Active Online Learning: Supporting Collaboration and a Sense of Community in Undergraduate Mathematics

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Abstract

Previous studies have shown that active learning in classroom contexts improves student engagement, motivation, and performance. However, recent changes to the educational landscape, resulting from the COVID-19 pandemic, have constrained many classes to online environments. Our study investigated how we could support active online learning with a learning community approach. We redesigned an activity for active learning classrooms, called Community Supported Worksheets (CSW), as an online activity. Results show how learning community pedagogy can be applied online to support group and whole-class interactions and individual learning in undergraduate mathematics. Challenges of asynchronous collaboration within this context are briefly discussed. This study serves to grow our understanding of how to develop flexible active learning patterns and provides implications for future iterations.

Introduction

Active learning, broadly defined as the infusion of student activities into lecture, has grown internationally as a normative instructional practice in K-12 and higher education (Bonwell & Eison, 1991; Freeman et al., 2014; Prince, 2004). Active learning is commonly linked to increased engagement, information retrieval (Prince, 2004; Beichner, 2008), improved student outcomes on exams and course grades (Freeman et al., 2014; Talbert & Mor-Avi, 2018), and deeper conceptual understandings (Beichner, 2008; Dori & Belcher, 2005). This approach is complemented by active learning classrooms (ALCs), learning spaces designed to combine lecture, student activities, and technology-rich learning (Beichner, 2008; Beichner et al., 1999; Wilson & Jennings, 2000). A range of different active learning approaches and strategies are associated with these spaces, e.g., collaborative learning (Barkley et al., 2014), problem-based learning (Grabinger & Dunlap, 2002), peer-instruction (Mazur, 1997), jigsaw (Perkins & Saris, 2001), and peer-assessment (Sluijsmans et al., 1998). ALCs, therefore, rely on a combination of physical space, technology, and activities. However, ALCs have been disrupted by the COVID-19 outbreak, that has led to over 1.5 billion learners globally being unable to return to their schools (UNESCO, 2020). Instructors who value active learning approaches have thus been challenged in developing flexible online learning experiences (e.g. Huang, et al., 2020; Reynolds & Chu, 2020). Despite challenges of teaching and learning online, the notion of active online learning (Dringus, 2000; Phillips, 2005; Salmon, 2004) is gaining attention as educators strive to improve effectiveness and engagement of online learning (e.g. Bao, 2020; Tan et al., 2020).
Research Purpose

This study investigates how patterns and principles of active learning can be migrated into the online space, to maintain and support students’ sense of community, collaboration, and inquiry in undergraduate mathematics. This study investigates an activity called Community Supported Worksheets (CSW), developed over the past two years for mathematics, for the context of face-to-face, synchronous learning in an active learning classroom (Li et al., 2020). We re-designed the activity, and developed new technology infrastructure to support the scripting and orchestration of a complex inquiry pattern (Slotta, Quintana, & Moher, 2018).

A key research question is concerned with the application of a learning community approach to support active learning. Learning communities have been studied as a powerful pedagogy of engagement and peer support, with a distinct epistemological perspective of collective inquiry and progress (Scardamalia & Bereiter, 1994; Slotta, Quintana, & Moher, 2018). Our initial work, performed in active learning classrooms, sought to unify all students in the class, aligning their work to support the progress of the community as a whole, with the community serving as a central resource for each individual’s learning. We sought to maintain this focus in our move to the online format. Hence our specific research questions are as follows:

1. How can a learning community pedagogy be applied to support whole-class interactions and individual learning activities in an undergraduate mathematics context?
2. What are the opportunities within a mathematics learning activity that allow students to support their peers and gain a sense of the value of the community?
3. What forms of exchange amongst students in a learning community are the most productive for student progress in undergraduate mathematics?

Method

Participants and Data description

This study took place in the Spring of 2020, with 302 students, self-selected from a larger sample of 1500 undergraduate students in a linear algebra course, offered at a large university in central China. These students were in COVID-19-related lockdown at the time. The instructor is a veteran of active learning methods and experienced in teaching large cohorts online (Li et al., 2020). This paper includes data from two enactments of the Community-Supported Worksheet (CSW) activity (described below). The database included 8216 records of data, representing student responses of various types (e.g. discussion posts, open responses, and multiple choice responses).

In this study, students were randomly divided into ten virtual classrooms, and then randomly assigned to five student groups. The virtual classes contained an average of 29.85 students ($SD = 5.00$, range 17 to 37). The group sizes were on average 5.97 students ($SD = 2.27$, range 2 to 11). In total, 284 students participated in the first run and 265 students participated in the second run.
**Activities and Materials**

The CSW pattern involves three successive linear algebra problems (see Figure 1), two solved collaboratively amongst small groups, one of which is impossible for most groups, thus requiring support from the community in the form of hints. The third question is a transfer problem, attempted individually. The CSW pattern, therefore, comprises 4 components (1) a group discussion to support peers’ understandings of the problem, (2) an individual attempt that aims to foster desirable difficulty (Bjork, 1994) through individual struggle, (3) a group level negotiation of individually generated answers, and (4) a whole-class hint board to generate, rate, and comment on hints to support all classmates to make progress. A post-study survey with both open and multiple choice questions was administered to elicit information about students’ feelings of connectedness, enjoyment, whether tasks were helpful, and whether they benefited from their peers. The CSW pattern was run twice with the same class of students. A survey was administered at the end of each run.

To support our research, we required a more nuanced control of student grouping and materials than is available through most eLearning environments. Therefore, in our broader program of research, we have developed a SCripting and ORchestration Environment (SCORE) that allows for fine control of student grouping, materials, and activities (see Figure 2).

**Variables and Indicators**

A description of variables and indicators is shown in Table 1. To address our research questions, we have reframed each in terms of the present study, to obtain specific indicators relating to the CSW pattern:

1. What factors affect students’ successful completion of collaborative worksheets?
2. Which factors within CSW affect students’ sense of connectedness?
3. What are the characteristics of an effective hint for CSW?

**Data Analysis**

To address the hierarchical structure of the data in this study (i.e. multiple individuals per group and multiple groups per class), the multilevel modeling (MLM; Peugh, 2010) approach was used for statistical analyses. MLM is used to address the questions about relationships between the variables when the assumption of independence is violated. This assumption is naturally violated in nested data structures, therefore, MLM is an appropriate analytic strategy for this study.

**Results**

**Predictors of Successful Completion**

Two outcomes were associated with the successful completion of the worksheets: (1) whether the final answer was achieved and (2) the perceived difficulty when solving this problem. Grading of students’ answers became unavailable for this study, but results regarding perceived challenge were analyzed. To investigate whether the perceived challenge of a problem was affected by the group size and whether the difficulty of questions acts as a moderator of this relationship, a 4-level MLM was performed, with the perceived challenge of a problem as an outcome (see Figure 3).
Group size had no significant effect on the perceived difficulty of the worksheets (see Table 2). Specifically, the effect of group size was nonsignificant for worksheet 1 (the easiest one), \( B = -0.008, SE = 0.027, p = 0.766 \). The interaction effects were non-significant as well: \( B = 0.006, SE = 0.033, p = 0.863 \) for Group*Worksheet 2 interaction, and \( B = 0.008, SE = 0.034, p = 0.811 \) for Group*Worksheet 3 interaction. However, as expected, the second worksheet (more difficult) had a significantly higher average value for the perceived challenge of a problem as compared to Worksheet 1, \( B = 1.104, SE = 0.218, p < 0.001 \). Similarly, Worksheet 3 was perceived as significantly more difficult than Worksheet 1 (\( B = 1.68, SE = 0.222, p < 0.001 \)).

**Predictors of Students’ Sense of Connectedness**

Similar MLM models were used to explore indicators of students’ sense of connectedness. The results provide insight into the relationships of group size and the number of posts with perceived sense of connectedness. The results of our analyses (see Table 3) show a non-significant relationship between the group size and sense of connectedness with peers (\( B = -0.016, SE = 0.029, p = 0.590 \)) and that the frequency of posts is not related to the perception of connectedness for discussion of worksheets (\( B = -0.014, SE = 0.015, p = 0.371 \)), the collective upload (\( B = -0.012, SE = 0.015, p = 0.399 \)), or hint posts (\( B = 0.017, SE = 0.018, p = 0.358 \)).

**Characteristics of Useful Hints**

Characteristically, hints were generally brief with references to rules, laws, or particular steps of a solution (see Figure 4). Usefulness of hints was investigated through an open response survey item. Students who reported affirmatively in the survey to whether hints were helpful described hints as: useful tips to get started, reminders of course materials, identifiers of errors, or collisions of ideas from different perspectives. Those who found hints unhelpful stated that there were too few hints at the time (as hints were contributed gradually by classmates), hints were too vague, general, or specific (as a few hints included the answer), students used additional social media to discuss with peers, or students were unsure whether others’ hints were correct.

**Discussion**

Prior to beginning the study, many of the students had reported wanting more opportunity to interact with their peers over their pre-existing online learning experience which was mostly lecture-based. The transition to both online and asynchronous formats appears to have reduced the effectiveness of the CSW script in a few ways. Due to the conflicting schedules of students, we were forced to adopt a flexible, asynchronous format that transitioned us away from the intended synchronous format.

At these early iterations of implementation, contrary to expectations (Rettie, 2003; Stangor, 2004), results show that group size did not have an effect on perceived difficulty or sense of connectedness. This suggests that the outcomes are related to individual differences rather than differences at the group level. This finding that group size has limited impact on other variables can be explained in part by the relatively low response rate among peers within each group. This highlights the importance of additional group process supports to encourage and scaffold the collaborative aspects of this activity in future iterations.

This study has served to step our understanding forward toward developing a flexible active learning pattern, including a technology environment that can support and be readily adapted to a variety of formats (i.e., single classroom, multiple classrooms, fully online, or
hybrid). Future research will add additional scaffolds associated with high levels of collaboration (Vogel et al., 2017), e.g., explaining (Webb et al., 2009), questioning (King, 1998), and arguing (Andriessen et al., 2003). We may also compare performance across synchronous and asynchronous enactments. Hints will be revisited to help students target both general tips (such as laws or rules), as well as more specific, procedural hints (as requested by students in this current study).

This research joins the growing effort to develop solutions to the challenging new context of interrupted education and hybrid learning contexts. We seek to develop active learning and social engagement opportunities that are robust toward current and future threats (e.g. natural disasters, pollution-based threats, pandemics, civic unrest, etc.). Although further design and development is required, our approach aims to bring both active learning pedagogy and bespoke technology environments to address the emerging needs of classes moving to online or hybrid environments, seeking means of student engagement, collaboration, and community.

References


### Table 1
*Description of Indicators and Variables*

<table>
<thead>
<tr>
<th>Indicators and Variables</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Successful Completion</strong></td>
<td>The successful completion of the collaborative worksheets is explored in terms of two indicators: (1) whether a correct final answer was reached and (2) the student reported perceived difficulty while attempting the question.</td>
</tr>
<tr>
<td><strong>Sense of Connectedness</strong></td>
<td>Students’ sense of connectedness during the CSW pattern as compared to their previous online learning was self-reported on a 5-point Likert scale.</td>
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<tr>
<td><strong>Difficulty</strong></td>
<td>Each CSW pattern contains three algebra problems: (1) an “easy” collaborative problem, (2) a “difficult” collaborative problem, and (3) a “difficult” transfer problem, worked on individually.</td>
</tr>
<tr>
<td><strong>Number of Posts</strong></td>
<td>The number of posts is calculated separately for the (1) student group worksheet discussion, (2) student group collective upload of answers and negotiation, and (3) hints across an entire class.</td>
</tr>
<tr>
<td><strong>Group Size</strong></td>
<td>Each class was randomly divided into five groups, the group size reflects this student group size.</td>
</tr>
<tr>
<td><strong>Perceived Challenge</strong></td>
<td>After the initial worksheet discussion, students individually attempted the problem and self-reported the difficulty on a 5-point Likert scale.</td>
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</tbody>
</table>
Table 2

Results from MLM Analysis for Perceived Difficulty

<table>
<thead>
<tr>
<th>Predictors (of perceived difficulty)</th>
<th>Interaction Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>Group size * worksheet 1 (easy)</td>
<td>-.008</td>
</tr>
<tr>
<td>Group size * worksheet 2 (difficult)</td>
<td>.006</td>
</tr>
<tr>
<td>Group size * worksheet 3 (difficult)</td>
<td>.008</td>
</tr>
</tbody>
</table>

Note: * p<.05 ** p<.01 *** p<.001

Table 3

Results of MLM Analysis for Sense of Connectedness

<table>
<thead>
<tr>
<th>Worksheet section</th>
<th>Predictor</th>
<th>Interaction Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
</tr>
<tr>
<td>--</td>
<td>Group size</td>
<td>-.016</td>
</tr>
<tr>
<td>Discussion worksheet</td>
<td>Number of posts</td>
<td>-.014</td>
</tr>
<tr>
<td>Collective Upload</td>
<td>Number of posts</td>
<td>-.012</td>
</tr>
<tr>
<td>Hints</td>
<td>Number of posts</td>
<td>.017</td>
</tr>
</tbody>
</table>

Note: * p<.05 ** p<.01 *** p<.001
Note. The first two are collaborative problems (one easy, then one difficult) and an individually attempted transfer problem.

Note. SCORE authoring tool (left) and student learning environment (right).
Figure 3

MLM of Group Size as a Predictor of Perceived Challenge

Figure 4

Whole-class Hint Board for Difficult Collaborative Problem

Note. Most notes are written in Chinese.