Engaging Students for Success in Calculus

A Course Revitalization Model

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Overview of Presentation

- Background and significance of research
- Research goals
- Research theories, teaching techniques, and technologies
- Study design, implementation, and results
- Ongoing study
- Future Directions
- Questions
Background and Significance of Research
Motivation

- Based on the national college and university statistics, only about 40% of students who plan to complete a degree in a science, technology, engineering, or mathematics (STEM) area actually do so.

- So how do we help the other 60% successfully complete STEM degrees?

- To address this issue a goal of our work was to increase student success rates in undergraduate calculus.
Recommendations for Change

- Three major reports were produced to inform about how to improve undergraduate STEM education.
  - PCAST
  - MAA Common Vision
  - Charting a Course for Success: America’s Strategy for STEM Education (CCSASSE)
In 2012, the President’s Council of Advisors on Science and Technology (PCAST) reported three recommendations to increase the number of STEM professionals:

1. Improve the first two years of STEM education in colleges/universities.
2. Provide students with tools/resources to excel.
3. Diversify pathways to STEM degrees.
Mathematical Association of America (MAA)
“A Common Vision for Undergraduate Mathematical Sciences Programs in 2025”

- In 2015 MAA released a report similar to PCAST.
- Written by members representing five different professional societies involved in mathematics education.
- Focuses on using curricula, course structure, workplace preparation, and faculty development to improve undergraduate education, especially in the first two years.
- Emphasizes using evidence-based pedagogical methods to enhance student learning.
In 2018, this report was developed by the Committee on STEM Education of the National Science and Technology Council.

Three goals were outlined in this report as follows:

- Build strong foundations for STEM literacy,
- Increase diversity, equity, and inclusion in STEM, and
- Prepare the STEM workforce for the future.
Research Goals
Research Study Goals

- Establish highly effective teaching strategies in undergraduate Calculus.
  1. To enhance student engagement.
  2. To improve student success rates in Calculus I.
  3. To increase STEM student persistence and graduation.
Levels of Impact

1. Implement teaching strategies to enhance student learning in Calculus I.
2. Increase student success in Calculus.
3. Improve the first two years of undergraduate STEM education.
4. Increase the number of graduates in STEM areas.
Research Theories, Techniques, and Technologies
Bloom’s Taxonomy

- A framework published in 1956 with primary author Benjamin Bloom which uses a multi-tiered scale to organize the levels of expertise required to achieve measurable student outcomes.
- It includes three taxonomies: knowledge based goals, skills based goals, and affective (i.e. values, attitudes, and interests) based goals.
- It includes six levels of cognition: knowledge, comprehension, application, analysis, synthesis, and evaluation.
# Bloom’s Taxonomy

Applications of Lower Order Levels of Bloom’s Taxonomy in Calculus I

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student will be able to recall fundamental facts.</td>
<td>The student will be able to demonstrate understanding of fundamental facts.</td>
<td>The student will be able to apply acquired knowledge in a new or different situation.</td>
</tr>
<tr>
<td>State a theorem, properties, or definition.</td>
<td>Use a theorem or properties to solve a problem.</td>
<td>Solve a multi-step problem that involves more than one theorem or definition.</td>
</tr>
</tbody>
</table>
## Bloom’s Taxonomy

Applications of Higher Order Levels of Bloom’s Taxonomy in Calculus I

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Synthesis</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student will be able to analyze information to determine relationships, structure, and relevance.</td>
<td>The student will be able to examine information to arrive at a conclusion.</td>
<td>The student will be able to prove statements and make judgements based on a set of criteria.</td>
</tr>
<tr>
<td>Determine if a theorem applies to a particular situation.</td>
<td>Generate a function based on given information and valid assumptions.</td>
<td>Evaluate a worked problem to prove or disprove its correctness by providing justifications or counter-examples.</td>
</tr>
</tbody>
</table>
What is active learning?

- In recent years, many studies have supported a move toward *active learning* in collegiate STEM courses.
- It is a process of education whereby students engage in activities, like reading, writing, discussion, or problem-solving that encourage analysis, synthesis, reflection and evaluation of course content.
- Many teaching techniques involve active learning.
- The following techniques were implemented in this research study: short reflective writing prompts, think-pair-share, the flipped classroom, inquiry-based learning, cooperative learning, and collaborative learning.
Active Learning

- The professor must find a balance between lecture and active learning activities.
- Providing guidance and instruction regardless of what type of class activity is taking place is important.
- It can be done individually, in pairs, groups, or as a whole class.
- It can be done with or without technology.
Potential Benefits of Active Learning

- Increase student learning.
- Enhance student motivation, enjoyment of, and personal investment in their education.
- Support deeper learning and contribute to the development of stronger critical thinking skills.
- Higher retention rates and better performance in the classroom learning environment.
- Students are given opportunities to participate in mathematical investigation, communication, and group problem-solving, and also receive feedback on their work from both professors and peers, which can have a positive impact on learning.
Clickers

- Also called student response systems, are small, handheld devices which allow students to respond to posted questions that are typically multiple choice.
- The student responses are immediately tallied and displayed for discussion and clarification.
- They can be implemented for many purposes in college classrooms, including:
  - To assess student understanding related to the course material,
  - To increase student involvement in the class,
  - To survey for student opinions, and
  - To manage group work activities (Caldwell, 2007).
Engaging Students for Success in Calculus (ESSC) Course Revitalization
Funding:

- Tennessee Board of Regents Course Revitalization Grant

Timeline of Study:

- Fall 2019 (pilot study)

Methodology:

- Implement a model used to heighten student learning, the ESSC course revitalization
ESSC

- A course revitalization designed to improve student success rates in calculus
- A research study grounded in the principles of Bloom’s Taxonomy with active learning strategies to promote higher order levels of thinking
- Implemented at Tennessee State University (TSU), a public Historically Black College/University (HBCU) which offers associates, bachelors, masters, and doctoral degrees
- Goal: to increase the academic performance, persistence, and graduation rates of students majoring in STEM disciplines
At TSU students majoring in mathematics, chemistry, architectural engineering, civil engineering, electrical engineering, mechanical engineering, and computer science are required to take Calculus I.

TSU has 79% African American students.

The revitalized course impacted a large number of students from underrepresented groups.

This study was motivated by the need to improve the success rate of students in Calculus at TSU and to graduate more underrepresented minority students in STEM areas to meet the national demand for more STEM professionals.
Pre-ESSC Data

- Academic Year: 2017-2018
- Course: Calculus I
- Course Enrollment: 192 students
- Overall success rate for all sections of Calculus I was 44.3%
- Course ABC Grade Percentages:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13%</td>
</tr>
<tr>
<td>B</td>
<td>14.6%</td>
</tr>
<tr>
<td>C</td>
<td>16.7%</td>
</tr>
</tbody>
</table>
Design, Implementation, Data, and Results
ESSC Model Development

- Goals:
  - To improve knowledge retention by developing multiple levels of cognition,
  - To promote student engagement through the implementation of active learning techniques, and
  - To support student learning outcomes through the integration of technology into the course.

- Goals were achieved by implementing Bloom’s Taxonomy, active learning, and clickers, which have been proven to be effective in increasing student learning.
ESSC

Objectives

- Implement active learning techniques.
- Utilize clickers during class.
- Design assessments using Bloom’s Taxonomy.
- Engage students in the learning process individually and in groups.
- Give students opportunities to practice concepts & show what they know using a variety of modalities.

Expected Outcomes

- Increase student success rates.
- Enhance student engagement.
- Enhance students’ confidence in their mathematics skills.
- Encourage collaborative learning.
- Expose students to the real-world problems
- Positively impact STEM student retention and graduation.
ESSC Design

- It has been shown that the academic development of students majoring in STEM disciplines can be improved if they have positive learning experiences in their mathematics courses.
- ESSC was designed so that students at varying levels of preparedness and experience could be successful.
- ESSC is novel in that principles of Bloom’s Taxonomy were combined with active learning strategies and clicker technology to increase student learning and improve their academic performance.
ESSC Implementation

Various Assessments Used to Track Learning Outcomes

- **Clicker Question**
  - Clicker questions were administered in a cooperative learning environment. This level of assessment occurred shortly after students were introduced to the skills necessary to solve the problem.

- **Homework**
  - Homework was given as individual assignments in an online environment as practice to develop skills after topics had been introduced and examples had been worked in class. Students could work independently or collaboratively.

- **Quiz Item**
  - Formative quizzes were administered as individual assignments. This level of assessment occurred after students were introduced to a few related topics and practiced similar problems inside and outside of class.

- **Test Item**
  - Summative tests were administered as individual assignments. This level of assessment occurred after students were introduced to several topics. At this level of assessment, the level of difficulty may not have increased, but the student had to use more analytical and evaluative cognitive skills.
## ESSC Data

### Responses from Pre-Survey

<table>
<thead>
<tr>
<th>Survey Items</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is useful for me to practice lots of problems when learning mathematics.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>I cannot learn mathematics if the professor does not explain things well in the class.</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td>25</td>
</tr>
<tr>
<td>To understand mathematics I discuss it with other students.</td>
<td>0</td>
<td>3</td>
<td>16</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Critical thinking skills used to understand mathematics can be helpful to me in everyday life.</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>I am looking forward to learning Calculus.</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>13</td>
<td>25</td>
</tr>
</tbody>
</table>
# ESSC Data

Responses from Post-Survey

<table>
<thead>
<tr>
<th>Survey Items</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The online homework helped to reinforce/improve my knowledge.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>The professor explained things well.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Working in groups helped to reinforce/improve my knowledge.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>This course helped me to develop/improve critical thinking skills.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>I feel ready for my next mathematics course or any courses which involve the content covered in this course.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>
## ESSC Data

### Grade Distribution for All Students

<table>
<thead>
<tr>
<th></th>
<th>Fall 2019</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Non-Revitalized Sections (n = 42)</td>
<td></td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>11</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Revitalized Sections Only (n = 47)</td>
<td></td>
<td>6</td>
<td>9</td>
<td>13</td>
<td>1</td>
<td>14</td>
<td>4</td>
</tr>
</tbody>
</table>

### Grade Distribution for African American Students

<table>
<thead>
<tr>
<th></th>
<th>Fall 2019</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Non-Revitalized Sections (n = 36)</td>
<td></td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Revitalized Sections Only (n = 38)</td>
<td></td>
<td>5</td>
<td>7</td>
<td>11</td>
<td>1</td>
<td>11</td>
<td>3</td>
</tr>
</tbody>
</table>
Post-Survey Responses to “What I liked most about this class was...”

- “how much we engaged as a class”
- “Having the professor engage with the students”
- “How the teacher was able to explain some of the most difficult things in the easiest way.”
- “She cared about us.”
- “The professor did not move too fast and the lectures did not feel rushed or too much information at once.”
- “she actually cared about the class”
ESSC Data

Post-Survey Responses to “What I liked most about this class was...”

- “The group work. My classmates helped me out a lot.”
- “Working together”
- “Everyone asked questions and was fun to work with.”
- “Everyone in class was willing to help each other and work together.”
- “Growing and improving in the subject. The group work where there were group leaders was super helpful with learning too.”
ESSC Summary of Findings

The components of the ESSC research study were implemented to improve student knowledge retention, to promote student engagement, and to support student learning. In order to determine the effectiveness of the study both qualitative and quantitative evidence were examined and suggests the following:

• Working cooperatively helped to reinforce and improve student knowledge.
• Levels of student-to-student and student-to-teacher engagement were increased.
• Having a variety of formative assessments helped students to perform better on summative assessments.
• Student success in Calculus I increased.
• Students experienced gains in affective learning.
Potential of ESSC

1. Contribute to the body of knowledge on ways to improve mathematics skills for students.
2. Identify successful teaching strategies and technologies that will promote the retention of STEM students.
3. Increase the success rate of students taking Calculus.
4. Help produce more students who are prepared to excel in STEM disciplines.
Merit of ESSC

- The overall merit of the ESSC study is strengthened by the empirical findings that suggest that the expected outcomes of the study were achieved.
- The information derived from the ESSC study expands the body of knowledge on Calculus I course design, instruction, and assessment and has transformed the teaching and learning of Calculus I at TSU.
- The findings of the ESSC study contribute significantly to understanding how to engage students as active participants in their learning.
Adaptability of ESSC

- In order to design engaging calculus curricula, mathematics departments must consider the diverse needs of their students and implement strategies to ensure that all students can learn regardless of levels of preparedness.
- A main component of ESSC is active learning, which has been shown to help increase student learning. Active learning techniques can be easily adapted to fit a variety of learning settings.
- The familiarity of the Bloom’s Taxonomy framework increases the ability of ESSC to be reproduced by a wide range of institutions of higher education.
Ongoing Research Study
Ongoing Research

• Current undergraduate mathematics research is focused on face-to-face, hybrid, and online teaching and learning.

• The aim of this new study is to identify, implement, and disseminate information about best practices in undergraduate mathematics courses, particularly for students at HBCUs and students who are underrepresented minorities.
Future Work
Future Directions

- Reimagining undergraduate STEM education in the midst of COVID-19
- Identifying best practices for mathematics face-to-face, hybrid, and remote instruction
- Effectively using technology (clickers, videos, online learning platforms, learning management systems, etc.) to teach undergraduate mathematics
- Contributing to the achievement of inclusive excellence in STEM higher education
Thank you!
Any Questions?
References


Tennessee State University Office of Institutional Effectiveness.