitate this process. Important lessons we have learned about team dynamics as our students have done investigative projects in teams:

- Teamwork requires active and explicit management of team process
- There are always team problems
- There are always two sides (at least) to the story
- Problems can be minimized by adhering to the principles of cooperative-learning groups (Johnson, Johnson, and Smith 1991)
- Early intervention in team issues can be critical ("An ounce of prevention is worth a pound of cure")

In this article we provide some tips for success in facilitating teamwork. Working collaboratively is common in science and the functioning of teams has a large impact on both implementation of a research project and student satisfaction with the experience. We divide our strategies into what can be done to minimize problems from the start and how to address the problems that do arise.

Setting up research teams

Difficulties can start from day one if the teams are put together without deliberation. We have found that careful attention at this stage helps minimize subsequent problems. For one, we have learned to stress from the beginning that the lab group is a *team*. Whereas a *group* is a collection of individuals, a *team* is a collection of individuals working together on a task or toward a common goal. The different connotations of the words *group* and *team* may seem subtle, but they are important and we are very careful to refer to the research teams as Team 1 or 2 and not as Group 1 or 2. We talk at the beginning of the project about what a team is and what it means to work in a team. Our explicit

focus on the nature of teams developed after one of the authors, Andrea Olson (whose area is industrial organizational psychology) gave a talk to the biology department entitled "Processes, Challenges, and Strategies for Working in Learning Teams." Based on her work and expertise we have developed a presentation that introduces important team concepts and a team evaluation form (Figure 1) that facilitates learning about how teams work.

Team size has a very big effect on team functioning. Our experience strongly supports the recommendations by Johnson, Johnson, and Smith (1991): Never, ever have teams of five for this kind of project; four is okay, but three is ideal. With two, you run the risk of a singleton if someone drops the course. With five team members, it is very possible to have a successful project with a lot of data collected, and one or two people who did little to nothing—when there is an easy out, some will take it. With three students it is more likely that all three need to participate fully to successfully complete the project, provided the project is complex enough.

We also pay careful attention to how those teams are formed. The literature on cooperative learning suggests that it is generally better to maximize heterogeneity, and that instructor-made teams often contain the best mix of students (Johnson, Johnson, and Smith 1991). We found, however, that when we assigned students to teams (even randomly), it was easy for them to blame instructors for any problems with team dynamics. When we give the students some say in team formation, they take more ownership of issues that arise. We encourage them to form teams based on their interest in an organism or a research question to ensure that the project engages their interest.

There are several other ways that team makeup has an impact on team functioning. Three common issues that we see are the problems of mixing resident students with commuter students, mixing students with different levels of family or job responsibilities, and

the impact of cultural background and temperament on teamwork. Commuter students generally have more scheduling constraints than resident students, who are not always willing to work within those constraints. At times we have let students form teams of just commuter students or just resident students, however, we value the integration of these two groups of students and feel that students need to learn to navigate difficulties. To decrease the probability that scheduling problems will have a big effect on team functioning, we incorporate time for teamwork into lab or class sessions. For instance, we give teams time during the Friday lecture period the week before the research proposal is due.

Designating class time for teamwork also helps to alleviate scheduling issues when team members have varied responsibilities outside of school. The student who is not personally paying for college and is attending full time may have difficulty determining reasonable accommodations for a team member who cannot make a team meeting or time for data collection due to family or job responsibilities. Developing clear expectations among team members from the start works also to minimize difficulties (see below about developing team norms).

We also pay special attention to the dynamics between students from cultures that value and expect verbal participation and questioning versus those from cultures that value demonstrating respect via deference and that do not expect or encourage students to question others in an education setting. Teaching good team process helps to bridge those cultural gaps. Similarly, variations in temperament—extroverted and outspoken versus introverted and quiet—can have an effect on team dynamics. Deferential or introverted students are sometimes seen as lazy and non-participatory, when in fact they may have the better understanding of the project. Helping students learn to listen and give each other the space to participate is an important part of facilitating teams. We model such

behavior in team meetings and set up the expectation that each person both talks in a team meeting and asks for the input and views of others.

Team norms or contracts are useful for the functioning of long-term teams. Having student research teams develop norms at the outset gets students talking about what is acceptable behavior, how they will work together, strategies for communication among team members, and what the consequences will be for not abiding by the norms. At a minimum these can be used to initiate discussion later when problems develop.

Assignments and expectations must be set up to enhance cooperation and minimize competition. According to Johnson, Johnson, and Smith (1991), the basic elements of cooperative learning groups include

- positive interdependence,
- face-to-face promotive interaction,
- individual accountability,
- interpersonal and small group skills, and
- group processing.

When students believe they cannot succeed unless the other members of the team succeed (and vice versa) they are more likely to act cooperatively. In a lab research project, this positive interdependence comes, in part, from limiting team size and having a sufficiently complex project such that it requires the participation of all members. If one person can do the project individually, this decreases the likelihood of cooperation. Such positive interdependence results in "face-to-face promotive interaction," which is defined as "...individuals encouraging and facilitating each other's efforts to achieve, complete tasks, and produce in order to reach the group's goal" (Johnson, Johnson, and Smith 1991, section 3, p. 7). As lab mentors we work to develop a cooperative, not competitive, culture.

Individual accountability and personal responsibility are "key to ensuring that all group members are in fact strengthened by learning co-

operatively" (Johnson, Johnson, and Smith 1991, section 3, p. 8). Most of our assignments are team assignments, but individual accountability must be built into the project. We have students sign each team assignment to indicate that they have read and agree with everything that is being turned in. We also use project quizzes to serve as a mechanism of individual accountability. We administer three quizzes during the project: (1) as they turn in their proposal (on their hypothesis and rationale); (2) during experimentation (on their methods); and (3) as they turn in a first draft of the paper or poster (on whether or not their hypothesis was supported, and which results support and which do not support it). Quizzes are completed individually and are evaluated by considering how well responses match the proposal, paper, or poster. Analysis of quiz scores can reveal potential problems in functioning of the research teams. Harker (1999) suggests another way to assess individual contributions and understanding of the project, which is to randomly select different students from the team to report on their findings and the plans of the team at each meeting with lab mentors. Our use of the team evaluation survey described below is another way that we convey the importance and expectation of individuals' contributions to their teams; students are asked about their own behaviors in addition to the team's performance.

We encourage students to work out their differences, however, as a last resort we offer authorship alternatives when team members have not contributed their share. A team member can be demoted to "second authorship" (or no authorship) on a team assignment and thus receive fewer or no points, but this requires a team meeting with the lab mentor and direct interactions among all team members.

Facilitating research-team functioning

Interpersonal skills and group processing are essential to cooperative learning (Johnson, Johnson, and Smith 1991).

Many students lack the social skills necessary to work well cooperatively and these skills must be taught, just as academic skills are taught. Johnson, Johnson, and Smith (1991) state: "Groups cannot function effectively if students do not have and use the needed leadership, decision-making, trust-building, communication, and conflict-management skills" (section 1, p. 19). Team meetings with lab mentors therefore focus on teamwork skills and issues along with the scientific issues. Encouraging open communication and evaluation of leadership, trust, and conflict management are just as important as trouble-shooting experimental problems.

We have found particular issues typical to each stage of the investigation. One of the first major team assignments is writing a proposal, which generally requires work outside of lab. Students who are not fully participating and team scheduling issues become apparent at this point, and this is when team members start to develop (or slip into) roles that may help or hinder the functioning of the team. Although the others may not be frustrated enough to do anything about it, this is a good time to assess teamwork and encourage discussion. It is important to emphasize that working in teams is often difficult and that we expect students will have team processes they want to improve; this helps to normalize tensions inherent to working in teams. The data-collection stage often runs smoothly, but if it requires time outside of the scheduled lab period (and it often does), issues of equal involvement and responsibility come up. Teams may need help bringing about accountability. This can also be a time when team members redeem themselves for lesser involvement in the earlier work and where the strengths of the less vocal and less assertive members can show through. In our experience, most of the big brouhahas occur during the final stages of data analysis and pulling together the final product (a paper, poster, or oral presentation). The smaller, earlier frustrations about involvement, taking

over, communication, or disrespectful treatment of team members coalesce and become big issues under the stress of producing a product for a grade, especially because this occurs toward the end of the semester. Our goal is to aid the teams in airing difficulties early and to encourage the team to work them out. We use the following strategies to identify issues and bring about open communication and conflict resolution.

The required use of a lab notebook helps us know what is happening and encourages participation by all team

members. Each team has one lab notebook that is kept in the lab. Students must write down everything, including miscellaneous notes about checking on, feeding, or watering organisms. They are asked to document their activities in chronological order, and to date and initial each entry. This often helps to settle questions about how tasks are being shared or divided and is an incentive to those who might otherwise skip organism maintenance or data collection. As lab mentors, we check the lab notebook regularly and ask questions or make remarks about what is contained in the

notebook and what is missing.

To monitor team functioning and to facilitate team communication we also use a team evaluation form (Figure 1). Team evaluations are used, in part, to teach students about collaborative work by introducing them to various behaviors that a team member may demonstrate (e.g., solving problems, coordinating tasks, helping others). This form asks students to think about what they, as individuals, are specifically doing to facilitate the team's work and what they could specifically do to make

FIGURE 1

Lab team performance evaluation.

The purpose of this exercise is to take some time to (1) reflect on what you are doing as a team member, (2) reflect on how your lab team is functioning, and (3) collaborate with your lab partner(s) to develop strategies for your continued work together. Seriously consider your strengths and the strengths of your lab partners in this exercise!

What am I doing as an individual team member?

The nine categories below* are various behaviors individual team members demonstrate. People tend to be more proficient in some areas and less proficient in others. This is normal! Each of these categories is based on skills we learn and practice. Each team experience you have is an opportunity to continue building your skills. Think about what you have been doing in your biology lab team.

Initiating Structure
Workload Distribution/Coordination
Fulfilling Task Responsibilities
Situation Awareness
Problem Solving
Monitoring Performance
Training Team Members/Sharing Information
Helping/Backup Relief
Consideration

What are 2–3 *specific* things you do that contribute to your lab team? Consider the nine categories above as a starting place.

I am contributing to this team by...

What are 2–3 *specific* things you could build upon, change, or do to further contribute to your team?

I think it would be helpful for our team if I...

How are we doing as a team?

What are 2–3 *specific* things your team is doing well? (Consider team processes such as communication, coordination, fulfilling tasks, fulfilling goals, meeting deadlines, monitoring, etc.)

What are 2–3 *specific* things your team could change, build, or improve upon?

I think it would be helpful for our team if we....

COMPLETE THE FOLLOWING ITEMS DURING DISCUSSION WITH YOUR LAB PARTNERS.

As a team, come up with one list of 2–3 *specific* things your team is doing well, things you want to be sure to continue doing the second half of the semester.

We will continue...

As a team, come up with a list of 2–3 *specific* things your team wants to build upon, change, or try during the second half of the semester.

We will...

*This taxonomy is based on Olson, A.M. 2000. *A theory and taxonomy of individual team member performance*. PhD diss., University of Minnesota, Minneapolis. Please direct questions or comments about this taxonomy to andreamolson@stkate.edu.

further contributions. They are also asked to reflect on the effectiveness of the team as a whole, and to decide together what they will continue doing and what they will change. The form encourages students to think about ways of distributing work according to the strengths of team members. Team evaluations also help lab mentors identify team process issues. Students are often reluctant to confront one another but we have found they will describe, in the written evaluations, specific problems or issues that they would refrain from bringing up in front of their team members. We use these evaluations to jump-start discussions within the team and help team members sort out conflicts at an earlier stage than they might choose without our facilitation.

Weekly meetings with lab mentors that explicitly focus on both teamwork and the science are essential. We facilitate processing how well the team is achieving its goals and maintaining effective working relationships. We have to fight our own urge to avoid conflict—confrontation is essential and conflict must be addressed explicitly because it doesn't just go away. Because students need to learn to communicate openly with each other in respectful ways, we ask teams to periodically answer questions such as "What did each team member do that was helpful to the team?" and "What is something that each team member can do to make the team function better?" We have also found that it is important that we, as facilitators, don't jump to conclusions about particular students, as we have found, over and over, that behind the apparent lack of involvement of one team member is the controlling team member who doesn't allow involvement by not listening or rejecting what is offered. It is also important to discuss the value of the different contributions that team members make, in order for students to think about variations in how work can be done in a team, and to look at their own strengths and weaknesses. Not every task needs to be divided equally

among all team members. The key is to help them be intentional about dividing work, using each others' strengths, and managing conflict.

Conclusion

As we have gotten better at facilitating effective teamwork, we have gotten better science from student research teams. We have had our share of team issues over the years as students have designed and conducted semester-long research projects, and have seen friendships torn apart by the difficulties of working with a small number of others on a demanding task. Despite the fact that our students typically have experienced group work in previous schooling or coursework, they often come to us lacking the skills needed for productive teamwork over a semester. We have learned that the skills of collaborative work must be taught and that unless we do so intentionally team problems can and do derail the academic goals of investigative labs.

Implementing these strategies has decreased the number of end-of-the-semester blow-ups. Our focus as lab mentors has been to help students learn how to work in teams and to figure out what the teamwork issues are so they can propose and implement changes. A college-wide goal at the College of St. Catherine is that students develop skills in collaboration—"the ability to work well with others, especially in joint intellectual effort." (College of St. Catherine 2005). By intentionally addressing team dynamics and teaching, and modeling and facilitating teamwork skills, we help our students hone lifelong skills for effective collaboration. ■

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