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A Systematic Review of Models for Calculus Course Innovations

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Abstract

Engineering programs employ a variety of approaches for improving student retention. Often, students leaving engineering cite difficulties in their calculus courses as a major contributor to their attrition. Specifically, students cite that early calculus classes lack practicality and seem disconnected from their engineering majors. Some researchers even argue against the necessity of many calculus concepts for success in later engineering courses. Consequently, many institutions are seeking to redefine and improve calculus experiences to retain engineering students. Indeed, a growing body of literature discusses innovations in calculus content, pedagogy, and/or course formats. A comprehensive review of prior efforts to improve calculus courses is needed to synthesize the effectiveness of available intervention models, as well as identify areas of needed work.

A systematic review of ASEE conference proceedings was conducted to identify models for promoting success in undergraduate calculus courses. First, a search of the ASEE PEER database for articles with “calculus” in the title yielded 101 results. Of the 101 papers retrieved from the database, 49 were identified to include a reproducible report of a calculus course innovation. Retained records were synthesized based on several emergent themes: Key Innovators and Innovation Format, Pedagogies Employed, Assessment Tools, and Degree of Reproducibility. Discussion of retained records will be used to provide a set of proven strategies for enhancing student learning of calculus that can be implemented to encourage persistence in engineering.

Introduction

For first-year engineering majors, calculus is considered a gateway course to success in future courses. Calculus forms the basis for all subjects in engineering, and it is used extensively in all disciplines of engineering education. Gainen and Willemsen [1] assert that calculus provides the foundation for future engineering courses. Without a good foundation in calculus, engineering majors will have difficulty in applying the knowledge in their junior or senior level courses. Many aspects of engineering require an application of calculus such as: design of storm drain and open channel systems; calculation of forces in complex configurations of structural elements; analysis of beams (i.e., shear forces, bending moment, deflection, stress distribution); analysis of structure relating to seismic design; design of a pump based on flow rate and head; calculations of bearing capacity, lateral earth pressure, and shear strength of soil; computation of earthquake induced slope displacements from strong ground motion acceleration time history; and the list goes on.

The importance of freshman engineering majors succeeding in calculus has been emphasized in several studies [1]. Due to poor performance in calculus by many freshmen, calculus has attracted an unprecedented level of interest [2]. Many freshmen engineering majors fail their calculus courses [3]. At many institutions, the most common reason freshman engineering majors switch to a different major is failure in a calculus course. Early student departure from engineering programs has become a grave concern in an era of declining interest among youth in pursuing a future in technology [4] – [5], coupled with high global demand for qualified engineering graduates [6]. Several strategies have been proposed and implemented to increase retention in engineering programs [7] – [12]. Some of the most commonly used techniques consist of addressing attrition related to calculus courses [9] – [10]. Some institutions have offered calculus courses with significant engineering content highlighting the applicability of calculus topics to solving engineering problems [8] – [9]. The inability of incoming students to successfully advance past the traditional freshman calculus sequence remains a primary cause of attrition in engineering programs across the country [13] – [14].

The Citadel is embarking on a project to improve the calculus experience of engineering students in order to enhance learning and promote retention. Before designing and implementing changes, a systematic review of calculus course interventions in the American Society for Engineering Education (ASEE) Papers on Engineering Education Repository (PEER) was conducted. The following research questions guided the review.

1. Which stakeholders initiate and execute calculus course innovations?
2. Are changes in course structure needed to implement calculus course innovations?
3. Which pedagogies are typically employed in calculus course innovations?
4. Which assessment tools and methods are used to capture efficacy?

Ultimately, the above research questions will be answered to provide broad insights on best practices for re-designing calculus courses, as well as identify areas for further work.

Systematic Review Methods

A review of ASEE conference proceedings that report on innovations in calculus courses was completed using the guidelines presented by Borrego, Foster, and Froyd [15]. Inclusion criteria were specified and records from the ASEE PEER database were screened and appraised based on their abstracts and full texts, respectively. Retained records were synthesized to provide broad insights on how to transform undergraduate calculus courses to encourage student learning and retention. Screening, appraisal, and synthesis of each record was conducted by one of three researchers.

Guiding Questions and Inclusion Criteria

The research questions above were used to guide the literature review. In addition, three inclusion criteria were specified to identify useful research records:

1. The study was published during 2005 to 2018.
2. The study presents an effort to improve the design and delivery of an undergraduate calculus course.
3. The course innovation is presented in enough detail to allow other institutions to implement similar changes.

Searching, Screening, and Appraising

The ASEE PEER database was searched to identify proceedings that present calculus course innovations. A search for any record with [calculus] in the title yielded 101 published since 2005.

Abstracts for the 101 records were screened against the inclusion criteria. Forty-seven records met all inclusion criteria, while 31 records violated one or more inclusion criteria. Most commonly, excluded abstracts reported on predicting calculus performance based on one or more independent variables (i.e., no calculus course innovation). The remaining 23 records did not include enough detail in their abstracts to determine their applicability to the study; therefore, they were retained to be appraised by their full texts.

In total, 70 records were retained for full text appraisal. Through review of full texts, 21 additional records were excluded for not including a calculus course innovation. Consequently, the remaining 49 records were qualitatively synthesized to provide insights into common tools and methods for improving calculus instruction.

Synthesis of Retained Records

Full texts of remining records were synthesized to provide data to inform the design and delivery of calculus course innovations. Based on notes recorded during the screening phase, emergent themes were identified: Key Innovators and Innovation Format (Table 1), Pedagogies Employed (Table 2), Assessment Tools (Table 3), and Degree of Reproducibility (Table 4). Several categories within each theme were specified. Each retained record was categorized accordingly.

Table 1. Description of categories within the Key Innovators and Innovation Format theme.

Innovators/Structure	Description	Example
Math faculty implement changes within calculus course	Math faculty are the primary implementing stakeholders who implement changes within their courses	Math faculty at Boise State transformed Calculus I into "a single coherent multi-section course with an active-learning pedagogical approach [16]"
Engineering faculty implement changes within calculus course	Engineering faculty visit calculus courses to engage students.	An engineering faculty at the University of Tennessee Knoxville visited precalculus courses every other week to show applications of precalculus for engineering [17].
Math and/or Engineering stakeholders lead parallel applications-based experience	Students complete an extra experience (course, seminar, lab, etc.) along with their calculus course to learn about engineering applications	At the University of Central Florida, students take Apps I with Calculus I where engineering professors demonstrate where calculus appears in upper level courses [18].
Math and/or engineering faculty lead math skills experience	Students engage in an in-person or online experience to improve math preparedness before or during their first college math course.	Nite et al. [19] reported on an online experience to prepare students for a math placement exam. Online components included practice problems, quizzes, example videos, and required time with an online tutor.
Other	Any innovation structure not outlined above.	At the University of North Dakota, Calculus I and II students were recruited into an option mentoring program with engineering faculty to learn about engineering applications [20].

Table 2. Description of categories within the Pedagogies Employed theme.

Pedagogy	Description	Example
Technology	Use of technology to enhance student learning, including the use of software and/or online learning environments.	Faculty at Tecnologico de Monterrey use augmented reality to foster spatial visualization in calculus courses [21].
Problem/project-based learning	Use of real-world problems and/or projects to scaffold learning of calculus concepts.	At the University of West Virginia, freshmen engineering and calculus instructors developed projects that spanned both courses [22].
Group work	Students interact with peers to learn about and/or practice calculus concepts and skills.	Students work in small groups to solve motivating examples that align with a student outcome related to teamwork and collaboration [23].
Games	Use of games, virtual or in-person, to motivate calculus learning	Faculty at Old Dominion University use CAPTIVATE, a computer game that mimics well-known computer and board games, to help students master calculus skills [24].
Flipped classroom	Direct instruction occurs before class and class time is used for practice and applications.	Before class, students watched instructional videos and class time was focused on computer lab work and group exercises [25].

Table 3. Description of categories within the Assessment Methods theme.

	Description	Example
Student reflections	Students are asked to report on their perceptions of the course innovation(s), typically using Likert scales and/or open response questions.	A five-point scale was used to ask students about the impacts of an engineering professor visiting precalculus courses [17].
Pre/post problems	Students complete a set of calculus problems before and after the intervention.	Pre- and post-test scores were compared between groups completing and not completing a parallel engineering applications course [26].
Grades	Final course grades are used to infer impact of a calculus course innovation.	Calculus I and II course grades were compared between groups taking a two-semester Calculus I course and those taking a one-semester Calculus I course [27].
Retention data	Persistence rates in engineering are compared before and after a major change in calculus courses or sequences	Retention in STEM was used to measure success of a major re-design of Calculus II at Boise State University [28].
Validated instrument	An instrument that has previously been shown to be valid and reliable for capturing changes in students knowledge, skills, and/or attitudes towards calculus is used.	The Mathematics Applications Inventory was rigorously developed and used to capture changes in basic mathematical skills resulting from collaborative problem-solving workshop [29].
Use of control group (in any of the above)	Impacts from an innovative calculus course are compared to a similar traditional course.	DFW rates were statistically compared between traditional and innovative multivariable calculus courses [30].

Table 4. Description of categories within the Degree of Reproducibility theme.

	Description	Example
Description/details available	The paper describes the major components of the innovation.	Information on the creation of multiple calculus tracks, based on math preparedness, are provided [31]
Materials available	The paper provides tangible resources for reproducing the innovation.	Motivating examples and mini-problems for a KEEN-sponsored integral calculus course are provided online [23].

Systematic Review Results

Analysis of Results by ASEE Division

Of the 49 records retained, most were published in the Mathematics Division (69.4%) of ASEE. Other divisions hosting papers related to improving undergraduate calculus learning included First Year Programs (12.2%), NSF Grantees Poster Session (6.1%), Engineering Physics & Physics (2.0%), Experimentation and Laboratory-Oriented Studies (2.0%), Biomedical Engineering (2.0%), and Military and Veterans (2.0%). Three papers (4.1%) published in 2005 were not published within ASEE divisions as they currently exist.

Analysis of Results by Target Classes

Most frequently faculty implemented innovations within typical first-year calculus courses (Table 5). Specifically, 59.2% and 30.6% of retained records reported modifications to or in support of Calculus I and II, respectively. Fewer retained records reported modifications to or in support of Calculus III (18.4%) and Calculus IV (4.1%). As some students arrive to engineering programs with insufficient math preparation, 26.5% of retained records reported modifications to or in support of Precalculus.

Some retained records (6.1%) focused on innovation of courses outside of the typical math sequence. Carpenter [32] describes integrating calculus concepts into introductory chemistry, biology, and physics courses to illustrate connections between math and the natural sciences. Lewis and Hieb [33] discuss integration of an online math learning platform in an existing first-year engineering course. Lowery et al. [22] present an initiative to implement projects that span across calculus and engineering courses.

Table 5. Retained records by targeted class(es) (n = 49).

	Frequency (-)	Percentage (%)
Calculus I	29	59.2
Calculus II	15	30.6
Precalculus	13	26.5
Calculus III	9	18.4
Other	3	6.1
Calculus IV	2	4.1

Analysis of Retained Records by Key Innovators and Innovation Format

Most calculus innovations were implemented by math faculty within traditional calculus courses (61.2%), although other key innovators also initiated change through other course formats (Table 6). For instance, 18.4% of retained records described implementation of a parallel engineering-focused course or seminar to demonstrate the importance of math for engineering. Even still, 12.2% of retained records reported on creation of course(s) and/or seminar(s) designed to provide students with prerequisite math skills to succeed in a traditional calculus sequence. Also, 10.2% of retained records reported on innovations led by engineering faculty implemented within traditional calculus courses.

Three retained records (7.7%) described key innovators and/or innovation formats not captured in the coding scheme. As previously discussed, Carpenter [32] presents improvements to natural science courses as a way to improve math skills. Dominguez et al. [34] describes an integrated calculus and physics course. Smith et al. [24] worked with a team composed for engineers and mathematicians to develop a virtual game to improve math skills, although the learning environment that the game will be implemented is not reported.

Table 6. Retained records classified by key innovators and/or innovation format (n = 49).

	Frequency (-)	Percent (%)
Changes lead by math faculty within calculus courses	30	61.2
Math and/or engineering faculty lead parallel applications course	9	18.4
Math and/or engineering faculty lead math skills course	6	12.2
Changes led by engineering faculty within calculus courses	5	10.2
Other	3	7.7

Analysis of Retained Records by Pedagogies Employed

All retained records used active pedagogies to enhance math learning (Table 7). Many (59.2%) included the use of technology (e.g., adaptive learning systems) to enhance student learning. Nearly half (49.0%) of retained records included the use of project- or problem-based learning to provide students to practice math skills in the context of relevant scenarios. Encouraging group working and learning was also very common within retained records (44.9%). The use of games (8.2%), demonstrations (6.1%), and flipped classroom (4.1%) approaches were reported less frequently.

Table 7. Retained records classified by pedagogies employed (*n* = 49).

	Frequency (-)	Percent (%)
Technology	29	59.2
Project/Problem Based Learning	24	49.0
Group work/Peer	22	44.9
Games	4	8.2
Demonstrations	3	6.1
Flipped Classroom	2	4.1

Analysis of Retained Records by Assessment Tools and Methods

Most retained records (73.5%) used assessment tools and methods to capture the efficacy of innovations (Table 8). The most commonly employed assessment method was statistical analysis of grades (46.9%) for calculus and related non-calculus courses. Nearly one-third of retained records (32.7%) used student reflections or self-report surveys to capture student perceptions of innovations. Some retained records used retention data (12.2%) and/or scoring of pre/post calculus problems (8.2%). A small percentage (4.1%) of retained records used rigorously-developed instruments.

Table 8. Retained records classified by assessment tools and methods employed (*n* = 49).

	Frequency (-)	Percent (%)
Analysis of course grades	23	46.9
Student reflection/Self-report	16	32.7
Use of control group in statistical analyses	10	20.4
Retention data	6	12.2
Pre/Post problems	4	8.2
Validated instrument	2	4.1

Analysis of Retained Records by Degree of Reproducibility

Overall, 22 retained records (44.9%) included tangible materials that could be implemented at other institutions (Table 9). Several records reported problems or activities within the publication (24.5%), while several others provided information on publicly available learning platforms (16.3%). Two records (4.1%) provided external websites with course materials.

Table 9. Tangible teaching and learning resources reported in retained records (*n* = 49).

	Frequency (-)	Percent (%)	References
Problems/projects provided in paper	12	24.5	[11], [17], [20], [22], [26], [32], [34] – [39]
Active website with materials	2	4.1	[23], [25]
Available learning platforms[1]	8	16.3	[33], [40] – [46]

[1]Examples include SimCalc, ALEKS, DyKnow, and MyMathLab

Discussion

What practices for implementing effective innovations to enhance calculus learning are illustrated in the literature?

Most frequently, improvements to traditional calculus courses are made with math faculty often leading the transformations (Table 1). While there were exceptions, most institutions described the re-design of one or more courses in the typical Calculus I-IV progression, with improvements to Calculus I being most common in the literature. Often, one of the goals for initiating reforms was first-year retention within engineering majors. Consequently, it seems that most institutions tended to focus on the calculus courses most commonly taken by first-year students.

Creating an engaging learning environment is important for promoting student learning in calculus courses. Indeed, all of the retained records described one or more active learning pedagogies as part of calculus course improvements (Table 2). Three tools and methods were common for eliciting student participation. In particular, online-learning-platforms (i.e., technology), was described as a way to engage students and provide frequent assessment of learning, as well as manage the workload for large classes. In addition, the use of problems and projects to provide real-world context for students was shown to be impactful. Often, engagement in applied problems and projects was completed in groups to allow peers to teach and learn from each other. The use of technology, project- and problem-based learning, and group learning have been presented as effective teaching and learning methods beyond calculus courses as well (e.g., [47] – [48]).

For most groups reporting in the ASEE literature, assessment was an important step in the calculus transformation process. Tracking of course grades, either in the target calculus course(s) or subsequent courses, was the most common method of assessment. Use of course grades is likely the most convenient method, although variability between instructors may limit comparability between institutions. Collecting student perceptions of learning, usually through Likert-type surveys, was also commonly employed. Considering the student perspective may be especially important, since resistance to active learning has been observed [47].

What gaps exist in the literature related to implementing calculus course innovations?

One clear gap in the literature is the lack of readily-available materials to allow for transfer of reported innovations to other institutions. While some authors provided sample materials within the publications, others provided links to external websites (Table 9). One observation was that some websites provided within publications were no longer active. Perhaps, given the lack of a page limit for ASEE proceedings, inclusion of appendices with course materials would allow a more permanent record.

In addition, development and/or use of rigorously-developed instruments could lend validity to results and facilitate comparisons between interventions and institutions. Schneider and Terrell

[29] reported on the use of certain sub-scales from the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument. They also reported on the development of the Mathematics Applications Inventory through a Delphi study using courses and faculty at Cornell University, although the validation process nor the instrument itself was provided [29]. Ma et al. [31] used the Student Assessment of Learning Gains instrument, which is not course-specific.

Finally, most calculus course innovations were led by math faculty within traditional math courses. Assembling teams that include math and engineering faculty to both reform and instruct courses and/or seminars may provide improved potential for enhancing student learning. Math faculty have important insights on how to teach math concepts (i.e., pedagogical content knowledge), while engineering faculty have important insights on which math concepts will be needed for success in engineering curricula. In addition, as integration of project- and problem-based learning was a common strategy for improving calculus courses, engineering faculty could provide relevant context and examples for these types of reforms. Of course, inter-departmental teaching collaborations may be difficult (e.g., teaching loads, student evaluations, etc.). Nevertheless, collaboration between engineering and math departments could lead to truly innovative calculus experiences for engineering students.

Conclusions

A systematic review of ASEE PEER proceedings with *Calculus* in the title was conducted by three researchers. Of the 101 papers retrieved from the database, 49 were identified to include a reproducible report of a calculus course innovation. The following conclusions were made after retained full texts were synthesized based on several emergent themes: Key Innovators and Innovation Format, Pedagogies Employed, Assessment Tools, and Degree of Reproducibility.

1. Most efforts have focused on improving learning in typical first-year calculus courses (Calculus I and II). Even though retention in engineering is not usually a concern by the time a student progresses to Calculus III and IV, learning in these classes could be enhanced by implementing many of the strategies employed for earlier classes.
2. Educators have focused on the re-design of traditional calculus courses. Additional collaborations between math and engineering faculty to align related courses could be impactful.
3. A limited number of records included tangible materials that could be used by other educators. A centralized, online database to host shareable materials would widen application of successful innovations.
4. Impact of calculus innovations could be better captured through the use of more rigorous assessment, including design/use of validated instruments and comparison to control groups (when possible).

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APPENDIX A:
Summary of Retained Records

The ASEE PEER database was searched to identify proceedings that present calculus course innovations. A search for any record with [calculus] in the title yielded 101 published since 2005.

Abstracts for the 101 records were screened against the inclusion criteria. Forty-seven records met all inclusion criteria, while 31 records violated one or more inclusion criteria. Most commonly, excluded abstracts reported on predicting calculus performance based on one or more independent variables (i.e., no calculus course innovation). The remaining 23 records did not include enough detail in their abstracts to determine their applicability to the study; therefore, they were retained to be appraised by their full texts.

In total, 70 records were retained for full text appraisal. Through review of full texts, 21 additional records were excluded for not including a calculus course innovation. Consequently, the remaining 49 records were qualitatively synthesized to provide insights into common tools and methods for improving calculus instruction.

Integrating Calculus And Introductory Science Concepts	2007 Annual Conference & Exposition, Honolulu, Hawaii	Jenna Carpenter, Louisiana Tech University	https://peer.asee.org/2021
Predicting Student Preparedness In Calculus	2006 Annual Conference & Exposition, Chicago, Illinois	Jenna Carpenter, Louisiana Tech University; Ruth Ellen Hanna, Louisiana Tech University	https://peer.asee.org/1428
Predicting Student Success In Calculus	2007 Annual Conference & Exposition, Honolulu, Hawaii	Jenna Carpenter, Louisiana Tech University; Ruth Ellen Hanna, Louisiana Tech University	https://peer.asee.org/1490
Longitudinal Success of Calculus I Reform	2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana	Doug Bullock, Boise State University; Kathrine E. Johnson; Janet Callahan, Boise State University	https://peer.asee.org/25580
Comparison of Paths to Calculus Success	2012 ASEE Annual Conference & Exposition, San Antonio, Texas	Robin A.M. Hensel Ed.D., West Virginia University; Todd R. Hamrick Ph.D., West Virginia University	https://peer.asee.org/21092
Engineering Introduction in Pre-Calculus Courses	2013 ASEE Annual Conference & Exposition, Atlanta, Georgia	Richard M. Bennett, University of Tennessee, Knoxville; Margaret Helen Russell, University of Tennessee, Knoxville; Claudia J Rawn, University of Tennessee, Knoxville	https://peer.asee.org/19526
Excel In Mathematics: Applications Of Calculus	2010 Annual Conference & Exposition,	Cynthia Young, University of Central Florida; Michael Georgiopoulos, University of Central Florida; Tace Crouse, University of Central Florida; Alvaro Islas,	https://peer.asee.org/15744

	Louisville, Kentucky	University of Central Florida; Scott Hagen, University of Central Florida; Cherie Geiger, University of Central Florida; Melissa Dagley-Falls, University of Central Florida; Patricia Ramsey, University of Central Florida; Patrice Lancey, University of Central Florida	
Redesign of Calculus Curriculum in Engineering	2017 ASEE Annual Conference & Exposition, Columbus, Ohio	Hui Ma, University of Virginia; Gianluca Guadagni, University of Virginia; Stacie N. Pisano, University of Virginia, School of Engineering and Applied Science; Bernard Fulgham, University of Virginia; Monika Abramenko, University of Virginia; Diana D Morris, University of Virginia	https://peer.asee.org/28783
Redesigned Application-oriented Integral Calculus Curriculum	2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah	Leszek Gawarecki, Kettering University; Yaomin Dong, Kettering University; Gina Rablau, Kettering	https://peer.asee.org/30921
Students With Calculus Credit: What Can We Do?	2007 Annual Conference & Exposition, Honolulu, Hawaii	Elton Graves, Rose-Hulman Institute of Technology	https://peer.asee.org/2135
Integration Of Engineering Concepts In Freshman Calculus	2007 Annual Conference & Exposition, Honolulu, Hawaii	John Quintanilla, University of North Texas; Nandika D'Souza, University of North Texas; Jianguo Liu, University of North Texas; Reza Mirshams, University of North Texas	https://peer.asee.org/2522
Leveling the Playing Field: Preparing Students for Calculus	2012 ASEE Annual Conference & Exposition, San Antonio, Texas	Deborah Worley, University of North Dakota; Jeremiah J. Neubert, University of North Dakota; Naima Kaabouch, University of North Dakota; Mohammad Khavanin, University of North Dakota	https://peer.asee.org/21654

Redesigning the Calculus Curriculum for Engineering Students	2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah	Stacie Pisano, University of Virginia; Hui Ma, University of Virginia; Bernard Fulgham, University of Virginia; Gianluca Guadagni, University of Virginia; Diana D Morris, University of Virginia; Monika Abramenko, University of Virginia	https://peer.asee.org/30922
The Crux: Promoting Success in Calculus II	2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah	Doug Bullock, Boise State University; Janet Callahan, Boise State University; Jocelyn B. S. Cullers, Boise State University	https://peer.asee.org/31085
Integrating Applications In The Technion Calculus Course: A Supplementary Instruction Experiment	2006 Annual Conference & Exposition, Chicago, Illinois	Shuki Aroshas, Technion-Israel Institute of Technology; Igor Verner, Technion-Israel Institute of Technology; Avi Berman, Technion - Israel Institute of Technology	https://peer.asee.org/700
Emphasizing Teamwork And Communication Skills In Introductory Calculus Courses	2007 Annual Conference & Exposition, Honolulu, Hawaii	Martha Allen, Georgia College & State University; Amy Kelley, Georgia College & State University	https://peer.asee.org/2166
Peer-Led Team Learning in an Introductory Calculus Course	2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana	James E. Lewis, University of Louisville; Gerold Willing, University of Louisville; Thomas D. Rockaway, University of Louisville	https://peer.asee.org/25874
Fostering Spatial Visualization Through Augmented Reality in Calculus Learning	2015 ASEE Annual Conference & Exposition, Seattle, Washington	Patricia Salinas, Tecnologico de Monterrey (ITESM); Eliud Quintero, Tecnologico de Monterrey (ITESM); Pablo Guillermo Ramirez, Tecnologico de Monterrey (ITESM); Eduardo GonzÃ¡lez MendÃvil, Tecnologico de Monterrey (ITESM)	https://peer.asee.org/24129

Coherent Calculus Course Design: Creating Faculty Buy-in for Student Success	2015 ASEE Annual Conference & Exposition, Seattle, Washington	Doug Bullock, Boise State University; Janet Callahan, Boise State University; Susan E. Shadle Ph.D., Boise State University	https://peer.asee.org/23694
Contextualizing Calculus with Everyday Examples to Enhance Conceptual Learning	2015 ASEE Annual Conference & Exposition, Seattle, Washington	Khalid El Gaidi, Royal Institute of Technology (KTH); Tomas Ekholm, Royal Institute of Technology (KTH)	https://peer.asee.org/23740
Integrating digital technology for the innovation of Calculus curriculum	2013 ASEE Annual Conference & Exposition, Atlanta, Georgia	Patricia Salinas, ITESM; Eliud Quintero, ITESM	https://peer.asee.org/19784
A Comprehensive Approach on Delivering Calculus to Engineering Students	2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana	Charles C.Y. Lam, California State University, Bakersfield; Melissa Danforth, California State University, Bakersfield; Ronald Hughes, CSUB STEM Affinity Group	https://peer.asee.org/19927
Creating Laboratories to Aid Student Modeling Ability in Calculus I	2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah	Ashley Bernal, Rose-Hulman Institute of Technology; Jeffery J. Leader, Rose-Hulman Institute of Technology; Jessa B. Ward, Rose-Hulman Institute of Technology	https://peer.asee.org/30235
Design of an International Bridge Program for Engineering Calculus	2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah	Sandra B. Nite, Texas A&M University; Brady Creel, Texas A&M University at Qatar; Jim Morgan, Charles Sturt University; Jowaher E. Almarri	https://peer.asee.org/30268
Unlocking the Gate to Calculus Success: Pre-Calculus for Engineers	2013 ASEE Annual Conference &	Tanya D Ennis, University of Colorado Boulder; Jacquelyn F. Sullivan, University of Colorado, Boulder;	https://peer.asee.org/22670

- An Assertive Approach to Readying Underprepared Students	Exposition, Atlanta, Georgia	Beverly Louie, University of Colorado, Boulder; Daniel Knight, University of Colorado, Boulder	
Adapting And Implementing The Scale Up Approach In Statics, Dynamics, And Multivariate Calculus	2007 Annual Conference & Exposition, Honolulu, Hawaii	Lisa Benson, Clemson University; Sherrill Biggers, Clemson University; William Moss, Clemson University; Matthew Ohland, Purdue Engineering Education; Marisa Orr, Clemson University; Scott Schiff, Clemson University	https://peer.asee.org/2354
Using A Web Based Homework System To Improve Accountability And Mastery In Calculus	2008 Annual Conference & Exposition, Pittsburgh, Pennsylvania	Jenna Carpenter, Louisiana Tech University; Brian Camp, Louisiana Tech University	https://peer.asee.org/4426
Utilizing an Emporium Course Design to Improve Calculus Readiness of Engineering Students	2015 ASEE Annual Conference & Exposition, Seattle, Washington	Virgil U. Pierce, University of Texas, Pan American; Javier Angel Kypuros, University of Texas, Pan American	https://peer.asee.org/25028
Emerging Themes in a Distance-Delivered Calculus I Course: Perceptions of Collaboration, Community, and Support	2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana	Angela Minichiello, Utah State University; Joshua Marquit, Utah State University ; Jim Dorward, Utah State University; Christine E. Hailey, Utah State University	https://peer.asee.org/20367
Emphasizing Core Calculus Concepts Using Biomedical Applications to Engage, Mentor, and Retain STEM Students	2012 ASEE Annual Conference & Exposition, San Antonio, Texas	John D. DesJardins, Clemson University; Ellen Breazel, Clemson University; Marilyn Reba, Clemson University; Irina Viktorova, Clemson University; Jonathan Bradford Matheny, Clemson University; Taufiquar R. Khan	https://peer.asee.org/21279

Using MyMathLab for Learning Reinforcement in the Classroom and Attendance Data for Engineering Calculus	2013 ASEE Annual Conference & Exposition, Atlanta, Georgia	James E. Lewis, University of Louisville; Jeffrey Lloyd Hieb, University of Louisville	https://peer.asee.org/22715
Closing the Gap Between Physics and Calculus: Use of Models in an Integrated Course	2015 ASEE Annual Conference & Exposition, Seattle, Washington	Angeles Dominguez, Tecnologico de Monterrey & Universidad AndrÃ©s Bello; Jorge Eugenio de la Garza Becerra, Tecnologico de Monterrey (ITESM)	https://peer.asee.org/23692
The Inverted Classroom in Introductory Calculus: Best Practices and Potential Benefits for the Preparation of Engineers	2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana	Robert Talbert, Grand Valley State University	https://peer.asee.org/23166
Impact of Collaborative Problem-solving Workshops in Engineering Calculus Course on Applied Mathematical	2011 ASEE Annual Conference & Exposition, Vancouver, BC	Lisa Schneider, Cornell University; Maria Terrell, Cornell University	https://peer.asee.org/18079
Using Undergraduate Mentors to Deliver Engineering Content to Calculus for Increased Persistence in Engineering	2011 ASEE Annual Conference & Exposition, Vancouver, BC	J. Neubert, University of North Dakota; Deborah Worley, University of North Dakota; Naima Kaabouch, Electrical Engineering Department, University of North Dakota	https://peer.asee.org/18972
Preparing Engineering Students to Take a Calculus Course: An Engineering-Oriented Approach	2011 ASEE Annual Conference & Exposition, Vancouver, BC	Kristi J. Shryock, Texas A&M University; Arun R. Srinivasa, Texas A&M University, Department of Mechanical Engineering; Jefferey E. Froyd, Texas A&M University	https://peer.asee.org/18704

Student Learning Modules in Trigonometry and Integral Calculus using LEGO MINDSTORMS NXT	2011 ASEE Annual Conference & Exposition, Vancouver, BC	Byron L Newberry, Oklahoma Christian University; Cory R. Davis, Oklahoma Christian University; Robert Andrew Stevenson, Oklahoma Christian University	https://peer.asee.org/18718
Building A Foundation For Pre Calculus Engineering Freshman Through An Integrated Learning Community	2005 Annual Conference, Portland, Oregon	Susanne Green; Michele Auzenne; Chris Burnham; Ricardo Jacquez	https://peer.asee.org/15060
Joint Math Engineering Projects To Facilitate Calculus Success In First Year Students	2010 Annual Conference & Exposition, Louisville, Kentucky	Andrew Lowery, West Virginia University; Steve Kane, West Virginia University; Vicki Kane, West Virginia University; Robin Hensel, West Virginia University; Gary Ganser, West Virginia University	https://peer.asee.org/16865
Breaking The Cycle Of Calculus Failure: Models Of Early Math Intervention To Enhance Engineering Retention	2008 Annual Conference & Exposition, Pittsburgh, Pennsylvania	Robin Hensel, West Virginia University; J. Ryan Sigler, West Virginia University; Andrew Lowery, West Virginia University	https://peer.asee.org/4172
CCLI: Evaluation of a Cost Effective Program for Augmenting Calculus with Engineering Content	2013 ASEE Annual Conference & Exposition, Atlanta, Georgia	Jeremiah J. Neubert, University of North Dakota; Deborah Worley, University of North Dakota; Naima Kaabouch, University of North Dakota; Mohammad Khavanin, Professor of Mathematics at University of North Dakota	https://peer.asee.org/19289
A Study of the Effects of Early Remediation in Prerequisite Material in a Calculus I Course	2013 ASEE Annual Conference & Exposition, Atlanta, Georgia	Jennifer Vandenbussche, Southern Polytechnic State University	https://peer.asee.org/19126

Flipping Calculus for Engineering Students: Pre-class Assignments and Readiness Assessment Strategies	2017 ASEE Annual Conference & Exposition, Columbus, Ohio	Jeffrey Lloyd Hieb, University of Louisville; William B. Corley, University of Louisville; Jaqi C. McNeil, University of Louisville	https://peer.asee.org/28369
Calculus I Course Policy Changes and Impact on Various Demographic Student Group Success	2017 ASEE Annual Conference & Exposition, Columbus, Ohio	Paran Rebekah Norton, Clemson University; Karen A. High, Clemson University; William Bridges, Clemson University	https://peer.asee.org/27999
Improving Performance in Trigonometry and Pre-Calculus by Incorporating Adaptive Learning Technology into Blended Models on Campus	2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana	Jennifer B. Daines, Colorado Technical University; Tonya Troka, Colorado Technical University; John M. Santiago Jr., Colorado Technical University	https://peer.asee.org/25624
An Optimizing Learning Strategy Employing A Selection Of Online And Onsite Modalities To Achieve The Outcomes Of A Calculus Course	2010 Annual Conference & Exposition, Louisville, Kentucky	Murray Teitell, DeVry University, Long Beach; William Sullivan, DeVry University	https://peer.asee.org/16547
Overview of Game and Content Design for a Mobile Game that will Prepare Students in Calculus and Physics Prerequisites to the Engineering Curriculum	2017 ASEE Annual Conference & Exposition, Columbus, Ohio	Katherine Smith, Old Dominion University; John Shull, Old Dominion University; Patrick Sean Heaney, Old Dominion University; Yuzhong Shen, Old Dominion University; Anthony W. Dean, Old Dominion University; Jennifer Grimsley Michaeli P.E., Old Dominion University	https://peer.asee.org/28729
Calculus Reform - Increasing STEM Retention and Post-Requisite Course Success While Closing the Retention Gap for Women and	2017 ASEE Annual Conference &	Doug Bullock, Boise State University; Janet Callahan, Boise State University; Jocelyn B. S. Cullers, Boise State University	https://peer.asee.org/28000

Underrepresented Minority Students	Exposition, Columbus, Ohio		
Guided-Lecture Team Based Learning at Work: Teaching Differential Calculus to Part-time Engineering Students in Latin America.	2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah	Jose Roberto Portillo, Universidad Galileo; Alberth E Alvarado, Universidad Galileo; Jorge Samayoa Ranero, Universidad Galileo	https://peer.asee.org/30567