The Impact of Inquiry Based Learning Techniques in College Algebra

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Abstract

In this paper the authors provide information about the general method of instruction known as Inquiry Based Learning (IBL) that they learned at the Academy of Inquiry Based Learning (AIBL). General information regarding implementation at a regional public university located in southeastern United States is shared. A focused discussion of implementation in co-requisite College Algebra follows. The authors present results suggesting a positive impact of using IBL methods on student perceptions and achievement. Limitations and possible implications are discussed.

Keywords: Inquiry based learning, remediation, active learning
Introduction

Inquiry Based Learning (IBL) is supported by a wide body of research and a long track record of student success. IBL’s roots lie in the Moore Method, named after R. L. Moore (182-1974) who devised a method where students were encouraged to solve problems using their own skills of critical analysis and creativity. Moore’s beliefs are well summarized in his statement, “That student is taught the best who is told the least.” The teaching practices suggested by the Moore Method lie in stark contrast to the traditional teaching practices utilized in most university mathematics courses. Most university mathematics professors employ a lecture format in which students are reduced to scribes. While some students respond well to traditional teaching practices, the vast majority do not. (Yoshinobu & Jones, 2012). In fact, only about 50% of students pass College Algebra (Ganter & Haver, 2011) and failure rates under traditional lecture are 55 percent higher than the rates observed under more active approaches to instruction (Freeman et al., 2014).

The Academy of Inquiry Based Learning (AIBL) is a component of the PROfessional Development and Uptake through Collaborative Teams (PRODUCT NSF DUE-1525058) $2.8 million, five-year project to expand the professional development capacity in undergraduate mathematics. One of the major challenges PRODUCT addresses in STEM education is the rate of uptake of empirically validated teaching methods. The project directly addresses this challenge by offering intensive workshops based on a proven model to undergraduate mathematics instructors, and by building teams of leaders who are skilled and effective in planning and guiding these workshops and in providing follow-up support to participants.

The components of the PRODUCT grant included: 2 four-day intensive IBL workshops (AIBL), 15 short, skills-based workshops, five Professional Development Preparatory Meetings, and a STEM Professional Development Summit for 50 STEM professional developers. Through these activities, PRODUCT aims to develop three new teams of faculty developers, provide professional development for 320 undergraduate math faculty, adapt and improve IBL workshop materials, and develop a framework for building professional development capacity. The AIBL philosophy is "big tent IBL." The staff of AIBL define IBL as the broad range of empirically validated teaching methods which emphasize (a) deeply engaging students and (b) providing students with opportunities to authentically learn by collaborating with their peers. The authors of this manuscript are alumni of AIBL and what follows is a report of their IBL implementation journey.

Methodology

Research Question

The following research question guided this study: To what extent does implementing IBL techniques affect instructors’ teaching practices, student participation, and ultimately student achievement?
The characteristics of self-study methodology include openness, collaboration, reframing, paradoxical nature, postmodernism, and multiple and multifaceted perspectives. Throughout the study the authors’ disposition was open to ideas from others. Collaboration played a critical role. Through dialogue and collaboration, the authors were able to frame and reframe a problem or situation from different perspectives. Additionally, there were opportunities to change how we looked at what was going on in our classrooms and ultimately change our practices. The study was paradoxical in nature, because it was about the individual, yet it involved collaboration (“critical friends”). Moreover, the study employed the postmodern assumptions that it is never possible to divorce ‘self’ from the research process or education practice and that we do not claim to know the answers, but rather we seek to understand the answers. The study was multiple and multifaceted, because the authors come from various theoretical orientations and used multiple and diverse qualitative methods (Lassonde, C., Galman, S., & Kosnik, C., 2009).

Participants

The authors all teach at a regional public university in southeastern United States. Since College Algebra is a general education course, the students are representative of the students who attend the institution. Thus we will share institutional demographic data as it provides an accurate picture of the students enrolled in College Algebra. In Fall 2018 the institution enrolled 3,715 students. Of these students, 59% are female and 41% are male. The school has high racial diversity, with mainly students (57%), but a significant population (36%). Although the average class size at the institution is 12:1, the authors’ classes typically have approximately 30-40 students. As seen in Table 1, from Fall 2012 to 2018, of the incoming students who provide ACT scores (transfer students are not required to), on average, approximately 42% earned a 21 or higher on the ACT (Institutional Research, 2019). According to the U.S. Department of Education (2018) earning a 21 or higher on the ACT is considered an indicator of readiness for college-level mathematics. The reader can imagine the challenges an instructor faces when less than half of the students in their class are considered ready to learn the subject matter at hand. Students in Dr. Putnam’s and Mrs. Townsend’s classes are a mixture of students with ACT scores below 21 (considered in need of remediation) and those with scores of 21 or higher.
### Table 1

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

<table>
<thead>
<tr>
<th></th>
<th>Fall 2012</th>
<th>Fall 2013</th>
<th>Fall 2014</th>
<th>Fall 2015</th>
<th>Fall 2016</th>
<th>Fall 2017</th>
<th>Fall 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percent of first-time freshmen who have an ACT composite score of 21 or above</strong></td>
<td>41.4%</td>
<td>41.2%</td>
<td>47.6%</td>
<td>46.4%</td>
<td>55.5%</td>
<td>54.6%</td>
<td>53.8%</td>
</tr>
<tr>
<td><strong>Percent of first-time transfers who have an ACT composite score of 21 or above</strong></td>
<td>24.1%</td>
<td>28.4%</td>
<td>31.1%</td>
<td>34.7%</td>
<td>40.9%</td>
<td>38.3%</td>
<td>44.8%</td>
</tr>
<tr>
<td><strong>Percent of first-time freshmen and transfers who have an ACT composite score of 21 or above</strong></td>
<td>35.5%</td>
<td>36.6%</td>
<td>41.6%</td>
<td>41.9%</td>
<td>50.5%</td>
<td>48.4%</td>
<td>50.3%</td>
</tr>
</tbody>
</table>

### Procedures

During the 2017-2018 academic year, the institution initiated a co-requisite model in all general education mathematics courses, including College Algebra. This model required all students, both traditional and remedial, to enroll in a concurrent lab associated with their chosen section. At the institution a remedial student is defined to be someone who scored below a 20 on the ACT mathematics sub-score. Labs are administered by the section instructor with the assistance of one supplemental instructor; that is, an undergraduate student who has successfully completed a College Algebra course with a grade of A or B. The purpose of implementing the co-requisite model was to increase gateway course completion, where gateway courses were defined to be any course necessary for a student to progress through his or her chosen major. In this paper, we will investigate both successful and unsuccessful instructional models incorporated in the academic years of 2017-18 and 2018-19. In all instances, we consider exclusively the sections administered by Dr. Catherine Putnam and Mrs. Chelsea Townsend.

In the first year of implementation, Dr. Putnam and Mrs. Townsend utilized some active learning techniques interspersed within a traditional lecture format. These techniques included guided notes, active questioning, class starters, and mindful wait time. On the other hand, the labs were primarily used for completion of homework and/or quizzes, and students were given greater autonomy in choice of remediation material. Just-in-time remediation was formally administered only prior to each unit assessment. In all other instances, remediation occurred informally as one-on-one tutoring.

In the summer of 2018, Dr. Putnam and Mrs. Townsend attended AIBL at the Mathematics Association of America (MAA) Carriage House in Washington, DC. In the fall of 2018, more active learning techniques were incorporated within the lab structure; however, the instructional format utilized within class time was primarily unchanged.

We now discuss in detail the Inquiry Based Learning methods practiced in the co-requisite College Algebra classes and labs. As referenced in the introduction, a critical element of “big tent” IBL is providing students with opportunities to authentically learn by collaborating with their peers. Our deliberate group design fostered student collaboration. Through
experimentation we determined the group design that was the most effective for our students. The two key design elements were group composition and how frequently new groups were formed.

Students were partitioned into instructor-designed groups of four. The instructors experimented with the method of partitioning, and eventually recognized an appreciable increase in student engagement and self-efficacy when using heterogeneous grouping. Heterogeneous grouping refers to the process of grouping individuals of varied levels of perceived ability by some chosen measure with predetermined thresholds. In this case, we chose a threshold of 20 percentage points on student overall test average at the time of group designation. That is, if one student had a test average of 80, no other student within the group could have a test average of less than 60.

Some of the more unsuccessful group designs included random allocation, homogeneous grouping, and heterogeneous grouping with a threshold of greater than 20 percentage points on overall test averages. Through instructor observation, the second and third methods appeared to be by far the least successful. Homogeneous grouping naturally created low-ability groups who were hampered by a deep-rooted pattern of low self-confidence, and the disparity of too large a threshold within heterogeneous groups resulted in ineffective communication between group members. Instructors perceived that each of these methods fostered frustration and as such were quickly discarded.

Once students were grouped in both lab and lecture, we then needed to address if and/or how often to re-structure groups. It should be noted that existing research on cooperative learning groups extolls both the benefits and the drawbacks of frequent group shuffling versus long-term groups (Heller and Hollabaugh, 1992; Johnson et al., 1998). Dr. Putnam and Mrs. Townsend each used different approaches within their sections. In some sections, groups were restructured after each unit exam. In others, groups were only re-structured at midterm or were not changed at all. The instructors chose the different approaches with regard to the disposition of each section as well as the existing groups.

We now discuss the instructional framework of the co-requisite labs with regard to the establishment of cooperative learning groups as well as the purposeful correlation to the ongoing implementation of active learning techniques within regularly scheduled class-time. Students attend their regularly scheduled class three days a week for 50 minutes each day. During that time, traditional lecture is utilized for approximately 5-10 minutes followed by individual student and/or student group work for approximately 5-10 minutes. Once weekly labs begin in the regular classroom with a small class starter for about 5 minutes in order to communicate to the students what material will be addressed within the lab time. Groups will then work together on a paper-based assignment for approximately 30 to 40 minutes.

During this time, students have access to guided notes, the instructor, and the supplemental instructor (SI). The instructor and the SI have the solutions to the lab assignment, and it is the responsibility of each group member to check at least one solution with either the SI or the instructor to report to their group members. The reporting member may not write any of
the steps to the solution, but must instead verbally communicate the process to their group members. Once the group has verified that all of the members have all of the correct and fully completed solutions, groups are given a “lab password” by the instructor and sent to the mathematics computer lab situated next door. At this point, typical active learning techniques would include a group presentation of solutions to the class. Given the nature of a general education gateway course, we felt it prudent to use this opportunity to require students to interact with the Learning Management System (LMS) in a low-stress environment. Groups are asked to correctly input their solutions into a lab quiz within the LMS. For full credit, all members must have correctly input all solutions within two attempts. After the groups have completed their assignment, the instructor gives the students a “quiz password.” To complete the lab, students are required to take an individual fifteen minute quiz on the material practiced in the group assignment. At this time, they are not allowed to use any outside materials.

As mentioned earlier, Dr. Putnam and Mrs. Townsend employed some active learning techniques prior to the reconstruction of the co-requisite lab. However, using an established four-person grouping as well as data from lab assignments prompted further opportunities for incorporating active learning techniques. In particular, instructors were able to reduce time spent in traditional lectures. For example, classes were typically broken into fifteen minute lecture blocks to prevent fatigue and loss of student engagement. Well-established groups enabled the instructors to use the instructional blocks for well-known activities such as “I Try, You Try,” “Think-Pair-Share,” and “Peer Reviewing.”

Results

In the spring of 2015, the College Algebra sections at the institution had a pass rate of 30%. Over the 2016-2017 academic year, the faculty researched and discussed the advantages of general education mathematics pathways and co-requisite labs. The new pathways and co-requisite labs were implemented in the fall of 2017. As part of the new approach to general education mathematics courses, Intermediate Algebra (previously used to remediate students) was no longer offered at Delta State. Students have a choice of taking Quantitative Reasoning, Elementary Statistics, or College Algebra to fulfill their general education mathematics requirement. The new remediation techniques discussed in this paper were implemented via IBL methods in all College Algebra sections in the fall of 2018. The authors are pleased to report that since implementing these techniques the pass rate has been above 50%. Additionally, there appears to be an increasing trend in the pass rate. This may be due to improvements in the authors’ implementation of the techniques. It may also be attributed to students who often struggle in College Algebra and do not need it for their major enrolling in one of the other two course options at an increasing rate.

As seen in Table 2, there was a negligible improvement in student pass rates, where we define passing as an A, B, or C final letter grade. These changes seem to have had a positive effect on pass rates.
Table 2
Pass/Fail Rates in College Algebra

<table>
<thead>
<tr>
<th></th>
<th>Fall ’16/Spring ’17</th>
<th>Fall ’17/Spring ’18</th>
<th>Fall 2018</th>
</tr>
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<tbody>
<tr>
<td>Pass</td>
<td>52%</td>
<td>55%</td>
<td>68%</td>
</tr>
<tr>
<td>Fail</td>
<td>47%</td>
<td>46%</td>
<td>32%</td>
</tr>
</tbody>
</table>

*Pass = A, B, C (70 or above), Fail = D, W, F, I (below a 70)*

**Discussion**

In this paper the authors presented quantitative results suggesting a positive impact of IBL on student learning in co-requisite College Algebra courses. The authors provided information about the general method of instruction known as Inquiry Based Learning (IBL) that they learned at the Academy of Inquiry Based Learning (AIBL). They also provided information about their implementation in a variety of courses at the institution. Finally, they shared preliminary findings in the courses where they implemented IBL teaching methods.

**Limitations**

The authors acknowledge several limitations of their self-study on the effectiveness of IBL. For one, the authors recognize that it is impossible to tell whether the increase in College Algebra passing rates is attributed to IBL teaching methods or other factors, such as the University change in mathematics requirements. Additionally, the authors acknowledge that they did not use a single well-defined teaching method. The authors self-reported their teaching practices and their students’ reactions to the new methods. The authors acknowledge that they may have inherent biases towards their own practices and students. To remedy this issue, the authors plan on observing each others’ classes and discussing findings in future semesters. While the authors believe that incorporating the IBL techniques had a significant impact on student success rates, the implementation of the required lab could also have played a role in the increased student success rates in the College Algebra classes. Another limitation was that the
study did not track student perception. In future work, the authors plan to collect data on student self-efficacy. Finally, the aim of self study research is to provoke, challenge, and illuminate. Therefore, this study does not claim to prove whether IBL is an effective method of instruction for math students at the authors’ institution.

Conclusion

Moving forward, the College Algebra instructors at the institution plan to continue exercising purposeful reflective practice in their choice of lab and classroom assignments. They also plan to incorporate activities such as weekly group presentations, flipped assignments, and student self-evaluated projects. Authors also aim to increase the quantity and quality of their measurements of effectiveness. Surveys will be incorporated quarterly to track student self-efficacy in addition to current quantitative measures already in place.

References


Institutional Research (2019). Percent of incoming students earning a 21 or higher on the ACT.


