USING COOPERATIVE LEARNING GROUPS IN CALCULUS II COREQUISITE LABS

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Abstract
In this paper, we will discuss Delta State University's (DSU) implementation of cooperative learning groups in a corequisite Calculus II course design. The template for this design emerged from the successful implementation of corequisite labs in the general education mathematics courses at DSU.

In fall 2016, Delta State University first implemented corequisite labs in general education mathematic courses. While each successive academic year thereafter has shown significant gains in student pass rates, the greatest gain occurred in fall 2018 with the establishment of lab-based cooperative learning groups. Based on the successes in the general education courses, DSU paired the Calculus I and II sections with corequisite labs starting fall 2019.

The course design for the new corequisite calculus courses is comparable to that currently in practice in the general education mathematics courses with one major addition to the model – Inquiry-Based Learning (IBL). Students are placed in instructor-chosen heterogeneous cooperative learning groups for use in both lab and class, and course material is delivered using both traditional lecture and "big tent" inquiry-based learning techniques. In addition, we will discuss lab design with regard to "just-in-time" remediation and targeted class projects. This paper will outline a typical lab lesson plan as well as several active learning activities.

Introduction
A regional public university, Delta State University is situated in the heart of the Mississippi delta located on the east side of the Mississippi River. In the fall of 2018, 3,715 students attended DSU. Of these students, 59% are female and 41% are male. The average class size/teacher to student ratio at the institution is 12:1 (Institutional Research, 2019), the Calculus classes typically have an enrollment of 6 to 12 students.

As seen in Table 1, from Fall 2012 to 2018, of the incoming students who provide ACT scores (at DSU, transfer students are exempt from this requirement), 58% earned less than a 21on the ACT (Institutional Research, 2019). The U.S. Department of Education (2018) has determined earning a 21 or higher on the ACT is an indicator of readiness for college-level mathematics. Therefore, only 42%, or significantly less than half, of the students at Delta State University are considered ready to learn college-level mathematics (Bondurant, Putnam, & Townsend, 2020).

Table 1

Percent of incoming students earning a 21 or higher on the ACT

	Fall 2012	**Fall 2013**	**Fall 2014**	**Fall 2015**	**Fall 2016**	**Fall 2017**	**Fall 2018**
Percent of first-time *freshmen* who have an ACT composite score of 21 or above	41.4%	41.2%	47.6%	46.4%	55.5%	54.6%	53.8%

At Delta State University, students were designated as either traditional or remedial according their ACT score. A traditional student is a student whose ACT mathematics sub-score was equal to/greater than a 20, whereas a remedial student is defined to be someone who scored below a 20 on the ACT mathematics sub-score. Students whose ACT mathematics sub-score was equal to/greater than 24 may enroll in Calculus I without the prerequisite courses College Algebra and Trigonometry.

Beginning in the 2017-2018 academic year, the Delta State University mathematics department initiated the co-requisite model in College Algebra (Bondurant, Putnam, & Townsend, 2019) and, in the fall of 2019, for Calculus I and II due to low student pass rates. This model requires students to enroll in a co-requisite lab section paired with their class. The instructor of record presides over the co-requisite lab.

Educational Framework

Research has long supported and verified student success utilizing Inquiry-Based Learning. R. L. Moore, the author of the Moore Method (Jones, 1977), devised a program which educators have dubbed Inquiry-Based Learning (IBL). This program follows the premise that students should be encouraged to solve problems using their own skills of critical analysis and creativity. The teaching practices suggested by IBL differs vastly from the traditional lecture form of pedagogy utilized in most university mathematics courses. The lecture format relegates most students to simple note-takers rather than active learning participants. Although there are many students who respond positively to traditional lecture formats, the vast majority of students do not. (Yoshinobu & Jones, 2012). Traditional lecture failure rates are 55 percent greater than the rates observed under more active approaches to instruction (Freeman et al., 2014).

Another pedagogical tool incorporated into the Calculus II classes is Cooperative learning. Recently, this form of instruction has become a learning tool showing positive results in college classes. The Delta State University mathematics professors focus their research on incorporating cooperative learning and Inquiry-Based Learning in order to align and integrate the online assessment to produce the positive results. Jones and Jones (2008) stated "Johnson, Johnson, and Smith (1991) define cooperative learning as the instructional use of small groups so that students work together to maximize their own and each other's learning." Beginning with this premise, the Delta State University mathematics professors researched for the best modalities for the integration of cooperative learning, Inquiry-Based Learning, and online assessments. The DSU professors chose to utilize the formal cooperative learning modality in the form of Peer-Assisted Learning (PALS).

Peer-Assisted Learning is typified by "students acquiring knowledge and skills through active helping among equal classmates" (Topping & Ehly, 1998). PALS encourages an ongoing dialogue process. Student interaction may be verbal or non-verbal. Students must be linked with each other in a way so that one cannot succeed unless others do (or vice versa), and other group members' work is mutually beneficial (Johnson, Johnson, & Roger, 2015). Different from peer tutoring, PALS support collaborative work produced through cooperation. The next step of the learning process is for the student to show proof of the skill acquisition. Students show mastery of content and skill through the online assessment. Assessment as proof of skill acquisition is one method to show concrete evidence of mastery of subject content (Bondurant, Putnam, & Townsend, 2019).

Model

We now review the implementation of cooperative learning groups in the co-requisite labs. Before discussion of the lab procedures, we define our style of cooperative learning. Students are placed in formal cooperative learning groups of size three to four with a heterogeneous structure. Heterogeneous grouping refers to the data-driven process of grouping individuals with varied levels of ability. In this case, a start of semester pre-test, which assesses fundamental algebraic and trigonometric concepts, pre-determines student grouping. Groups are defined so that no two students within the same group have pre-tests scores more than twenty points apart. For example, if one student has a pre-test score of 80, no other student within the group could have a pre-test score of less than 60. In addition, formal base grouping prescribes that groups remain intact for longer periods of time, often for the entirety of the course. From instructor observation of student interaction, some reshuffling is typically necessary to encourage a more productive class culture. Such instructor observations include managing compatible student dispositions and diversifying student learning styles within groups. Based on early trials, groups typically stabilize within the first few lab meetings and maintained throughout the semester.

We now outline the model used in our co-requisite labs. Labs are weekly meetings of seventy-five minutes hosted in a computer lab. These meetings are partitioned into five phases: 1) a whole group introduction, 2) group work, 3) presentation of group products, 4) individual assessments, and 5) a whole group debriefing.

In phase one, the instructor leads an introductory session referred to as a lab starter. These lab starters may consist of an open-ended discussion, a short whole-group quiz, or a quick reteaching of remedial content. Most importantly, the lab starter involves the class as a whole and lasts no more than five minutes. The primary function of the lab starter is to outline the objectives and expectations for the upcoming group products.

In phase two of the co-requisite lab, groups are given a paper-based assignment generated by the Learning Management System (LMS). The paper-based assignment is partitioned amongst the groups, and each group is expected to complete their subset of the assignment within the allotted thirty minutes. During this time, they have access to their course notes, textbook, and the instructor. Groups must prepare a final product in the form of either a lesson, a hand-written solution, or a presentation, and the final product should be reviewed by the instructor before progressing to the next phase.

In phase three, groups present their product in a fifteen to twenty-minute time frame. Depending on the nature of the assignment, the instructor chooses to do this in one of three ways: 1) group teaching, 2) peer review, or 3) whiteboard work.

For group teaching, a randomly chosen representative from each group is asked to travel from group to group to "teach" their problem. Groups are responsible for preparing each of their members for this responsibility. This product typically involves a direct numerical solution. For example, students may be asked to calculate the limit at infinity of a Riemann sum.

For peer review, groups pass their hand-written solution to another group for review. That group edits the solution before sending it along to the next group for review. All groups have the opportunity to view all solutions before returning the work to the original group for final review. This product is typically in the form of a written concept-based assignment. For example, students may be asked to discuss the process for approximating the area under a smooth, nonlinear curve.

Finally, for white board work, groups present their solutions at the board to the whole class. Groups may choose to send a representative or may choose to delegate responsibility. This product typically involves a highly analytic solution with more emphasis on proper notation and strategic approach than what would be seen in the group teaching format. For example, students may be asked to identify and apply the appropriate technique for solving an indefinite integral.

In phase four, students separate from their groups to take an individual, closed-notes exit quiz administered by the LMS. The quiz is a computer-generated subset of the lab assignment with new values for each problem. In order to receive full credit for the quiz, students must also hand in their scratch work to show evidence of organization and proper notation.

In the fifth and final phase, the whole group will reconvene to discuss and debrief the individual quizzes. Given the nature of the shortened feedback loop from the LMS, the students are able to self-assess their results and self-identify where remediation may be needed both individually and as a whole group. The author notes that this phase requires the instructor maintain a sense of community for open dialogue. A communicative class culture quickly manifests through the use of the cooperative learning groups but require direct maintenance in the form of instructor feedback. Feedback was typically tailored to foster a positive growth mindset; that is, what to do rather than what not to do.

Throughout the five phases, the instructor monitors the groups for emerging needs in content remediation or necessary reteaching. During this process, the instructor utilizes Just-in-Time Teaching (JiTT) methodologies. The intent is to develop a learning environment that is assessment-centered. Students are encouraged to view the exit quizzes as a valuable tool that allows them to adjust their thinking prior to a summative assessment (Bondurant, Putnam, & Townsend, 2019). Thus, students are regularly reminded by the instructor to view the group work and the group product as a time to review and prepare not only for the upcoming lab quiz, but also for future unit tests. The final debriefing feeds into the following class meeting as a warmup exercise. In this way, data from weekly lab quizzes is used to inform the next several lessons.

Results

In the first full semester of implementation of cooperative learning and co-requisite labs in Calculus II at Delta State University, the student pass rate was 83%, where passing was defined to be a final letter grade of A, B, or C. The author notes that the second semester of implementation was abbreviated due to a university-wide shift to online instruction in the spring of 2020; however, the pass rate as of midterm and prior to the online transition was 78%. The author is of the belief the increasing trend in the pass rate may be attributable to the adoption of the co-requisite lab in the Calculus I and II sections.

During the first semester of full implementation of this lab model, the instructor observed an appreciable shift in student anxiety and self-efficacy. This shift occurred through the culture/climate shift within the student population. Student dialogue within the groups as well as with the instructor during post-assessment debriefings increased suggesting a drop in anxiety.

Conclusion

Data from the fall of 2019 through the midterm of 2020 are indicative of the success of the implementation of the cooperative learning in conjunction with a co-requisite lab. Given the observations over the last two semesters of implementation, the author plans to proceed as well with a quantitative study of the retention of calculus concepts throughout both the calculus sequence and the overall mathematics degree program with the inclusion of assessments in Calculus IV and the senior mathematics capstone course at Delta State University.

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