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LESSONS FOR SUCCESS: ACTIVE AND COOPERATIVE LEARNING IN SCIENCE CLASSROOMS

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Lessons for Success: Active and Cooperative Learning in Science Classrooms

Synopsis:

This paper examines the successes and challenges for both faculty and students associated with the implementation of cooperative learning in medium to large science classroom settings.

Abstract

In 2011, the University of the Incarnate Word (UIW) was awarded an HSI-STEM and Articulation grant (Department of Education, Title III, Part F) for strengthening programs and increasing graduation of students in science, technology, engineering and mathematics. UIW is a liberal arts university in San Antonio, Texas with a high number of Hispanic and first generation students, and rapidly growing programs in STEM. A major initiative in this grant is the implementation of high impact teaching practices, including the use of cooperative learning. Cooperative learning has been integrated into a variety of courses across STEM disciplines, including biology, chemistry, engineering, and physics. The researchers who are faculty in biology and chemistry participated in a five day workshop on how to use cooperative learning practices in the college classroom. The workshop was based on methods developed by David W. Johnson and Robert T. Johnson (Johnson et al, 2006). This paper examines the successes and challenges for both faculty and students associated with the implementation of cooperative learning in medium to large science classroom settings.

Lessons for Success: Active and Cooperative Learning in Science Classrooms

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The University of the Incarnate Word (UIW) in San Antonio, Texas, is a liberal arts university. The majority of UIW students are Hispanic, first generation or both. The institution has strong roots in health care education, and the STEM disciplines comprise a large percentage of the student body. In Fall 2014, 14% of the incoming Freshmen declared life science majors. As an institution, UIW is committed to student engagement as a means to increase retention and four-year graduation rates. The administration supports a culture of faculty development to support faculty in providing learner-centered education in all disciplines.

Beginning in 2014, faculty in the Biology and Chemistry departments at UIW implemented cooperative learning in multiple classes as a result of participating in a faculty development workshops funded through the UIW HSI-STEM grant (Department of Education, Title III, Part F). The purpose of this grant is to strengthen STEM programs and to increase graduation rates of STEM majors. The researchers who are faculty in biology and chemistry participated in a five day workshop to learn how to use formal cooperative learning groups in the college classroom. The workshop was based on methods developed by David W. Johnson and Robert T. Johnson. (Johnson et al, 2006) This paper examines the successes and challenges for both faculty and students associated with implementing cooperative learning in medium to large classroom settings.

Active Learning in College STEM Courses

There is wide support in the literature for using some form of active learning in science classrooms. The National Science Foundation (NSF), the National Research Council (NRC) and the American

Association for the Advancement of Science (AAAS) are among the major scientific societies advocating a change in teaching science from traditional lecture to some form of active learning (2006). Active learning is defined as any type of instruction that engages students in the learning process during class time (Prince, 2004). Active learning can occur through individual activities, share pairs, collaborative learning in groups or cooperative learning groups. Collaborative learning can be defined as learning activities that take place in group (Faust & Paulson, 1998). Cooperative learning is a type of collaborative learning that includes the additional elements of group interdependence, individual accountability, and group processing as part of achieving a common learning goal (Johnson, et al. 1998).

In a recent study, Freeman, et al. (2014) conducted a meta-analysis of 225 studies that examined test scores and failure rates of STEM students enrolled in courses using some form of active learning compared to courses using traditional lecture formats. The forms of active learning included diverse approaches and included both individual and group activities. Their findings indicated that students enrolled in active learning courses improved their test scores by 6% and that students in traditional lecture courses were 1.5 times more likely to fail the course. A review of different types of active learning found that all forms of active learning improved student achievement, attitudes, self-esteem, quality of interpersonal interactions, and retention in academic programs (Prince, 2004). Meta-analysis of cooperative learning by Johnson and Johnson (1993) compared cooperative, individualistic and competitive teaching methods. Their results demonstrated that that cooperative learning models resulted in greater increases in individual learning and retention measures, fostered positive attitudes toward the subject, and encouraged development of better social skills.

Barriers to Implementing Active Learning in Science Classrooms

The evidence from the literature clearly supports the use of active learning in science classrooms, so why do faculty cling to traditional lecture dominated classrooms? Faust and Paulson (1998) identify three reasons for this: 1) faculty perceive that active learning prevents them from covering as much material if time is spent on active learning; 2) incorporating active learning takes too much preparation time; and 3) active learning is intimidating to both faculty and students. Additional reasons identified by Herreid (2007) are that faculty are more comfortable with lecture, have not heard of cooperative learning techniques or dismiss them, do not want to invest the time to revise teaching methods, and don't believe they can be used in large classes. Targeted professional development opportunities are a remedy to the barriers faced by faculty that lack the pedagogical background and confidence to implement change in their classrooms (Wright and Sunal, 2004)

Implementation of Cooperative Learning in Biology and Chemistry Courses

At the beginning of the 2014 academic year, the researchers participated in a faculty development workshop based on the work of David and Roger Johnson (2006). The workshop consisted of five three-hour sessions held once a week. Two of the researchers had previously attended a week-long workshop to learn how to train other faculty in cooperative learning techniques and one served as the leader of the sessions. As a result of the workshop, the researchers committed to incorporating a

variety of active learning activities with formal cooperative groups and cooperative base groups. Formal cooperative groups are defined by the Johnsons (Johnson, D. W., Johnson, R. T., & Smith, 1998) as students working together for a period of time to complete a task or assignment. This differs from informal groups which are temporary and formed for a brief period of time. Share pairs are an example of an informal group. Formal groups necessitate positive interdependence of group members, individual accountability, group self-monitoring, group assessment, and acquisition of social skills. Cooperative base groups are longer term groups whose members support each other throughout the semester in accomplishing the course objectives. The details of using these groups can be found in Johnson, D. W., Johnson, R. T., & Holubec (2013).

All of the researchers used some form of active learning and cooperative groups in their classrooms and laboratory classes prior to the collaborative workshop. One of the barriers to implementing cooperative learning groups that all of us struggled with was classes with large numbers of students. As enrollment has grown in the sciences at UIW, we have increasing numbers of classes with 50 or more students taught in a large auditorium. The researchers committed to implementing cooperative learning groups in both large and small class sections. At the conclusion of the semester, faculty completed surveys to document the frequency that cooperative learning groups were used and the types of active learning activities that were incorporated. The researchers also wrote reflections on their methods, successes, and challenges of using cooperative groups.

In all classes where the researchers used cooperative learning it was used every class period at least once. The researchers with the most experience and training used cooperative groups two or more times every class period. Formal cooperative groups were used all of the time in seven out of ten courses taught and most of the time in three. Base groups were used in half of the courses. Fostering group interdependence, using some form of group assessment, and having a mechanism for self-monitoring were aspects of cooperative learning that were used less often (Table 1).

The researchers also used a variety of active learning techniques. Problem solving, share pairs, and critical thinking questions were used on average at least once in most class periods across all courses. Problem solving was the most widely used. Figure analysis was also used extensively. Case studies and puzzles were used infrequently in most of the courses. Jigsaw activities were used in half of the courses at least once. Role play was used in two courses and simulations in one upper division course (Table 2).

Instructor Reflections on Implementation of Cooperative Learning

Brian's Experience

I was initially exposed to collaborative learning teaching methods in a three-day workshop that I attended in 2004. From that experience I began to informally incorporate cooperative learning techniques in my chemistry lecture and laboratory sections at the University of the Incarnate Word. Since that time, I attended an additional training session in 2010 and a weeklong

leadership training conference in 2012. As a result of that experience I have had the opportunity to train other over 30 faculty in Cooperative Learning Workshops at both UIW and St. Phillips College in San Antonio. I now incorporate these activities in all of my chemistry lecture and laboratory sections and can speak to the successes and challenges of using collaborative learning in the college classroom.

In my Chemical Principles lecture courses I use formal cooperative learning groups. I find that the primary successes of using cooperative learning techniques involve social interactions, group teaching and evaluation of material, and individual accountability between members of each group. I typically start my classes with three topics to cover. I have my students greet each other and ask to briefly review material from the previous lecture. I feel that this social interaction is important and provides a connection for subsequent collaborative interaction. The first new of the three topics is presented and then students are asked to work cooperatively on a problem based on the new material. This collaboration is often in the form of a modified "pair-share" procedure. Students in groups of two or three are each asked to each read the problem and then one of the group member is assigned to present and explain to the other how the problem would be solved without writing anything down. The students listening are encouraged to provide feedback and assistance in the analysis and then the problem is attempted. If students are absent for a particular lecture the other students will move to complete a group. After independent completion of the problem the student are asked to compare their answers with other group members and finally with other groups. This process is continued for each of the three topics presented with a total of 3-6 problems worked for each lecture. I find that using these methods give students multiple methods of learning the material and a comfortable outlet to discuss problems. It also provides instant feedback when students have the ability to compare answers.

I extend this process in my laboratory lectures in the utilization of cooperative base groups. In this class, several laboratories sections meet for a common pre-lab lecture. Groups are assigned prior to the first day of class in groups of three with each member from a different lab class. Over 60 students are in this class and each three-person group creates a group folder where they store material as well as monitor their individual and group activity in a data summary chart. Each member of the group is assigned different parts of the labs to be explained to other group members. In all of these activities I believe that an excellent benefit of cooperative learning method is that provides additional oversight of every student's work.

Along with the benefits of using cooperative learning techniques, there are several challenges of using these methods in the classroom. These challenges include finding time to prepare a collaborative lesson prior to the class, providing proper instruction of activities, and "letting go" of control. I have gradually incorporated more and more cooperative learning techniques in my classes. Most of my pitfalls involve not properly preparing for the problems students may encounter and not giving enough of a description of the cooperative learning process prior to presenting a problem in class. In addition, I initially found it very challenging to "let go" and allow students the time necessary to work through their misconceptions and understand the

material. In all of this I am still learning how to fully incorporate cooperative learning in my teaching. I have evolved my teaching style from rarely using group work to incorporating cooperative learning in every class. I see the benefits in my student's academic abilities, their interactions with one another, and their test results.

Sara's Experience

I began trying to integrate active learning into my courses about 10 years ago, but was only marginally successful at first. After attending workshops with Drs. Roger and David Johnson on cooperative learning in 2012 and again in 2013, I began specifically using their strategies in planning lessons. My courses have been restructured over the past three years to include more and more cooperative learning, and I have had much more success. I began with informal cooperative activities in a large Anatomy and Physiology 1 lecture course of 73 students. Lecture was broken up into 15-20 minute segments, interspersed by informal cooperative lessons, often involving worksheets, short group quiz games, or partnered discussions. Group sizes were typically two or three, as we were limited by the fixed furniture, and students were asked to find partners or turn to neighbors. While students worked, I circulated between groups and monitored student discussions. I found that most students were far more willing to ask questions or express ideas when I visited their small groups than when we were in lecture format. I found that my students were extremely responsive to this format, even in the large lecture. Multiple students commented in my teaching evaluations that the activities made a large class feel personal and intimate. Not only did the students seem more comfortable with me and with the material, but performance overall went up when I began using cooperative activities in class. My class average shifted up, but even more exciting was that I had fewer students earning Fs and Ds, and more students earning Bs and As. With this encouragement, I moved to the next level of cooperative learning and began incorporating formal group activities and finally, base groups.

My current classes typically involve segments of lectures (approximately 10 minutes at a time) interspersed with both formal and informal cooperative activities that can take 5-20 minutes each (depending on complexity). Three or even four cooperative activities can be done in an hour and 15 minute class period. I usually start with an informal warm-up exercise to define new vocabulary, briefly review material from the previous class, or discuss overarching concepts from the chapter.

Alternately, I may start with a base group meeting as a warm up and ask students to briefly evaluate their progress before proceeding with a short exercise. I sometimes keep base groups together for the entire period and work together on formal cooperative lessons, but more often I shuffle partners and assign students to temporary formal groups of three to four, and the students stick with those partners the rest of the period. With formal groups, I usually assign roles (although not always) and give very specific goals in the form of questions over material from the chapter that need to be answered as a group, or an interrupted case study.

I occasionally use a jigsaw method to cover longer topics where students are assigned to a group, then to a topic, and then they break out to create a topic-specific mini-lesson before returning to their main group to teach their topic to their group. I was initially terrified of using jigsaws, as I feared the students would not understand what I was asking them to do, and that the results would be chaos. However, I've implemented them at least three times this semester in my Animal Behavior class and students were surprisingly receptive. After the first one, they grasped the concept and subsequent jig saws were easy. One student even reported back the moment of realization that she learned her assigned jigsaw material far better than other chapter topics for the exam, and understood why we use that method in class.

For formal group activities, I always assign partners, usually by using a deck of playing cards and having students locate group members by number. The assigned groups have allowed several benefits. The first is that students must work with different partners and therefore, meet new people constantly. By the time the semester ends, each student has worked with nearly everyone in the class at least once, made several new friends (even the very shy students), and learned to work much more effectively in a group setting on the fly (and with no complaints). Formal group assignments have also allowed me to split up unproductive or easily distracted students, or those with negative attitudes (who often seem to gravitate together if allowed to choose partners.) The performance of struggling students usually goes up if I separate them from a negative or easily distracted friend. A third benefit, and one that was quite unexpected, was that *assigning* groups seems to help students who have social anxiety over group work. For example, when told to pick their own partners, I've had several extremely reserved students who simply could not seem to initiate conversation with strangers and would remain sitting alone, refusing to find a partner. However, when specifically *assigned* to a group, they found their partners quickly and worked as asked. The formal group structure seems to work very well for these types of students.

I structure my formal cooperative activities very carefully to create the positive interdependence and individual accountability as described by the Johnsons. However, my struggle with formal groups has been in remembering to include time for group processing. I tend to focus lessons on answering questions about chapter material or building a table of information that creates a study guide for the group members. I only remember to build in group processing when I begin having "problem students" who either don't do their share of the work, or carry a negative attitude into a group interaction. Group processing gives group members an outlet to politely "vent" and allows them some necessary introspection for those who aren't fully participating. When asked the question "what could we have done better?" most students answer honestly, even when it means admitting fault. I have an easier time including group processing with base groups when students do a weekly self-inventory to see how well they are keeping up with assignments and expectations.

Another difficulty for me is in fostering "face-to-face promotive interactions," particularly in rooms with fixed furniture that can't be moved to allow students to face one another. Most

recently in a large lecture room, I positioned groups with partners in two different rows so that the front row could turn to those behind them and this worked well. I also incorporate a few social skills lessons early in the semester to ensure that students understand what I expect their group interactions to look like. I find that college students need reminders to put away their electronic devices, make eye contact with their group members, listen politely, and contribute to the conversation.

Overall, the majority of students have been very agreeable to using cooperative learning techniques in the classroom. Giving very specific instructions helps, and I must project a friendly confidence at all times to keep it moving smoothly. Circulating between groups to answer questions and monitor work is critically important, as unsupervised groups often become distracted from the task. Having a teaching assistant in class is also a huge help, as it puts another person on the floor to circulate, especially in a large class where it is hard to get to all groups during each cooperative lesson. Having base groups is a helpful way to learn student names more quickly and also a good way to have students turn in and receive back work.

As I mentioned earlier, class performance overall has gone up, even as I've integrated more challenging material. More students are earning As and Bs in my classes, and fewer Cs and Ds. I have found that I can give more rigorous exams and students still perform better than ever. I rarely have a student earn an F if they are attending class every day and participating fully. Unfortunately, I still have a small population in each class who struggle, but they are almost exclusively students with serious attendance issues and time management problems. I think that the most powerful impact of a truly cooperative classroom is on the marginal students who might otherwise lose motivation and only attend part time. With the right encouragement, these students attend class more often, participate more fully, and feel more positive about their class experience. Cooperative learning gives them a sense of responsibility and inclusion that draws them back to class. The students who would typically earn Cs or Ds often become motivated enough to start earning Bs and even As.

Bonnie's Experience

I have used active learning and collaborative groups in my teaching for the last 20 years, mostly in combined lecture and lab courses and laboratory courses. It has work well in these types of classrooms where the room contains tables for four students and the class period lasts for 2.5 hours. With that amount of time, most faculty would not lecture the whole time, and there is plenty of time to integrate active learning experiences. However, it seems that after several weeks, students fall into the same roles and are not as enthusiastic about group activities. It is also harder to translate some of these activities into lecture only courses, especially when faced with 70 students in the room.

I began using cooperative base groups in two of my classes. At first the students were reluctant to be part of a formal group, however, they quickly embraced the idea. If I forgot to bring the group folders, they asked where their folders were. The base group folders were an efficient

method of having the students record group attendance and turn in group activities for participation grades. In my large Anatomy and Physiology class, I was able to assess student misconceptions and areas of confusion as they worked on problems and figure questions. This was not possible before. When students were unable to come to a satisfactory conclusion in their groups, they would ask questions, something that they rarely did in previous semesters. Over the course of the semester, students began to feel free to interrupt explanations and ask for clarification. There was also a continuation of the discussion immediately after class. In general, it appears that when students cooperate with each other and with the instructor, they feel more comfortable seeking clarification and verbalizing what is unclear or confusing.

There have been fewer students with failing grades, fewer have withdrawn and the class average is higher than in the past. I have no evidence to support this, but it seems to me that if the students can see that you are trying to help them learn and that you want them to succeed, they do better. Part of this could be that many of the activities I use in class show them how to learn and review the material outside of class. Even in an upper division class that has always been discussion based and used some form of collaborative groups, adding cooperative base groups improved the quality of discussions and prompted the students to do the reading and be prepared for class.

For me the hardest part of implementing cooperative learning was the amount of planning it takes to use formal and base groups. Even when you have a number of learner-centered activities that are already developed, integrating these into formal group structure requires additional preparation. It is not easy to determine the timing of the activity, the additional time it takes to monitor a large number of groups, and unexpected glitches. I often was only able to accomplish one activity because it took much longer than I expected. It was also difficult to use a variety of groups and as the semester progressed, I relied too much on just using the base groups to save time and cut down on confusion. However, what I learned from my small class was that when I use base groups every class period in conjunction with formal cooperative groups and carefully planned each class, it was a great experience for me and for the students. In the future, I intend to spend more time planning and recording successes and failures in order to improve the learning experience.

Discussion

Although all of us were aware of the benefits of active learning, and have been incorporating active learning in our classrooms for a number of years, we were not entirely satisfied with the implementation of active learning in our classrooms. As the result of our participation in several faculty development activities focused on cooperative learning, we believe that we now have a mechanism that allows for purposeful implementation of active learning. Just as informal groups last for a short period of time and are ad hoc in nature, so is the learning experience for the student. Although this is better than not using any form of active learning, formal cooperative groups and base groups impose a structure for active learning to take place in a framework that fosters academic progress and social support. It also requires faculty to think deeply about the

learning process, the learning objectives, and assessment of the learning taking place in cooperative groups.

An important factor in our own implementation of these techniques was the mutual support and encouragement we received from each other. Just as students benefit from positive group interactions, so do faculty, especially when trying new and challenging pedagogies in class. As mentioned earlier, restructuring courses to try new techniques can be daunting and time consuming. Having our own faculty "base group" was helpful both as a source of moral support and as an intellectual resource.

We all see a change in how students interact with each other and with faculty. The students are more successful when measured by course grades and failure rates. This is consistent with what has been documented in the literature. We also see areas where we need to improve. As a group, we are the weakest in the areas of group assessment, fostering social skills, and self-monitoring of groups. Our hope is that as we continue to use cooperative learning and to work with each other to improve implementation in our individual classrooms, we will be able to come closer to full implementation of all aspects of cooperative learning groups. In addition, we plan to examine success and difficulties with this process from the student perspective.

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Table 1.

Cooperative Learning Activities in Science Courses

How often do you use elements of cooperative learning in your classroom? (1=not used, 2=some of the time, 3=most of the time, 4=all of the time)	More than 35 students					Less than 30 Students					Average
	CHEM1203 Didactic Lab Section	BIOL 2321 Anatomy & Physiology I		BIOL2322 Anatomy & Physiology II		CHEM1301 Chemical Principles I	CHEM1302 Chemical Principles II	BIOL4499 Medical Humanities	BIOL4430 Animal Behavior	BIOL4320 Neuro-biology	
Formal cooperative groups	4	3	4	4	4	3	3	4	4	4	3.70
Base Groups; folders, name tags	4	1	1	4	4	1	1	4	1	4	2.50
Group learning activities	4	3	4	4	4	4	4	4	4	4	3.90
Use a variety of groups	2	3	2	4	2	2	2	4	4	4	2.90
Foster group interdependence	2	2	2	4	2	2	2	4	3	3	2.60
Facilitate acquisition of group skills	2	2	2	3	2	2	2	4	2	3	2.40
Use some form of group assessment	3	2	2	4	2	1	1	1	3	4	2.30
Have a mechanism for groups to self monitor	3	1	2	3	2	1	1	1	2	3	1.90
Average	3.00	2.13	2.38	3.75	2.75	2.00	2.00	3.25	2.88	3.63	2.78

Table 2.

Frequency of Active Learning Activities

Active Learning Activities 1= not used, 2= at least once some class period, 3= at least once most class periods, 4=at least once all class periods	More than 35 students					Less than 30 students					
	CHEM1203 Didactic Lab Section	BIOL 2321 Anatomy & Physiology I		BIOL2322 Anatomy & Physiology II		CHEM1301 Chemical Principles I	CHEM1302 Chemical Principles II	BIOL4499 Medical Humanities	BIOL4430 Animal Behavior	BIOL4320 Neuro-biology	Average
Share pairs	4	3	2	3	2	4	4	4	3	3	3.20
Problem solving	4	4	2	4	2	4	4	4	4	4	3.60
Critical thinking question	2	3	3	3	3	3	3	4	4	3	3.10
Figure analysis	3	3	3	3	3	3	3	1	2	3	2.70
simulations	1	1	1	1	1	1	1	1	1	2	1.10
Puzzles and games	1	2	2	2	2	2	2	1	2	2	1.80
Role play	3	1	1	1	1	1	1	2	1	2	1.40
Case studies	3	2	1	2	2	2	2	2	2	2	2.00
Jigsaw activities	2	1	2	1	2	1	1	3	2	1	1.60