Experimental evaluation of a difficult to assess learning goal: effective communication and productive collaboration towards a common goal

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Overview

An important aspect of many active learning strategies involves students working in pairs or in small groups to solve problems, answer specific questions, or complete some sort of assignment directed towards advancing student learning gains along one or more axes. As instructors, we recognize the value of peer instruction but we often ask our students to engage in productive and collaboration interactions without providing students tools that enable productive and collaboration interactions. Moreover, we often create scenarios in which the burden of small group work rests on the diligence of a few students and other students are allowed to "parasitize" their peers, a scenario that can result in students practicing strategies that erode rather than promote effective communication and productive cooperative.

I regularly use small group work as a means for student-centered learning activities and I know from observational data that the quantity and quality of interactions and the ultimate product of student work varies among groups. In some groups, one person may become a surrogate instructor that provides answers other students, and sometimes the answers are good and sometimes poor. In some groups, certain students may opt out or practice copying the answers of their peers. Some groups may function at very high levels but remain focused on getting the correct answer—if there is one—rather than fleshing out the conceptual foundation of a topic or collaborating to find a novel solution. If students are asked to work in groups and the result is they practice unproductive and individualistic behaviors, the end result is worse than if students were asked to work individually because the activity reinforces behaviors that act against developing effective communication and collaboration skills.

This is an important issue because there is clear consensus that one of the core competencies for undergraduate STEM education is being able to communicate effectively and work productively with people of varying abilities and perspectives. Most challenges in today's world absolutely require that people work together, leveraging individual talents, and generating products and solutions that would be impossible by single individuals working alone. We need to create situations in our classrooms where students can practice effective communication, productive interaction, and cooperation towards a common goal. This is not easy to do, especially in large classes. This proposal is designed to investigate the effectiveness of one type of active learning designed to address these important learning goals.

Background

The work described in this proposal is inspired by my investigations of how students interact in the classroom and by published work of a number of educational researchers. Pazos et al. (2010) and others have focused on describing and assessing multiple dimensions of group learning, and developed a tool for quantifying the behavior of students along two orthogonal axes: group interaction style (whether students are individual-oriented or collaborative) and the problem-solving approach (simple or elaborated instruction). Springer et al. (1999) investigated different performance measures of group work, and emphasized the importance of providing the students opportunities to engage in authentic collaborative group work and accurately measuring and valuing collaboration as opposed to individual-based competitive reward systems. Additionally, Springer et al. revealed that collaborative group work yields significant and positive effect sizes along several important axes of student cognitive development. Damon and Phelps, Damon, Webb and others showed peer collaborative instruction promotes equitable and mutualistic learning environments (e.g. Damon 1984). These and other papers have shaped how I think about small group peer cooperation as a consistent mode of active learning in the context of my large courses that emphasize science process skills aligned with the Vision and Change learning goals (http://www.visionandchange.org/).

Study design

The proposed research is centered on an important learning goal for STEM majors identified by the Vision and Change document: communicate and collaborate with other disciplines. While this is an important overall goal, we have re-interpreted this core competency. Instead of other disciplines, we assume that it is first necessary for students to be able to effectively communicate and collaborate with people of varying knowledge and points of view towards common goals. Unlike most other learning goals articulated by the Vision and Change document (e.g. ability to use the process of science, ability to use scientific reasoning, ability to use modeling and simulation), this learning goal poses considerable challenges for assessment and for designing curriculum to achieve this goal.

The proposed research will happen in an entry-level STEM course called Introduction to Quantitative Thinking for Biologists (EBIO 1010). The course was developed by Brett Melbourne and Andrew Martin and is designed to achieve many of the core competency learning goals described in Vision and Change and NRC: use quantitative thinking, use simulation and modeling, address cross-cutting concepts (e.g. cause and effect, issues of scale, and scope of inference). We target this course because we are developing a curriculum for the major that emphasizes student interactions and collaboration and it is important that we introduce students to behavioral practices that enhance interactions and learning from peer instruction—beyond what is possible using clicker questions—early in their career as students of biology in the 21st century.

Overview of the experiment

The research will involve an experiment in one large class: an introductory quantitative biology course (EBIO 1010). The design has two treatments: a control and an experimental treatment. The instructor (me) will offer two sections of the course, back-to-back on the same days (approximately 80-100 students in each section). Both courses will use the same active learning curricula that includes an emphasis on student preparation prior to class coupled with activities that have students working in small groups in class to solve specific problems as practice for quantitative thinking, effective communication, and collaboration.

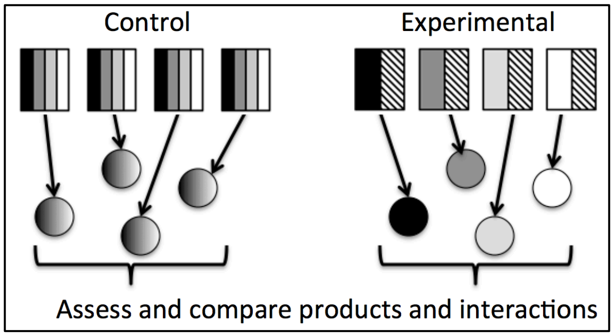

Figure 1. An illustration of the experimental design. On the left is the control in which each student is provided with the same information (in this case four different "bits" of information shown with shaded boxes) so that all individuals have the same information and there is maximum redundancy. In the experimental treatment, each student is provide with only one "bit" of information but the information provided is more in depth and there is more specific practice. In addition, the students are provided with some effective interactive strategies (diagonal shade boxes). Ideally the amount of information to each student is approximately the same for both treatments (indicated by the area of each rectangle). The products and interactions for all students will be assessed and compared.

A model of the experiment is shown in figure 1. Briefly, in the control section, we will implement the developed curriculum in which each student is provided with the same information and students pursue solutions to problems in class (solid rectangles in figure 1). In this sense, there is content and skills redundancy in the group. Importantly, students in the control section are NOT provided with any strategies of effective communication and productive interaction. They are left to develop these "on their own" which is typical of many courses that require students to work in small groups. Even in courses that assign students particular roles within a group, there is still asymmetry of student motivation and role because there is no penalty for not preparing fully for the classroom small group activity.

In the experimental section, each student is provided with only a specific part of the content and process skills required to solve the problem; thus, each student has insufficient information for solving the problem and there is no (or limited) redundancy across students. Instead, each student in a group has valuable information that has to be shared with the group for developing a complete solution. Another important difference from the control is that each student is also provided with a set of interaction strategies shown to improve communication and foster productive collaboration. Finally, an additional difference between the two treatments is that group membership will be assigned in the experimental treatment and will be up to the students in the control treatment. Moreover, in the experimental treatment group membership will vary over time and all groups will be assembled randomly. Group membership will be recorded in both treatments.

The experiment depends on modifying the developed curriculum that will be used in the control section into puzzle lessons. In puzzle lessons, students in a small group are provided with a different set of information and skills and they have to work together to solve the problem. A key aspect of this model is that *ALL* students have to be accountable: when one or two students in a group of four fail to prepare, the whole group suffers because the grades are based on completeness and accuracy of the problem solution. Thus, there is an important component of peer "pressure" for productive engagement and participation, similar to the expectations in the "real world" of STEM.

Students in both sections will take a pre- and post-assessment for estimating learning gains and student interactions in small groups will be recorded using an observation protocol. Each time students engage in a puzzle lesson (in the experimental treatment) or the non-puzzle activity (in the control), interactions will be recorded using the observation protocol and the products graded for both treatments. The analysis will focus on the difference in mean interaction scores and products between the two groups with time as a covariate.

Observation protocol

We have developed an observation protocol that quantifies student interactions. The protocol involves embedding student observers in the class so that they record the number, direction, and type of student interactions. The observer records five behaviors: the number of questions asked by an individual (Qu), the number of responses to questions provided by a student (Re), the number of unsolicited gains of information (e.g. copying someone else's work)(Ga), the number of times an individual is used as a source of unsolicited information (e.g. the number of times a student's work is copied)(So), and the number of "intense" bidirectional interactions (Bi). The first four metrics enable calculation of a composite individual source-sink score. A source is an individual that routinely provides information either by answering questions or as a source for copying by another student. A sink is an individual that asks more questions than answers questions and copies work of other individuals. Although questions can promote effective communication and productive interactions, our observations suggest that most questions are not pedagogical in nature but are asked to obtain specific information. An overall interaction score is calculated based on all metrics.

Our experience with the observational protocol indicates that a trained observer can collect reliable data on a maximum of 7-8 students comprising 2-3 groups (depending on dynamics) in an open environment at a single round table (i.e. GOLD A120). Table 1 shows data from one table for one class session that involves an approximately 25 minute group activity. The summary statistics (number of interactions, sink, source, score, exclusivity) estimate the characteristics of each individual's participation in interactions within groups. Number is the sum of the observed interactions of an individual, sink is a measure of the number of Qu and Ga behaviors relative to the average of these behaviors, source is the number of Re and So behavior relative to the average, score is an overall composite measure of the interaction of an individual (higher numbers are more interactive), and exclusivity is a measure of the number of times an individual interacts within the core group. Group score (G_score) is the product of the average exclusivity for a group and the average individual score.

Perusal of Table 1 reveals there is tremendous variation among students in their participation in groups. The greatest contrast is between TW and KM. TW were involved in 8 distinct "intense" back and forth interactions with JG (coded as Bidirectional) and these 8 interactions resulted in a high overall interaction scores (8.3). By contrast, JK largely copied the work of others (Ga) or asked questions (Qu), never engaged in any pairwise bidirectional interactions, was a source of information only once (So), and was never asked a question: JK's overall score was dominated by her sink score (she is a measurable drain on the her group's productivity).

Table 1. Interaction data from a single observation episode during an active learning activity in EBIO 1010. The data are from 3 groups at a single table (see figure 1 below)

Student	Qu	Re	Ga	So	Bi	N	Sink	Source	Score	Exclusivity	Group	G_score
CF	2	0	3	3	0	8	8.5	8	-0.1	0.75	1	0.05
JK	2	0	3	0	1	6	8.5	0	**-0.7**	1	1	
NS	1	1	0	0	1	3	0.7	0.7	1	0.6	1	
TW	1	3	0	0	8	12	0.7	2	**8.3**	0.78	2	5.7
JG	1	3	1	0	8	13	1.5	2	8.1	0.6	2	
AP	2	1	1	1	3	8	2.1	1.6	2.9	1	3	4.0
SS	2	3	1	1	5	12	2.1	2.9	5.1	1	3	
KM	1	1	1	4	2	9	1.5	14.9	3.9	1	3	
Average	1.5	1.5	1.3	1.1	3.5	8.9	3.2	4	3.6	0.8		3.2
Variance	0.3	1.7	1.4	2.4	10	11.6	11	25.2	12	0.03		8.3

Interaction data can also be summarized as a network. Networks are useful description of interactions among students during a lesson (Figure 1, left) and various metrics of network structure can be used to describe the composite behavior of students, including connectedness, distribution distance to other students, whether students are "nomadic" or "sedentary" with respect to group membership, and whether there are cliques. In addition, the collection of interaction data enables detailed description of the learning community within a classroom (Figure 1, right) that often yields insights into the effects of instructional approach not readily apparent from standard metrics of student performance (e.g. GPA).

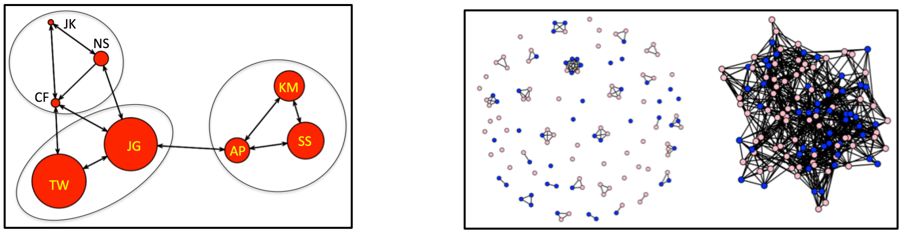

Figure 1. *Left*. The network of interactions for the individuals in Table 1. Each circle is a student and the arrows between students represent interactions. Size of circles is proportional to each student's calculated interaction score (see Table 1). There were three groups and some interactions between groups mediated by a few individuals. *Right*. The overall student interaction network in a single course (EBIO 3080) based on repeated observations of students over the course of a semester. The large network on the left is a constellation of small group interactions based on a single day of observations. The network on the right is based on the cumulative observed student interactions based on 18 single day observations.

Interaction training

An important aspect of the experiment is that students in the experimental section (using the puzzle curriculum) will be specifically trained and allowed to practice behavioral strategies that foster effective communication and productive collaboration. Students will practice listening with purpose and intention, re-iteration of information when responding to peer communication, developing consensus, and making sure all members of a group have the opportunity and support to contribute. We will also introduce short play-acting episodes in which sets of students will be asked to model specific behaviors while others students watch. Examples will emphasize productive engagement and also unproductive behaviors (using phones, chatting off topic, working on homework form other classes, etc).

All in class assignments in both classes will have a corresponding checklist of things that should be included in the solution to the problems. In the experimental treatment, the checklist will include demonstration of specific behavioral traits that promote the learning goals. Importantly, the checklist is used to record grades and so the behavioral traits will be graded and valued in the same way that student content and skills products are valued. Thus, there will be a grade-based incentive to display specific behaviors in class. Additionally, feedback to students in the experimental treatment will include comments on their behavior. Behavioral feedback will not be provided in the control.

Assessment

A critical part of this experiment is developing an assessment approach that captures relevant data. We are interested in three axes of student learning: mastering the content, demonstrating the science process skills, and exhibit behavior consistent with effective communication and productive collaboration. Our prototype assessment includes a checklist of goals that will not be provided to students when the assessment is implemented but the checklist will be used multiple times in the semester as guidance for students. The prototype is designed as a puzzle for the experimental group and is not implemented as a puzzle for the control. This mirrors the experience of the students in the two treatments.

The assessment is designed to be simple. Students are provided with different packets of information and are asked to come together and use the information to solve a problem. Scores for students will be based on whether information from all students is used, the solution is correct and complete, and the interactions among students are effective and productive.

In addition, students will self assess learning gains using the Self Assessment of Learning Gains (SALG) tool. The questions will be designed to obtain quantitative and qualitative data on student's perceptions of the gains in content, skills, and communication and collaboration strategies.

Timeline and personnel

Curriculum development, assessment development, and training and validation of the observation protocol will be accomplished in the fall, 2015, and the experiment will be done in Spring 2016 in the Introduction to Quantitative Thinking (EBIO 1010) course. We will train students—most likely learning assistants—to use the observation protocol during EBIO 3080 (my fall course) and the students will be hired as hourly employees to record behavioral observations during the spring. Cynthia Buchenroth-Martin (see CV) will coordinate the efforts of the undergraduates, grade the student work, and compile the data. I will oversee all aspects of the project, teach the courses, and develop the puzzle-based curricula.

Outcomes and impacts

We imagine several significant outcomes. First, we will measure learning gains for a difficult-to-assess but extremely important learning goal that asks STEM undergraduate to be able to interact productively with different individuals. Second, the research will involve several undergraduates in observing behavior of their peers and our work thus far indicates that students enjoy collecting observational data and gaining an understanding of the value of educational research and scientific teaching. Third, the fact that the course targets first year students will hopefully prepare students to more fully engage with their peers as they move through their degree programs towards graduation and into the real world where effective communication and production collaboration are often the keys to success. Finally, we will develop puzzle-based curricula focused on quantitative thinking and the analysis of data we will make available for others that may be interested in fostering environments that allow students to practice strategies for effective communication and productive collaboration.

References

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