SCALE-UP Instructional Redesign of a Calculus Course at an HBCU

[a]Paramanathan Varatharajah, [1] [a]D.P. Clemence-Mkhope, [a]Janis M. Oldham, [a]Barbara Tankersley, [a]Seong-Tae Kim, [b]Belinda G. B. Clemence-Mkhope, [a]Kathy Cousins-Cooper, [a]Choongseok Park

[a]Department of Mathematics, North Carolina A&T State University, Greensboro, NC, USA
[b]Office of Institutional Research and Decision Support, Forsyth Technical Community College, Winston-Salem, NC, USA
[1]To whom correspondence should be addressed. E-mail: clemence@ncat.edu

Abstract

It is now generally accepted that many students enter college severely underprepared for their mathematics college courses in terms of basic skills and study habits, and that intervention is expected to overcome these deficiencies. As a result, many mathematics departments nationwide have over the last two decades redesigned their algebra and calculus courses to incorporate technology and active learning in various combinations, some of which have utilized extensive learning space designs. This article is a preliminary report of one Historically Black College or University's (HBCU) experience with its redesign of the first semester of Calculus for STEM Majors that resulted in a course-wide partial implementation of the Student-Centered Active Learning Environments with Upside-down Pedagogies (SCALE-UP) method. Preliminary results show that the redesign, enabled by institutional and external resource coordination, has led to moderate improvements in course pass rates, from a normal of 40% and below to a new normal of above 50%. The pass/fail student profile suggests that weakness in pre-requisite skills is a major cause of failure.

Keywords: SCALE-UP, Calculus course redesign, learning spaces, learning outcomes, HBCU

1. Introduction

While incoming freshmen are generally under-prepared for college mathematics, in the United States the problem is worse for minorities. According to Noble & Sawyer (2004), a major cause of poor science, technology, engineering, and mathematics (STEM) degree completion rates for minorities is poor math proficiency and readiness: while 69% of all test-takers meet ACT benchmarks in English, only 43% do so in math. The gap by race is even more striking: in math, while 49% of whites meet the benchmarks, only 25% of Latinos and 12% of African Americans do. African-Americans therefore start college severely under-prepared, and thus unlikely to continue in a STEM major after failing a math course (Brainard & Carlin,1988; Adelman, 2006), which perpetuates their under-representation in STEM and fuels the national shortage of STEM professionals. As highlighted in Freeman et al (2014), the President's Council of Advisors on Science and Technology (PCAST) has recommended (PCAST, 2012) adoption of empirically validated teaching practices as critical to achieving a 34% increase in the number of STEM bachelor's degrees completed per year, their goal for combating the national shortage of STEM professionals.

The project reported here was conducted at North Carolina A&T State University (NCA&T), a mid-sized, high research activity Historically Black College or University (HBCU) and nationally top-ranked producer of African-American STEM undergraduates. Its population is over 85% African-American, with over 50% being first generation to attend college, over 80% qualified for need-based financial aid, and over 50% of incoming freshmen are from the lowest 50% of their graduating classes (Goins et al, 2016). Amongst the factors contributing most to risk of failure are poor academic preparation, social integration, and study skills; leading characteristics fueling these risks include being first generation to attend college, and coming from low-income families (Moses et al, 2011; Kuh et al, 2006; Lotkowski, Robbins, & Noeth, 2004; Noble & Sawyer, 2004) which correlates to attending low-performing high schools and/or being in the bottom half of one's high school class (Burkum, et al, 2010). Over 75% of incoming freshmen at this institution are therefore labelled by research as being at risk of failure. As reported in Goins et al (2016), when NCATSU was compared to majority institutions of similar size in the Wabash National Study of Liberal Arts Education (2009), too many NCA&T freshmen exhibited deficits in critical thinking and writing, as compared to freshmen at other institutions in the same study; Blaich & Wise (2011) further found that most NCA&T students lacked study habits conducive to success.

As in all institutions with a focus on STEM, Calculus I is a gatekeeper course for a varied range of high-demand majors: it is a required University General Education (Gen Ed) course for all STEM majors at NCA&T and is a prerequisite for a wide range of higher-level courses in various subjects, thus impacting the future career and life prospects of a large number of students. During the period of this study, incoming students were placed in mathematics courses according to their SAT/ACT scores or placement tests, with placements into Math 099 Hybrid (a developmental course), Math 101, Math 103, Math 110 or 111 (Pre-Calculus), or Math 131 (Calculus I); over 50 % are placed directly into Calculus I (Table 5). Most STEM majors thus enroll in Calculus I during an intense and often difficult transition from high school to college and are unable to make the transition to college-level math. After many years of poor pass rates, the first semester of Calculus for STEM Majors (Calculus I) at NCA&T was redesigned in 2012 using the Student-Centered Active Learning Environments with Upside-down Pedagogies (SCALE-UP) method (Beichner and Saul, 2004), with the long-term goal to increase pass rates to above 70%.

This article describes the spaces and course redesigns of Calculus 1 at NCA&T and presents preliminary data to address the following questions about the redesigned course: (1) Did the redesign improve pass rates? (2) Did the students' pre-course backgrounds affect their performance? (3) Was there a concept-learning gap between passing and failing students?

2. Methods

The redesigned learning spaces, including photographs from a tour of the redesigned spaces, are described against a wider background of technology-enhanced active learning (TEAL) spaces. A description is given of the course, including its history and evaluation, based on NCA&T Undergraduate Bulletins (2008-2016). Data provided by the NCA&T Office of Institutional Research (OIR) consisted of student gender (male/female), residency status (in-state/out-of-state), SAT and/or ACT scores, course taken prior to Calculus I (Math 099, Math 101/102/ Math 110, Math 111/112, or high school), and pass/fail status; while gender and pass rates were available for 2012-2016, data complete in all variables was available only for 2014-2016. For the control sample, the only data available from the OIR were the pass/fail rates, which were not segregated by gender. The pretest and posttest scores for the experimental group were obtained from the Mathematics Department; pretest/posttest scores were not available for the control group. The 2008-2012 pass rates are compared to the 2012-2016 rates to answer the first research question while the second and third questions are addressed from student profiles created from the available data.

3. Student Profile and Course History

3.1 Student Profile

For comparison purposes in this study, the experimental sample consists of the 2630 students enrolled in the Calculus I course during 2012-2016, and the control sample consists of the 3200 students in the traditional course during 2008-2012. The characteristics of the 2014-2016 experimental group in respect to the above variables (except the course taken prior to enrolling in Calculus I) are summarized in Table 1. The characteristics of the students in the experimental group during 2012-2014 and of those in the traditional course during 2008-2012 are assumed to be similar.

Table 1. Characteristics of Students in SCALE-UP Calculus I for 2014-2016

		Pass		**Fail**		
Variable	Category	Count	Percent	Count	Percent	P-value
Total		754	51.82	701	48.18	
Gender	Female	443	79.5	114	20.5	0.0553*
	Male	680	76.1	214	23.9	
Residency	In-state	519	48.1	561	51.9	<0.0001*
	Out-of-state	235	62.7	140	37.3	
		Mean	SD	Mean	SD	
SAT	Total	986.1	128.5	929.8	109.1	<0.0001†
	Math	509.1	71.0	479.5	62.6	<0.0001†
ACT	Math	22.0	3.5	20.7	3.1	<0.0001†
Pretest		15.0	4.7	12.0	3.8	<0.0001†

SD denotes the standard deviation; * chi-square test; † t-test. The p-values were calculated using either a two-sample t-test for mean or a chi-square test for proportion.

3.2 The Course and Performance History

Until Fall 2010, when it was changed to the version given in Section 5.2.1, the course description was the following: *Limits and continuity of functions, the derivative, applications of the derivative, the definite integral and applications of the definite integral will be studied. Prerequisite: Grade "C" in MATH 110 or appropriate equivalent.* Through the Spring 2012, all Calculus I was taught in the traditional lecture style, with four 50-minute lectures per week, and normal course section size of 45 students. There was no TA for the four lectures, there were no recitation sessions for the course, and class time consisted of lectures and very minimal or no other in-class activities. As shown in Table 2 below, pass rates were very low.

Table 2. Pass Rates for Calculus I with Traditional Lecture Method (2008-2012)

School Year	Students Enrolled (#)	Pass Rate (%)
2008-09	727	36.7
2009-10	857	38.9
2010-11	784	40.8
2011-2012	832	48
4-Year Total	**3200**	**41.2** (mean)

There existed a clear need to adapt and implement proven instructional approaches that would facilitate student engagement in complex problem solving, build higher level mathematical understanding, and cultivate the social skills and attitudes necessary for success. After consideration of several TEAL models, the SCALE-UP model was selected for Calculus I.

4. Innovative Learning Space and Course Redesigns

In response to the need for intervention, many colleges and universities have over the past two decades found innovative ways to redesign their Algebra (Twigg, 2011; Vallade, 2013; Williams, 2016; Cousins-Cooper et al, 2019; Webel et al., 2017) and Calculus courses (Monteferrante,1993; Frid, 1994; Bookman & Friedman, 1998, 1999; Schwingendorf, McCabe, &. Kuhn. 2000; Biggers et al. 2007; Bullock, Callahan, & Shadle, 2015), moving from traditional classrooms to some form of technology-enhanced learning environment. Some researchers consider space redesigns as inevitable to improving learning outcomes, arguing that technology-enhanced classrooms are the natural environment for today's technology natives (Park & Choi, 2014; Beichner, 2014; Dittoe, 2002); others argue that traditional classrooms may lead to anxiety and negative attitudes, with negative impacts on their likelihood of success in math (Hegeman, 2015; Lipnevich et al, 2011; Singh, Granville & Dika, 2002; Stevenson & Newman, 1986). Soneral & Wyse (2017) conclude that *classrooms may thus be facilitating an emerging but unintentional paradox: as increasing numbers of students become accustomed to active learning and reap its benefits, their classrooms lock them into a mold not suited for their learner-centered expectations.* In a meta-analysis of 225 TEAL studies, Freeman et al (2014) reported that across STEM disciplines *average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing* *were 1.5 times more likely to fail than were students in classes with active learning;* they conclude that their *results raise questions about the continued use of traditional lecturing as a control in research studies, and support active learning as the preferred, empirically validated teaching practice in regular classrooms.*

The SCALE-UP model is one TEAL method that has been widely adopted across disciplines and shown to be effective in improving course retention and overall performance (Beichner et al, 2007; Foote et al, 2014), and for Calculus in particular (Roop et al, 2018; Zachary & Biggers, 2007), with an increase from 56.4 % to 77.4 % reported by Zachary & Biggers (2007). However, not all secondary TEAL implementations improve learning outcomes (Stoltzfus & Libarkin, 2016) and even those that do may not improve outcomes for everyone (Webel et al, 2017). Finding no significant improvement of SCALE-UP over traditional instruction Stoltzfus & Libarkin (2016), concluded that *adding technology to a classroom, remodeling classrooms to facilitate interactions, flipping instruction, or even adding active learning to a course is not a panacea that produces better outcomes for students*; Cassani (2008) found that the *SCALE-UP model as implemented … did not increase science teaching self-efficacy of non-science majors*. In an investigation of the design features of the SCALE-UP classroom that are most conducive to teaching and learning, Soneral &Wise (2017) concluded that while collaboration and whiteboards enhanced the learning experience, *technology may not be as important as originally conceived*, suggesting that the benefits of the SCALE-UP model can be attained without the high cost of technology.

While success at improving learning outcomes for African-Americans has been claimed in some TEAL studies, there is a dearth of literature on SCALE-UP implementation or student performance in any subject at HBCUs or other minority institutions. When included, this sub-group is often a very small portion of the study populations (Foote et al, 2016; Beichner & Saul 2004; Benson et al, 2009; Stoltzfus & Libarkin, 2016). Further, while some researchers (Beichner & Saul, 2004) have reported that *the results for African Americans and females are particularly interesting, with traditional class failure rates, respectively, nearly four and five times larger than those seen in SCALE-UP classes*, their study population usually has very different characteristics than those of A&T students (Gasman, 2014), where African-Americans make up about 85% of the population. There is need therefore, as Freeman et al (2014) have called, for research to elaborate on recent work indicating that underprepared and underrepresented students may benefit most from active learning, which this article addresses.

5. Redesigned Learning Spaces and Calculus I Course

5.1 SCALE-UP Learning Spaces

Following the 2010 departmental self-study recommendation, support was obtained from the then College of Arts and Sciences to convert two traditional classrooms into a 45-seat SCALE-UP laboratory, shown in Figure 1 below. The adaptation followed site visits to the North Carolina State University (NCSU) SCALE-UP physics project, the Clemson Calculus adaptation, and the University of Maryland, Baltimore County (UMBC) *'CASTLE'* SCALE-UP adaptation. Mostly influenced by the NCSU space designs, the proof-of-concept lab was completed in 2012. It features five internet-ready portals located beneath each of the five

7-foot tables, an audio-visual system with multiple projection screens, and three walls of white boards, each of which can be partially overlaid by projector screens.

Figure 1: The 45-seat SCALE-UP Laboratory

Figure 2: The 72-seat SCALE-UP Laboratory

That SCALE-UP proof of concept project, along with the Math Emporium Model (MEM) redesign of College Algebra (Cousins-Cooper et al, 2019), formed a foundation for the Glaxo Smith Kline (GSK)

STEM Center of Excellence for Active Learning (CEAL). As part of the GSK CEAL project, two chemistry laboratories and two traditional classrooms were remodeled to create a 72-seat SCALE-UP lab, completed in 2014. Shown in Figure 2 below, this lab is outfitted with eight 7-foot round tables, each with nine seats and three thin-client servers for students, one instructor workstation, various types of audio-visual presentation equipment, and a combination of fixed and portable white boards.

5.2 Redesigned SCALE-UP Calculus I Course

5.2.1 Course Description

The following description has been in use since Fall, 2010: *The course presents the concepts of calculus from geometric, numeric, and symbolic points of view. Students will develop their reading, writing and questioning skills, as well as their ability to apply the concepts in real-life problems. Topics include a review of algebraic functions, inverse, logarithmic, and exponential functions, and trigonometric functions and their inverses, followed by discussion of limits, continuity, derivatives and their applications to real-life problems in various fields. An introduction to integration (indefinite and definite) and its application (area under curves) conclude the course. Prerequisite: Grade "C" in MATH 110 or appropriate equivalent.*

5.2.2 Student Learning Outcomes Assessment

The course units being assessed were: *Functions and Limits, the Derivative, Applications of the Derivative*, and *Introduction to Integration*. Assessment was by a scaled combination of quizzes, homework, a common one-hour open response test for each unit, and a common final exam with twenty multiple choice and ten open response questions. A common pretest (second Thursday of semester) and posttest (Thursday before exam week) were administered starting in Fall, 2014; the two were the same 30-item, multiple choice test.

5.2.3 Course Modules

The course was packaged into ten similarly formatted modules along existing topical divisions: *Functions and Limits*, *Derivatives*, *Applications of Derivatives*, and *Introduction to Integration*.

5.2.4 Course Workbook

A workbook was developed and published by Pearson Publishing company (Varatharajah et al, 2014) which is a compilation of notes, completely workout examples, and practice exercises, with templates for note-taking, grouped under ten modules. While the current textbook has web-based materials, they are not suitable for the "tangibles and ponderables" instruction format; this project did not incorporate the 10-15 minute "tangibles and ponderables".

5.2.5 Online Materials

MyLabsPlus, a licensed commercial product of the Pearson Publishing company, was used for online reading materials and problem banks for homework assignments; the Calculus (I, II, and III) sequence used a textbook from the Pearson Publishing Company. The software provides immediate feedback and assistance: online assignments are graded immediately and hard copies made available for review.

5.2.6 Course Delivery

Besides a designated instructor, two graduate teaching assistants (TAs) were assigned to each section. All fall 2012 to spring 2014 sections met in the 45-seat SCALE-UP lab for two 110-minute weekly sessions plus one 50-minute recitation. Starting in 2014, sections met in either the 45-seat or the 72-seat lab for four 50-minute weekly sessions plus one 50-minute weekly recitation in a regular classroom or SCALE-UP lab . In contrast to the traditional method, in SCALE-UP there were only 20–25 minutes of lecture time, with the rest of the time spent on other structured activities. In class students were divided into groups of three, members working together on assigned activities. Table 3 summarizes the main features of the two methods.

Table 3. The main features of the SCALE-UP and traditional methods

SCALE-UP	Traditional
1. Meets four days/week in SCALE-UP classroom plus one 50-minute recitation session/week 2. TA support in class 3. TA support for recitation session 4. SCALE-UP style teaching 5. MyLabsPlus (online) homework 6. Usage of Workbook (graded exercises), since Fall 2014) 7. In-class Worksheets with group and TAs support 8. In-class quizzes (closed Book, no calculator, no support) 9. Common Final Examination	1. Meets four days/week for lectures in traditional classroom with no recitation or TA support in class 2. Traditional lecture style teaching 3. MyLabsPlus (online) homework 4. Some worksheet usage 5. In-class quizzes (closed book, no calculator, no support)

5. Learning Outcome Results

5.1 Did the SCALE-UP redesign improve pass rates in Calculus I?

To answer this question, 2012-2016 pass rates (Table 4), are compared to 2008-2012 pass rates (Table 2).

Table 4. Pass Rates for Calculus I with SCALE-UP Method (2012-2016)

School Year	Enrolled (N)	Pass Rate (%)
2012-13	632	55.1
2013-14	554	49.7
2014-15	750	53.5
2015-16	695	60.4
4-year Total (mean)	**2631**	**54.5**

SD denotes the standard deviation; * chi-square test; † t-test. The p-values were calculated using either a two-sample t-test for mean or a chi-square test for proportion.

Comparison of Table 2 and Table 4 shows that there was an average pass rate improvement from a normal of 36%-40% in 2008-2011 to a new 50%-60% normal in 2012-2016. While statistically significant (the p-value of two-sample proportion test <0.0001), this improvement leaves the pass rates still low. Table 2 also shows a rate improvement from the 36%-40% range to 48% in 2011-2012, the year before SCALE-UP.

5.2 Did the students' pre-course background affect their performance?

To answer this question, a pass-fail profile by path into Calculus I of the 2014-2016 population is presented in Table 5. It shows that students placed into Calculus I by standardized test criteria such as ACT or SAT Math score achieved a much higher pass rate (58%-65%) than those placed into or took College Algebra or pre-calculus courses MATH 101/102/103/104/110/111/112 before Calculus I (34%-47%). The ELSE category includes advanced placement, Math Department Placement Test placement, transfer credit, and other items which could not be disaggregated. A further look at Table 1 also shows that in-state students pass at much lower rates (48%) than out-of-state students (63%).

Table 5. Paths to Calculus I Pass Rates for 2014-2016

	Pass		Fail	
Path to Calculus I	Count	Percent	Count	Percent
Total Enrolment	754	51.82	701	48.18
MATH099	3	75	1	25
MATH101/102	24	38.1	39	61.9
MATH103/104	109	41.13	156	58.87
MATH110	173	47.79	189	52.21
MATH111/112	31	34.07	60	65.93
ACT≥24	76	63.87	43	36.13
SAT≥550	115	65.71	60	34.29
ACT≥24&SAT≥550	34	65.38	18	34.62
ELSE	189	58.33	135	41.67

5.3 Was there a concept learning gap between passing and failing students?

To answer the third research question, a pass-fail profile by pretest-posttest score and Hake Factor of the 2014-2016 student population is presented in Table 6 below.

Table 6. Pass/Fail Pretest-Posttest Profile for Students in 2014-2016 SCALE-UP Calculus I

	Pass		**Fail**		
	Mean	SD	Mean	SD	P-value
Pretest	15.0	4.7	12.0	3.8	<0.0001†
Posttest	18.1	5.3	13.4	4.3	<0.0001†
Hake Factor	**0.31**		**0.11**		

Table 6 shows that students who fail generally start with lower pretest scores than those who pass and the gap between them widens for the posttest, with the former group showing a less learning gain than the latter by a ratio of almost 1:3.

6. Discussion and Conclusions

This article has described the partial transition from traditional to SCALE-UP instruction in Calculus I, including the background and context of the course as well as that of the SCALE-UP methodology. Between 2012 and 2014, considerable internal and external resources were expended to introduce and expand the SCALE-UP methodology, in the form of an initial 45-seat SCALE-UP laboratory and a subsequent 72-seat laboratory as part of a college-wide active learning infrastructure development, all created from extensive remodeling of existing traditional classrooms and laboratories. The course redesign consisted of adoption of common syllabus, pretests-posttests, common tests and final examinations, a course workbook and online materials, and revised course procedures. The resulting redesigns have been presented, and pass rates from the first four years (2012-2016) of the project have been summarized to address the questions: (1) Did the redesign improve pass rates? (2) Did the students' pre-course background affect their performance? (3) Was there a concept-learning gap between passing and failing students?

Preliminary results show moderate but significant improvements in course pass rates, from a normal of 40% and below before SCALE-UP (Table 2) to a new normal of above 50% after SCALE-UP (Table 4), and that the difference in the pass rate is marginal for gender Table 1). While this increase is much lower than that reported by Zachary & Biggers (2008) for example, it is a 32.3 % increase over prevailing rates and much higher than the 6% average increase reported by Freeman et al (2014). Further, a pre-SCALE-UP increase from a normal pass rate of below 41% in 2008-2011 to 48% in 2011-2012 (Table 2) suggests that in its present form, the SCALE-UP intervention may account for only part of the observed improvement from the 2008-2012 to the 2012-2016 pass rates, with the rest due to other institution-specific factors. The partial implementation of the SCALE-UP Calculus I did therefore result in improved pass rates, albeit not enough to reach the stated 70% target.

The pass/fail student profile (Table 5) suggests that weakness in pre-requisite skills while the characteristics profile (Table 1) suggests that in-state residency may be the main factors causing failure. While all pass rates clearly need improvement, Table 1 shows that the worst-performing students in Calculus I are with in-state residency while Table 5 shows the worst performers as those who arrive in the course via Math 101/102, Math 103/104, Math 110, or Math 111/112; these categories therefore need further investigation in a quasi-experimental setup.. Interestingly, while the sample is small, Table 5 also shows that students going directly from Math 099 to Calculus I are more likely to pass the course than those who take other courses in between. Further, Table 1 shows that there are strong positive correlations (p-value <0.0001) between passing and the SAT or ACT scores as well as between passing and pretest scores. These results imply that instructional innovation should focus on precalculus for students who are not ready to take Calculus I, especially in-state students.

The pretest-posttest profile (Table 6) shows a three-point pretest score gap between passing and failing students which widens to a five-point gap on the posttest. It also shows that if both groups had the same learning gains starting from the present pretest scores, then the failing students would end up with an average posttest score of about 16. That is, the failing students would at the end be only slightly better than where the passing students came in, which at 53% (16/30) is still only in the DFW range; on average, they currently fall short of even that mark, with a failing posttest score of 43% (13/30).

A major limitation of this study is that it is not a direct comparison of student performance in the SCALE-UP and traditional classrooms. It is therefore not possible to conclude that SCALE-UP instruction was responsible for the observed increase in pass rates; what is not beyond doubt, however, is that pass rates did improve from prior to consideration of any TEAL method through the process of initial implementation. It is not possible to compare either gap with the traditional method, but the widening knowledge gap in this SCALE-UP adaptation raises need to investigate the observation by Park & Choi (2014) of a *narrowing of the gap in learning attitudes*. It is also of note that the course structure and resources underwent considerable revision (Table 3) aside from the room redesign, leaving open the question of Soneral & Wyse (2017) whether the benefits of the SCALE-UP model can be attained without the high cost of technology. Therefore, even a partial implementation of the SCALE-UP method can lead to improved pass rates, but such improvement may not be enough unless there is better preparation for pre-requisites, design of course materials and faculty development.

7. Acknowledgements

The work reported here is based upon work previously by a College of Arts and Sciences Innovation grant, the NCA&T Academy of Teaching and Learning, the NSF-funded Talent-21 project, and the Glaxo Smith-Kline STEM Center of Excellence for Active Learning , for which the authors thank M. Kanipes, S. Simkins, and G.Tang. Support by the National Science Foundation under Grant Nos. NSF HRD-1610482 (DPC-M, KC-C, & S-TK); NSF HRD-1818710 (KC-C & PV), NSF HRD-1719498 and NSF HRD-1818710 (S-TK) is also acknowledged. The authors also thank R. Beichner (NCSU), R. Moss (Clemson), D. Caplan (UMBC), and W.R. LaCourse (UMBC) and their departments for their hospitality and assistance.

8. References

Adelman, C. (2006). *The Toolbox Revisited: Paths to Degree Completion from High School through College*. Washington, DC: U.S. Department of Education.

Beichner, R.J. & J. M. Saul (2004). Introduction to the SCALE-UP (Student- Centered Activities for Large Enrollment Undergraduate Programs) Project. In *Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education,* proceedings of an April 2004 conference, AAAS/NSF.

Beichner, R J., Saul, J.M., Abbott, D.S., Morse, J.J., Deardorff, D.L., Allain, R.J., Bonham, S.W., Dancy, M.H., & Risley, J.S. (2007). The Student-Centered Activities for Large Enrollment Undergraduate

Programs (SCALE-UP) Project. In *PER-Based Reform in University Physics*, E.F. Redish and P.J. Cooney (eds), (American Association of Physics Teachers, College Park, MD), Vol 1, 2–39.

Beichner, R.J. (2014). History and Evolution of Active Learning Spaces. In *New Directions for Teaching & Learning*, John Wiley & Sons, Inc.

Benson, S. B. L., Moss, W., Ohland, M., Orr, M., & Schiff, S. (2009). Adapting and Implementing SCALE‐UP Approach in Statics, Dynamics, and Multivariable Calculus. *Inter. J. of Eng. Ed.*, *26*(5), 1097-1110.

Biggers, S., L. Benson, W. Moss, M. Ohland, M. Orr, & S. Schiff (2007). Adapting and Implementing the SCALE‐UP Approach in Statics, Dynamics, and Multivariable Calculus. In *ASEE Annual Conference and Exposition* (Honolulu, HI).

Blaich, C. & Wise, K. (2011). *The Wabash National Study - The Impact of Teaching Practices and Institutional Conditions on Student Growth.* Paper presented at the 2011 AERA Annual Meeting. Online at http://www.liberalarts.wabash.edu/storage/Wabash-Study-Student-Growth_Blaich-Wise_AERA-2011.pdf

Bookman, J. & C. Friedman (1998). Student attitudes and calculus reform. *School Science and Mathematics*, *98*(3), 117-122.

Bookman, J. & C. Friedman (1999). The evaluation of Project CALC at Duke University, 1989-1994 [Electronic]. In B. Gold, S. Keith, & W. Marion (Vol. Ed.), *MAA Notes: Vol. 49. Assessment practices in undergraduate mathematics* (pp.253-258). Washington, DC: The Mathematical Association of America.

Bullock, D., Callahan, J., & Shadle, S.J. (2015). Coherent Calculus Course Design: Creating Faculty Buy-in for Student Success. 122nd Annual ASEE Conf. and Exposition, Seattle, WA, 2015. Paper ID # 14209.

Brainard, S.G. & Carlin, L. (1998). A Six-Year Longitudinal Study of Undergraduate Women in Engineering and Science, *Proceedings of Frontiers in Education* 1, 134–143.

Burkum, K., Habley., W, McClanahan, R., & Valiga, M. (2010). *What works in Student Retention (Fourth National Survey): Four-Year Colleges and Universities with Twenty Percent or More Black Students Enrolled*, ACT 2010 (ACT Inc., Iowa City, Iowa).

Cassani, Mary Kay (2008). *Impact of SCALE-UP on Science Teaching Self efficacy of Students in General Education Science Courses.* D.Ed. Thesis, University of Central Florida

Cousins-Cooper, K., Clemence-Mkhope, D.P., Redd, T.C., Luke, N. S., and Kim, S. (2019). Math Emporium Instructional Course Design: Algebra Course Evolution at an HBCU. In *Broadening Participation in STEM: Effective Education Methods, Practices, and Programs for Women and Minorities*, Diversity in Higher Education Series, Volume 22, Wilson-Kennedy, Z.S., Byrd, G.S., Kennedy, E., and Frierson, H. (eds), Emerald Publishing Limited, 237-263

Dittoe, William (2002). Innovative Models of Learning Environments. *New Directions for Teaching & Learning,* 2002(92), 81-90.

Epstein, J. (2013). The calculus concept inventory – Measurement of the effect of teaching methodology in mathematics. *Notices of the American Mathematical Society*, 60(8), 2-10.

Foote, K. F., Neumeyer, X., Henderson, C., Dancy, M., & Beichner, R. (2014). SCALE-UP Implementation and Intra-Institutional Dissemination: A Case Study of Two Institutions. In Engelhardt, Churukian, & Jones (Eds.), 2*014 PERC Proceedings*. Minneapolis, Minnesota. doi:10.1119/perc.2014.pr.017

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H, & Wenderoth, M.P., (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS* (USA), 111, (23), 8410-8415. http://www.jstor.org/stable/23776432

Frid, S. (1994). Three approaches to undergraduate calculus instruction: Their nature and potential impact on students' language use and sources of conviction. In E. Dubinsky, A. Schoenfeld, & J. Kaput (Eds.), *Research in Collegiate Mathematics Education*, *1*(pp. 69-100). AMS, Providence, RI.

Goins, G., Redd, T.C., Chen, M., White, C.D., & Clemence, D.P. (2016). Forming a Biomathematical Learning Alliance Across Traditional Academic Departments. *International Journal for Innovation Education and Research,* 4(6), 16-23.

Hegeman, J. S. (2015). Using instructor-generated video lectures in online mathematics courses improves learning. *Online Learning* 19(3), 70-87.

Kuh, G.D., Kinzie, J., Buckley, J.A., Bridges*, B. K., and* Hayek, J.C. (2006). What Matters Student Success: A Review of the Literature. Commissioned Report for the *National Symposium on Postsecondary Student Success: Spearheading a Dialog on Student Success*. http://nces.ed.gov/npec/pdf/kuh_team_report.pdf

Lipnevich, A. A., MacCann, C., Krumm, S., Burrus, J., & Roberts, R. D. (2011). Mathematics attitudes and mathematics outcomes of U.S. and Belarusian middle school students. *Journal of Educational Psychology*. doi:10.1037/a0021949

Lotkowski, V., Robbins, S.B., & Noeth, R. (2004). *The Role of Academic and Non-Academic Factors in Improving College Retention*. ACT Policy Report 2004 (ACT Inc., Iowa City, Iowa).

Monteferrante, S. (1993, May). Implementation of calculus, concepts, and computers at Dowling College. *Collegiate Microcomputers*, *11*(2), 94-98.

NCA&T Undergraduate Bulletins (2008-2016). 2008-2014 available on disk, 2014-2016 available online at https://www.ncat.edu/divisions/academic-affairs/bulletin/:

Noble, J. & Sawyer, R. (2004). *Predicting Different Levels of Academic Success in College Using High School GPA and ACT Composite Score*, ACT 2002-4 (ACT Inc., Iowa City, Iowa).

NSSE-FSEE (National Survey of Student Engagement-Faculty Survey of Student Engagement) (2012). http://nsse.iub.edu/html/annual_results.cfm

Oldham, J.M, Mers, R., & Burns, S.D. (2002). Cooperative Efforts Among HBCU Mathematics Departments in the Production of African American Ph.D.'s in the Mathematical Sciences. *Proceedings of The Ronald E. McNair Symposium on Science Frontiers: The Role of HBCU's in 21st Century Higher Education*; January 2002

Park, E.L. & Choi, B.K. (2014). Transformation of classroom spaces: traditional versus active learning classroom in colleges. *High Educ*, 68,749–771. DOI 10.1007/s10734-014-9742-0

PCAST (2012). President's Council of Advisors on Science and Technology 2012 Report. *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Online https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Roop, John Paul, Edoh, Kossi & Kurepa, Alexandra (2018). Instructional Selection of Active Learning and Traditional Courses Increases Student Achievement in College Mathematics. *Journal of Education and*

Learning ,7 (5), 11-19.
Schwingendorf, K., G. McCabe, & J. Kuhn. (2000). A longitudinal study of the C4L calculus reform program: Comparisons of C4L and traditional students. In E. Dubinsky, A. Schoenfeld, J. Kaput, & T. Dick (Vol. Ed.), *CBMS issues in mathematics education: Vol. 8. Research in Collegiate Mathematics IV* (pp. 63-76). Washington, DC: American Mathematical Society & The Mathematical Association of America.
Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *J. of Ed. Research*, 95, 323-332. doi:10.1080/00220670209596607.
Soneral, Paula A. G. & Sara A. Wyse (2017). Student Learning Gains in High- and Low-Tech Active-Learning Environments. *CBE—Life Sciences Education*, 16 (12),1–15.
Stevenson, H. W., & Newman, R. S. (1986). Long-term prediction of achievement and attitudes in mathematics and reading. *Child Development*, 57, 646-659.
Stoltzfus, Jon R. & Julie Libarkin (2016). Does the Room Matter? Active Learning in Traditional and Enhanced Lecture Spaces. *CBE—Life Sciences Education,* 15 (68), 1–10.
Twigg, Carol A. (2011). The Math Emporium: Higher Education's Silver Bullet. C*hange. The Magazine of Higher Learning, 43*(3), 25-34.
Vallade, James K. (2013). *An evaluation of the emporium model as a tool for increasing student performance in developmental mathematics and college algebra*. Ed.D. Thesis, The University of Toledo, The University of Toledo Digital Repository.
Varatharajah et al (2014). Calculus I Workbook (NCA&T State University), Pearson Publishing Company.
Wabash National Study of Liberal Arts Education. (2009). A large-scale, longitudinal study to investigate critical factors that affect the outcomes of liberal arts education: www.liberalarts.wabash.edu/nationalstudy
Webel, C., Krupa, E., & McManus, J. (2017). The math emporium: Effective for whom, and for what? *International Journal of Research in Undergraduate Mathematics Education,3*(2), 355-380. doi:10.1007/s40753-016-0046-x
Williams, S.P. (2016). *Math Emporium Model: Preparing Developmental Students for College Algebra*. Ph.D. Thesis, University of Southern Mississippi. The Aquila Digital Community: Dissertations
Zachary, M. & Biggers, S.S. (2007). An Analysis of Reformatting Curriculum and Instruction in the Calculus Sequence. Presented at the International Conf. of the Math Education into the 21st Century Project, Charlotte, NC. Online at http://math.unipa.it/~grim/21_project/21_charlotte_ZacharyPaperEdit.pdf