Bridging the Valley: Recruiting and Retaining STEM Majors

Bob Kolvoord James Madison University
Robyn Puffenbarger Bridgewater College
Ray McGhee SRI
Roman J.Miller Eastern Mennonite University
Ken Overway Bridgewater College
Kenneth Phillips Blue Ridge Community College
Lynne Ryan Blue Ridge Community College
Jennifer Sowers Blue Ridge Community College
Jordan Brown SRI

Introduction

The late 1990's and early 2000's saw a major decline in the number of undergraduate students majoring in Science, Technology, Engineering, and Math (STEM) fields. Research shows that of the students who enter college with the intention of majoring in a STEM field, less than half actually do so (Laws, 1999; Rask, 2010; Higher Education Research Institute, 2010). In considering the problems associated with the retention of STEM majors, researchers have looked closely at both student characteristics as well as institutional settings to identify causes and possible solutions (Higher Education Research Institute, 2010; Watkins, & Mazur, 2013). Higher education leaders have used the research on these two factors to shape their understanding of student retention and inform proposed efforts to improve student outcomes (Tinto, 2000; Watkins & Mazur, 2013; Wilson, Zakiya et al, 2012; Shaw, 2010). Engineering education research has posited that students need guidance in four areas to increase their interest in pursuing STEM opportunities and persisting through course plans: (1) clarifying career goals, (2) developing realistic outcome expectations, (3) managing environmental barriers and (4) building support systems to enhance their sense of self-efficacy (Lent et al., 2003; Wilson, Zakiya et al, 2012).

In the face of declining STEM enrollments, four neighboring institutions in Virginia's Shenandoah Valley came together to address the issue of STEM retention on their campuses with support from the National Science Foundation. James Madison University (JMU), Blue Ridge Community College (BRCC), Eastern Mennonite University (EMU), and Bridgewater College (BC) undertook a six-year project, with funding from National Science Foundation's STEM Talent Expansion Program (STEP) grant (DUE-0756838), to enhance student retention in STEM on each campus. The partnership, dubbed Bridging the Valley (BTV), developed a set of interventions designed to actively improve student outcomes. A summer bridge workshop (SBW) and collaborative learning communities (CLC), implemented during the academic year, were two of the most substantive interventions included in the BTV program. In this paper, we will:

- Summarize background literature upon which the BTV interventions were founded
- Describe the components of the BTV interventions
- Describe the findings derived from data collected on the BTV implementation
- Share the most important lessons learned from this project

Background

Since the 1950s, education researchers have worked to identify the key factors that influence individuals' decisions to pursue a particular major or career path. These efforts have produced a large variety of theories for understanding the issue (Leppel, 2001; Eagan, 2010; Rask, 2010). Social Cognitive Career Theory (SCCT) is one model that has explained how cognitive, contextual and cultural elements link to students' academic and career decision-making processes. SCCT informs much of the BTV project's theory of change and forms the basis for many of its interventions. According to SCCT, personal and contextual factors shape individuals' perceptions of academic or occupational endeavors (Lent et al., 2003; Bandura 1986). The individual's perception of his or her own success and anticipation of valued compensation in the field lead to a greater likelihood of interest and action than if the individual does not perceive the potential for opportunity and accomplishment (Lent et al., 2003; Tinto 2002). This sense of self-efficacy, or the perception that one will be able to successfully perform in a STEM major or career is grounded in four influential factors: previous accomplishment, vicarious learning, social persuasion, and psychological reaction (Lent et al., 2003; Bandura 1986). In considering ways to promote enrollment and retention in STEM majors and careers, SCCT offers a nuanced insight into career development intervention as it not only illuminates the individual belief system but also addresses the influence of social context.

Researchers have also found that the extent to which students involve themselves, and the quality of such involvement, influences several educational outcomes. According to Astin's (1984) Theory of Involvement, students who are actively involved in both the academic and social aspects of their collegiate experiences learn more and perform better than those who do not (Hunt, 2003; Rendon, 2002; Astin, 1985). Involved students spend significant time on academics while also participating in student activities and interacting with faculty members. Hunt (2003) posited that cognitive learning, student retention and overall college satisfaction are outcomes also positively shaped by the balanced combination of academic and social involvement. Enhancing student academic and social involvement proves to be a difficult task at many universities and colleges, though. In particular, studies have found that students from low socio-economic backgrounds find it especially difficult to get involved without assistance (Rendon, 2002). These individuals are often first-generation college students and (1) do not know how to get involved in different activities, (2) are reluctant to ask for assistance, or (3) feel alienated from other student groups.

Of the several strategies utilized to enhance student involvement and consequently retention rates, small learning communities have proven especially successful (Waldron, 2007). Learning communities connect students across groups by creating cohorts that take classes together, in addition to participating in other activities. The ultimate goal of most learning communities is to create a supportive environment for heightened intellectual interaction among students, faculty and staff. These communities foster collaboration, comfort, confidence and motivation at levels which students might not experience when working alone (Alston, 2008). Generally, student cohorts are based around a common discipline of study, such as science or mathematics. In an attempt to improve STEM major retention, several institutions, such as Syracuse University and the State University of New York (SUNY), have implemented STEM-specific learning communities. After the first year of establishing STEM learning communities, SUNY found that 98% of community members persisted into their second year of studies, as compared to an overall STEM retention rate of 78% (DeBaise & White, 2004).

Faculty members usually lead and mentor student cohorts within learning communities. The goal of utilizing faculty members as leaders is to create and support substantive partnerships between faculty members and students. Studies show that participation in learning community environments significantly increases faculty interest in teaching and learning while also creating opportunities for the investigation and creation of new teaching methods (Alston, 2008; Waldron, 2007). Learning communities provide opportunities for faculty members to step outside of their disciplinary silos and enhance collegiality, collaboration and support across fields (Stein, 2004; Waldron, 2007). In these environments, faculty interact more with their peers and utilize collaboration across disciplines to create linked curricula.

Research examining the effects of summer bridge programs reveals some promise in supporting student retention. Data collected from directors of programs that aim to recruit and retain underrepresented students in science and engineering shows that overnight, residential, and/or summer programs are most frequently cited as being closely linked to success (Matyas, 1991b). Several studies analyzing retention and grade point average (GPA) indicate that students in support programs, such as summer bridge workshops, tend to earn higher GPAs than those not enrolled in comparable programs (Murphy et al., 2010). Most of these studies lack a formal control group, making it difficult to quantify the impact of the bridge program (Santa Rita & Bacote, 1996). However, students' mathematical performance during summer bridge workshops has been positively correlated with first semester overall GPA (Gilmer, 2007). In addition to enhanced academic performance, summer bridge programs have been shown to positively affect STEM major retention. The Houston-Louis Stokes Alliance for Minority Participation (H-LSAMP) is a program that focuses on increasing the number of minority students who earn baccalaureate degrees in STEM fields. Analysis of the program reveals strong, positive impacts for the roughly 40 students served each year. Over the past four summers, only two H-LSAMP participants have not matriculated along the approved course plan for a Bachelor of Science degree in their respective STEM field (Texas Higher Education Coordinating Board, 2009).

Successful Strategies

Within retention-focused interventions, such as summer bridge programs and learning communities, a variety of specific activities improve student outcomes. The existing literature highlights several activities that have proven to be successful. In the context of STEM major retention and the SCCT, faculty directed research projects, internships, tutoring and mentoring produce strong gains.

Faculty Directed Research Projects

Summer internships and other research opportunities outside the classroom have been identified as important transitional activities for undergraduate students. Participation in research activities connects the student's experiences to the professional world, establishes mentoring relationships and opens a window on career options as well as helps them build positive connections to the particular discipline (Sabatini, 1997; Kardash, 2000; Hurtado et al., 2009). Some institutions have chosen to integrate hands-on STEM research experience directly into the classroom to help ensure that students get the opportunity to participate in research during their college career. For example, the Integrated Teaching and Learning Laboratory of the College of Engineering and Applied Science at the University of Colorado at Boulder has developed a team-based, first-year research project course. The course emphasizes several elements: academic preparation for engineering study and enhancement of the in-class learning environment, attention to curricular content, scope and design, and curriculum delivery and instructional style. Analysis reveals that course has increased retention for participating students compared to a matched cohort of non-participating students. The retention rate gain was 19% for all participating students.

Internships

Internships are another way to supply students with hands-on research experience and opportunities to use scientific information learned in the classroom in an applied setting (Kim, 2009). Students who participate in internships often view the experience as positive and worthwhile. In a survey study of computing majors who were completing internships, Schambach and Kephart (1997) found that students generally expressed a favorable response to the experience, and reported perceived benefits that included "recruitment advantages, an excellent method of learning, better understanding of organization and career focus, as well as reinforcement of course-learned skills and enhanced confidence in their own professional capabilities" (p. 214). In a study of the Myerhoff Scholars Program at University of Maryland, Baltimore County, a comprehensive program geared toward increasing the number of minorities in STEM fields, students consistently viewed summer research internships as important contributors to their success. In participant interviews, a number of Meyerhoff scholars also indicated that these experiences contributed to their desire to pursue a doctoral degree, and provided them with access to leading researchers.

Mentoring

Providing students with mentors is yet another way in which institutions attempt to retain STEM majors. Mentoring has been associated with positive outcomes such as higher GPA, increased self-efficacy, lower attrition and better defined academic goals (Santos & Reigadas, 2002; Schwitzer & Thomas, 1998; Thile and Matt, 1995). According to Redmond (1990), mentoring addresses several causes of college attrition and delayed graduation by facilitating aspects of students' academic and social integration.

Peer mentoring, which usually matches a first-year student with an upperclassman, may be beneficial to protégés in a number of the same ways as a more traditional student-faculty member pairing (e.g. information sharing, emotional support, personal feedback, and friendship). However, a very limited amount of research has been devoted to this type of mentoring relationship. Some scholars suggest, though, that the peer mentor-protégé relationship is likely to have a stronger bond, since typically there is less difference in age and hierarchical levels, more mutuality of interaction, and longer relationships (Grant-Vallone & Ensher, 2000).

Tutoring

Tutoring is an additional strategy used to enhance student learning and increase student retention. Tutoring can be used to complement mentor relationships but frequently exists independently from these relationships. Tutoring programs, especially at the college level, are implemented in a large variety of ways. Several different people fill the role of tutor including other students, staff members or faculty members. Interestingly, many studies that compare achievement outcomes of students tutored by either peers or staff members have found no significant differences (Moust & Schmidt, 1994).

Program Overview

With this background in mind, we designed the BTV program with the following components:

- A summer bridge workshop (SBW)
- Academic year student collaborative learning communities (CLC)
- Support and assistance in identifying internships and employment
- A program of faculty development workshops.

In this paper, we'll focus on the first two components.

The summer bridge workshop was a multi-week residential experience for rising freshmen at each school that combined STEM programming and college readiness skills. In discussions about the format of the summer bridge workshop, all four institutions agreed that part of the program should focus on building foundational student math skills necessary for STEM success. Each SBW student participated in a math class in the morning taught by a BRCC math instructor. The students were placed in groups through the use of a diagnostic exam and the course content focused on algebra and pre-calculus topics, with the aid of extensive online homework and in-class practice. Students received community college credit for successfully completing the math class.

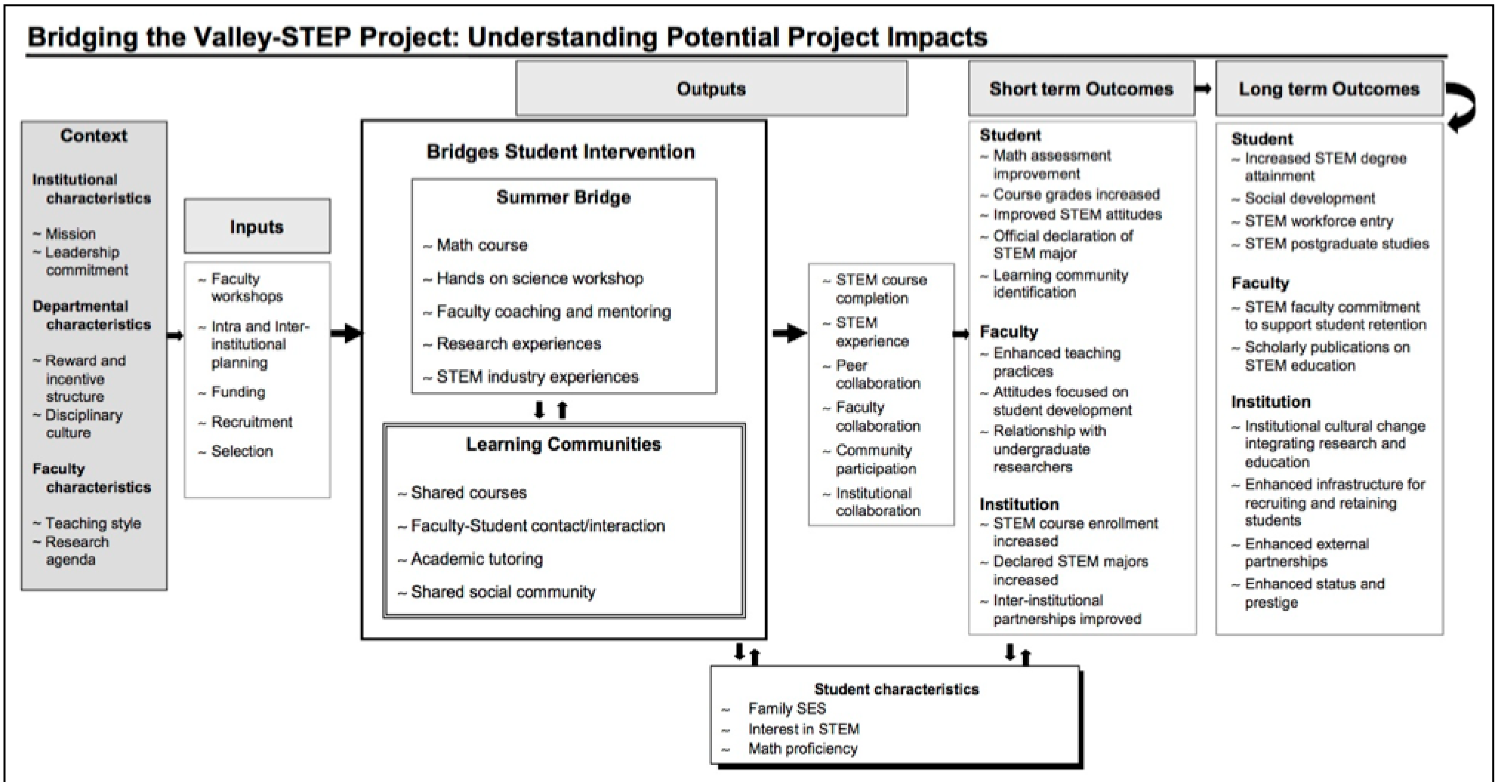

Figure 1: Logic Model

We developed afternoon sessions focusing on science and engineering to introduce students to a broad range of STEM disciplines. These sessions were hands-on, often extended over multiple days, and were conducted on the campuses of BC, EMU, and JMU. The topics ranged from building circuits to water chemistry to sequencing DNA, and served to introduce students to the range of STEM options available on their campus, as well as give them a hands-on introduction to research in different disciplines.

The residential (evening/weekend) component featured sessions to develop study skills and coping mechanisms so that the students would be ready to succeed when they began their freshman year a few weeks after the end of the SBW. A trained residential staff of upper-class students provided support and mentoring in the dormitory. We also had a range of social and recreational activities to model the school-year experience.

The SBW was designed to give student participants exposure to their campus, and develop acquaintance with faculty, students, and facilities on all four campuses. Students received a stipend for participation, as well as room and board and the mathematics credit. We chose to give stipends since students had to give up the opportunity for summer work to participate in the multi-week SBW.

Each campus customized its school-year CLC's based on local needs and included classes focused on learning skills and opportunities for reflection on being in college, living in common dormitories, career seminars, research opportunities, service learning, and more. SBW participants were required to participate in the school-year learning communities and all campuses except JMU chose to open CLC participation to non-SBW students. JMU had the largest number of SBW participants and could not accommodate more students.

The project team hired a full-time project coordinator with a student services background who helped oversee all aspects of the project, including the CLC portion. Many of the campus learning communities included peer mentors as an additional means of support. The project coordinator also served as an informal mentor to STEM students on all four campuses, including the SBW participants. She provided career counseling, direction in finding internships and connections to businesses, facilitated by the local Shenandoah Valley Partnership, an independent organization devoted to economic development in the Shenandoah Valley.

We realized early on that simply focusing on the students would not drive long-term change at the four institutions, so we planned a program of workshops intended to engage STEM faculty with issues in recruiting and retaining majors in STEM. The project brought in external speakers and gave faculty on all four campuses the opportunity to interact with peers to think about curricular and pedagogical change. Lastly, we engaged SRI International to serve as project evaluators who would document the project's implementation efforts and provide formative feedback to improve the project's activities. They developed the study design and generated the findings described below based on much of the data that we report in this article.

Design and Methods

SRI International designed an evaluation whose goal was to document the implementation of the BTV activities and to assess their effectiveness. The logic model depicting the theory of change that illustrates the *Bridging the Valley* project goals is presented in Figure 1. This logic diagram is a useful tool that specifies the project's assumptions, resources, activities, objectives, and likely outcomes.

Within this framework, the data collection and analysis strategies focused on the student recruitment and retention activities, the way these activities affected students, and how the different institutions adapted to support the retention of these students.

A variety of methods were utilized to collect data regarding the two main components of the BTV program: (1) Summer Bridge Workshop and (2) Collaborative Learning Communities. The data collection for the SBW component included

- Student and faculty surveys
- Interviews with project leadership
- Focus groups with faculty and students
- Pre- and post-assessments of the mathematics course.

Each year, survey data from the SBW were collected in the months immediately following the workshop's completion. Surveys, which ranged from 20-25 questions in length, were electronically distributed to all participating students and faculty members. The size of the sample for the SBW survey averaged 50 students. This sample was typically representative of each cohort's total population.

Further information regarding response rates and sample sizes for surveys can be found in Table 1. Simple descriptive statistics include proportions (for binary variables and some ordinal variables), means (for some ordinal variables and for interval variables), and cross tabulations (for counts of categorical variables) along with associated standard errors[1].

Data from the CLCs were collected using the following methods:

- Student surveys
- Interviews with project leadership
- Focus groups with faculty and students
- Student transcript data obtained from university registrars and institutional research offices

Project evaluators distributed surveys electronically to participating students at the end of each fall term. For the first year of the CLCs, only freshmen were surveyed. As cohorts matriculated through their respective institutions, past participants answered surveys designed to capture the perceptions of sophomores, juniors and seniors. Surveys generally consisted of between 20 and 25 questions, using a variety of question formats. Response rates varied throughout the program and subsequently the ability to generalize data across all learning community participants varied. The response rates and sample sizes for each year's survey are displayed in Table 1. Evaluators synthesized findings from the CLC surveys using analytic strategies similar to those utilized to examine data from the SBW surveys.

[1] Copies of each year's survey and detailed breakdowns of response patterns are available upon request.

Project evaluators conducted annual site visits at each institution collecting qualitative data through interviews and focus groups with participating faculty, students, co-PI's, program staff and administrators. An average of 20 students participated in focus groups each year. The methods were designed to elicit detailed descriptions of program practices, as well as institutional features and environmental factors that supported student growth. Focus groups were conducted only in 2010 and 2011 and interviews were conducted in all years 2010-2013. No qualitative data collection was done in the final year of implementation.

In addition to collecting data from students in their freshman years, we collected survey data on sophomores each year as well as seniors in project year 5. The focus of most of the data analysis was on students in each cohort of entering freshmen participants; in project year 5, data from seniors were analyzed to provide a retrospective view of their college experience in light of their participation in the SBW and/or the CLCs. In the analysis, we sought to triangulate data from multiple sources to support findings as often as possible.

The research questions that guided the project's data collection efforts were as follows:

1. How and to what extent were project activities (summer bridge workshop, collaborative learning communities, faculty workshops, etc.) implemented as intended?
2. Which strategies were effective at recruiting students to STEM majors at each of the partner universities?
3. How effective were project activities at retaining students in STEM majors and increasing the number of STEM majors at each institution?
4. Do SBW math course and CLC participation lead to better math skills and understanding (i.e. math course completion, course grades) relative to non-participating students?

Project Year	SBW	CLC Freshman Survey	CLC Upperclassmen Survey
2009	Sample Size: 33 Response Rate: 100%	N/A	N/A
2010	Sample Size: 51 Response Rate: 100%	Sample Size: 101 Response Rate: 47%	N/A
2011	Sample Size: 50 Response Rate: 100%	Sample Size: 77 Response Rate: 82%	Sample Size: 22 Response Rate: 50%
2012	Sample Size: 43 Response Rate: 100%	Sample Size: 70 Response Rate: 90%	Sample Size: 69 Response Rate: 67%
2013	Sample Size: 51 Response Rate: 100%	Sample Size: 70 Response Rate: 92%	Sample Size: 90 Response Rate: 37%
2014	N/A	Sample Size: 61 Response Rate: 79%	Sample Size: 111 Response Rate: 46%

Table 1. Sample size and response rate for assessment surveys.

Limitations

The findings presented in this report are subject to a number of limitations. As a result of small sample sizes at some of the participating institutions, constructing a viable control group was difficult. Consequently, we try to avoid making inferences related to causality about academic performance and science competencies. Another limitation that prevents us from generalizing from this research is that the participating institutions sought to tailor aspects of the program to fit into the unique context of their institution. For example, the variation in eligibility criteria and recruitment strategies produced different characteristics and cohort sizes for each institution. Also, with regards to the CLC component, each institution created a support structure that gave participants a variety of different supports. While co-PIs and institutional leaders exercised this level of autonomy to effectively address the unique needs of each campus, the variation in individual characteristics, cohort features and types of support limit the generalizability of the impact analysis. A final limitation was a reliance on self-reported data obtained from student surveys. Although our analysis includes the triangulation of multiple data sources to support the major evaluation findings, a few findings are based solely on student survey responses.

JMU was the one school in the project with a sufficient number of participating students to conduct a comparison study. The SRI evaluation team collaborated with JMU's Center for Assessment and Research Studies to conduct a comparison group study with students at JMU. The goal of the study was to isolate the impact of the BTV program on the relevant student outcomes. Researchers selected 70 students from JMU who possessed similar characteristics to program participants but had not participated in any component of the project. The characteristics utilized to identify the students were: cohort year, class standing, race, math SAT score and gender. All of the students in the comparison group had indicated an interest in STEM on their admissions applications. After the students were selected, a one-to-one nearest-neighbor propensity matching score formula was used to match individual students. The group was designed to resemble a randomized control group.

Findings

Analysis of the data collected on the BTV interventions reveals several notable findings regarding the effectiveness of the strategies adopted to recruit and retain students in STEM, student outcomes and future prospects for the students. The findings are organized according to the research question they address. We omit an extended discussion of Research Question #1 as the analysis simply demonstrated that the project was implemented as intended. Research findings were used to make year-to-year changes to improve implementation of both the summer bridge workshop and the learning communities.

Research Question #2: Which strategies were effective at recruiting students to STEM majors at each of the partner universities?

At the onset of the project, program leaders identified effective student recruitment and identification strategies as a crucial component of potential success. Recruitment strategies varied considerably over the grant's lifespan but there were some common factors each institution took into account in identifying students who would benefit most from the experience. Serving at-risk students was consistently an integral part of each institutional mission and recruiting strategy. Project leaders defined at-risk students as individuals who demonstrated interest in STEM fields but possessed characteristics that made them unlikely to successfully complete STEM course plans (e.g., inadequate math competencies). Working with Institutional Research and Admissions Offices at each campus, we identified and recruited students who met the campus criteria for being "at risk". Derived from our past experiences with STEM students, these criteria helped to target students across the four campuses that, with the appropriate supports, could ultimately succeed academically in a STEM discipline.

Each campus chose a different recruiting strategy based on campus size. At JMU, the students were initially identified after they had paid a deposit indicating their intent to matriculate. This caused the recruiting to be very late and many potential participants had already made alternative summer plans. In subsequent years, JMU identified potential SBW participants from those that were offered admission, with the collaboration of the Admissions Office, and invited them to apply. Participants were then chosen from the applicant pool. This accelerated the selection process and led to a more than ample pool to fill JMU's slots in the SBW. BC and EMU each worked with their Admissions Offices to alert applicants to the possibility of participation in the SBW. This proactive process allowed BC and EMU to identify potential participants very early in the process and use the SBW as an incentive to enroll. Initially, BC took a very aggressive approach and worked with students with an interest in a STEM major, but very weak mathematics preparation. The SBW and CLC were unable to sufficiently remediate the math preparation and a number of these students did not persist. In subsequent years, BC focused on students with stronger math skills who were still underprepared and the retention rate improved substantially. BRCC faced the challenge of "just in time" admission making it difficult to identify students in May to participate in the SBW. BRCC reached out to high school career coaches and other partners to help identify students likely to apply to BRCC and encourage them to do so in time to be considered for SBW. This strategy resulted in a steady stream of SBW participants.

While the strategies varied across campus, the focus remained on students who declared an interest in a STEM major but needed some additional assistance to persist. Each campus evolved its particular recruiting regimen to best serve its students, ranging from JMU's "wholesale" approach given the large number of students, to the "retail" approach of BC, EMU, and BRCC. As was the case in many parts of the project, one size did not fit all.

Research Question #3: How effective were project activities at retaining students in STEM majors and increasing the number of STEM majors at each institution?

One of the main goals of the BTV project was to support student persistence in a STEM major and thereby increase the numbers of STEM majors at each institution. Analysis of data collected on the BTV project's effects on student retention generated positive findings in several important student outcome domains. In addition to data on the number of participants retained in STEM majors, survey and interview observations also indicate which specific activities were especially supportive. These findings are grouped into three categories: (1) Easing Students' College Transition, (2) Perceptions of Success and Understanding, (3) Overall Retention, and (4) Participants' Future Plans.

Easing Students' College Transition

One area where the BTV project placed heavy emphasis was easing participants' transitions into college. Activities incorporated into both the SBW and CLC components utilized several strategies designed to accomplish this goal. A major element of the program's overall mission was developing communities of support for participants. The communities fostered during the SBW were comprised of students, peer mentors, faculty members and program staff. Students' survey responses indicated that they found the formal and informal relationships formed with teaching assistants and faculty members very helpful. Students valued their in-class experiences with faculty members, in particular. While participants' responses indicate that they found their in-class experiences with TAs supportive, they placed higher value on the out-of-class encounters. Survey data collected from the 2012 and 2013 CLC cohorts reveal that the program's goal of establishing a supportive community was successful. A large portion of respondents, 75%, agreed that the CLC provided a community of support for students (See Figure 2). A comparable portion, 76%, agreed that the intervention created opportunities to interact with faculty and upperclassmen outside of the classroom (See Figure 3).

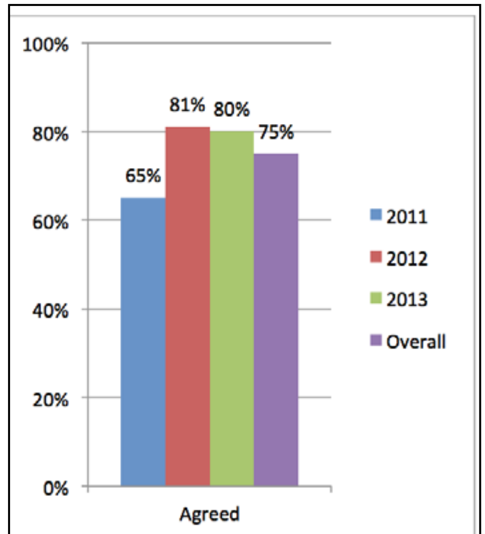

Figure 2: Provided Positive Opportunity to Get to Know Other STEM Students

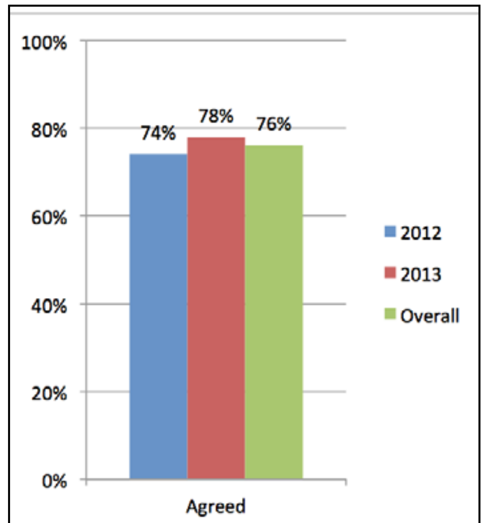

Figure 3: Created Opportunities to Interact with Faculty and Upperclassmen Outside the Classroom

Helping students to identify campus resources that could aid them in their adjustment to college was a central focus of many CLC activities. For example, each year JMU students participated in a campus-wide scavenger hunt designed to familiarize them with the institutional tools at their disposal. While there were some differences in the strategies utilized at each partner institution, we agreed that this strategy was important for the project's overall retention goal. Survey data reveal that across cohorts freshmen respondents found these efforts to be successful and beneficial (See Figure 4). Analysis of upperclassmen survey data shows that as students progressed through their undergraduate careers, they continued to place high value on the supports and activities offered by the CLCs.

Perceptions of Success and Understanding

Research on STEM major retention stresses the importance of students' attitudes towards STEM fields and perceptions of self-efficacy. Student surveys and inter-

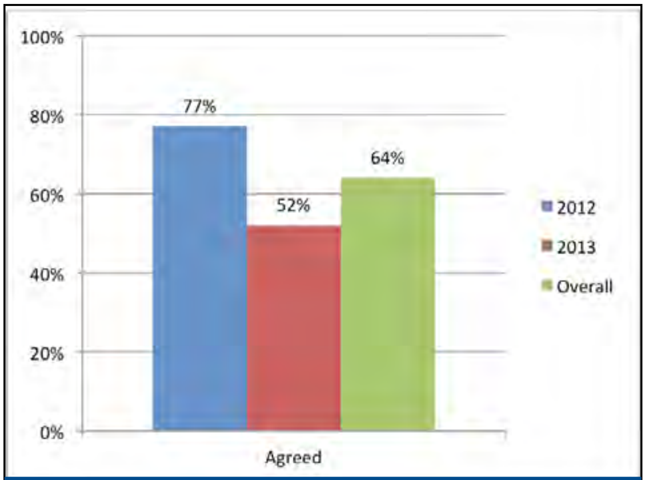

Figure 4: Helped Identify Campus Resources

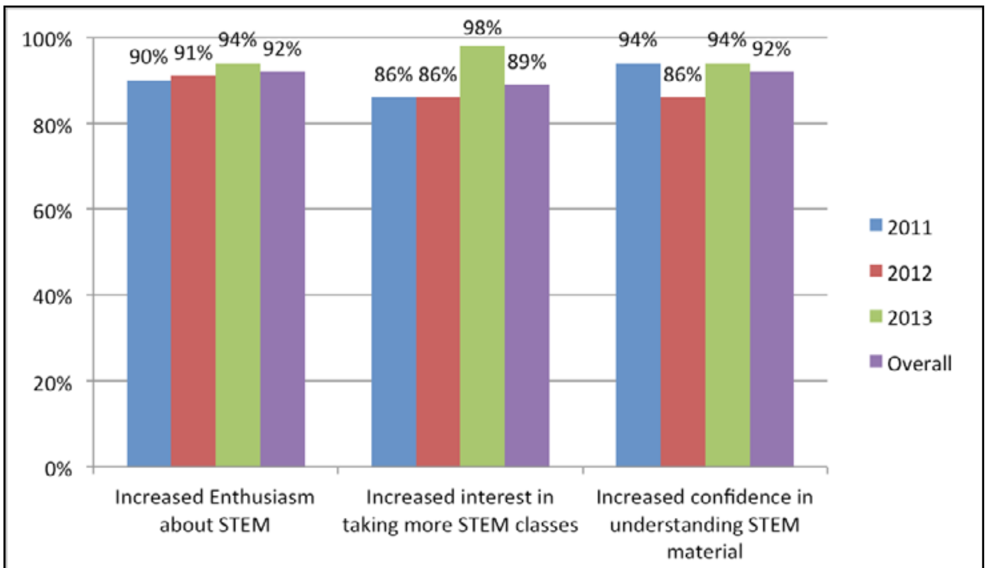

Figure 5: Student Perceptions of Success and Understanding

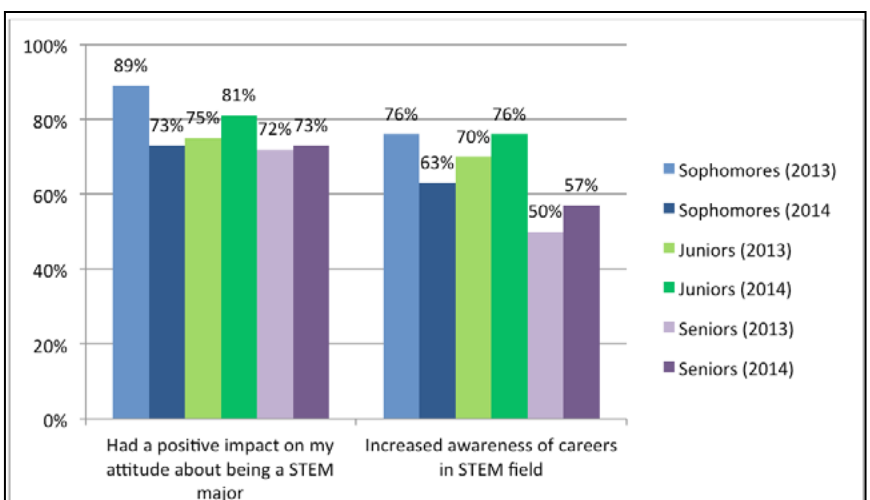

Figure 6: Upperclassmen Attitudes towards STEM Fields and Career Awareness

views were designed to measure the extent to which the BTV program had some influence on these perceptions and attitudes. Ninety-two percent of respondents from the 2011-2013 cohorts said that the SBW helped to increase their confidence in understanding STEM material (See Figure 5). When asked if the workshop had increased their enthusiasm for STEM topics, 92% of respondents agreed.

<Figure 5>
Figure 5: Student Perceptions of Success and Understanding

One of the primary goals of the BTV program's CLC intervention was to foster a long-lasting interest in STEM disciplines. Data collected from surveys of students then currently enrolled in the CLCs indicate that the program helped participants to develop a positive attitude about being a STEM major. Upperclassmen's responses indicated that these feelings persisted as participants progressed through their college coursework (Figure 6). Of the junior and senior STEM majors surveyed, notable majorities said that participation in the CLC program encouraged them to persist as STEM majors (Figure 6). Because of the emphasis on the importance of career outcomes in the existing research, program leaders took particular interest in the degree to which the project's interventions helped participants become more aware of STEM careers. Figure 7 shows that findings are strong, but mixed across cohorts, on this particular topic. Survey data suggests that participation in the CLC influenced students' perceptions of success in their STEM coursework. Seventy-eight percent of respondents from the 2011-2013 cohorts reported that their experiences in the CLC effectively prepared them for STEM classes. An equal percentage of participants said that CLC activities helped to improve their 1st semester grades.
<Figure 7>
Figure 7: Perceptions of Success in STEM Fields

Retention

The primary metric for the overall success of the BTV program was the retention rate of participants enrolled in STEM majors. The data reveal that both the SBW and CLC components of the program achieved notable successes with regards to STEM major retention. Working with students whose prior academic records suggested they would not persist to obtain a STEM degree, the program obtained an overall retention rate of approximately 60%. A number of students have already graduated with STEM degrees and many more are on track to follow suit in the coming years. In accordance with the program's goal, STEM enrollments rose at all four institutions during the grant's implementation.

There was some variation among the SBW CLC retention rates. Of the 233 students who participated in the SBW, approximately 70% persisted in STEM fields. Fifty percent of CLC participants from all cohorts were retained in STEM majors. Tables 2 and 3 give a detailed breakdown of retention rates by program component and cohort. Variation across cohorts and components may partially be attributed to changes in institutions' recruitment strategies (as mentioned above), student characteristics and institutional representations.
<Table 2>

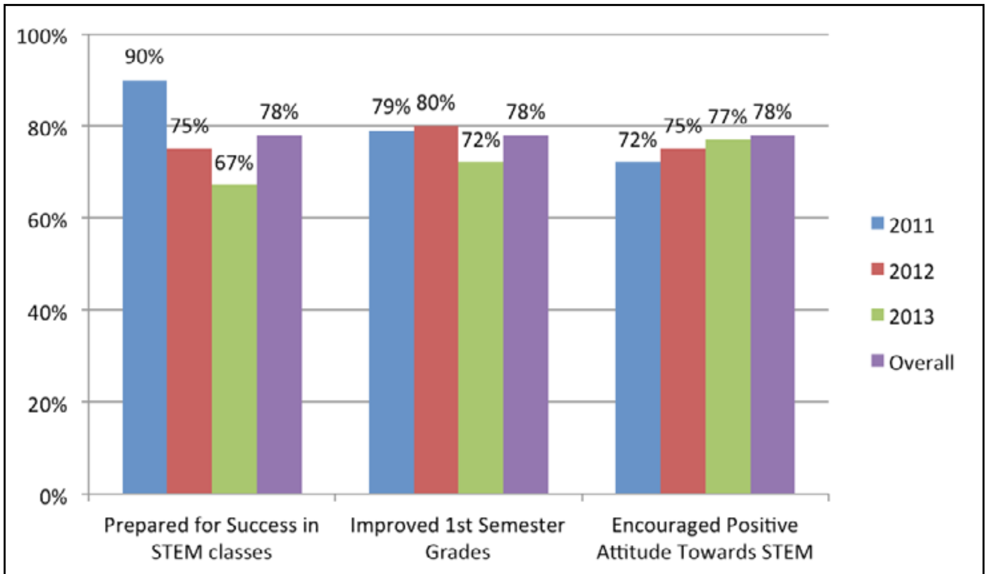

Figure 7: Perceptions of Success in STEM Fields

Probably the most compelling metric of success for the BTV intervention is the degree to which the number of STEM majors increased on each campus. For the BTV project, the combination of summer workshop and school year learning communities proved to be very effective in retaining STEM majors at the four institutions, particularly for at risk groups of students. In fact, STEM enrollments increased dramatically at all four institutions as shown in Table 4.

<Table 4>

Table 4 – Increase in Declared STEM majors at BTV Institutions

*Increase reflects the change from 2008 - 2013

Future Plans

Program leaders took a strong interest not only in students' experiences and performance during college, but also their post-graduation plans. Data collected from surveys of past BTV participants at various stages in their college coursework reveal many important findings about students' plans for the future. Of the upperclassmen surveyed in the spring of 2014, 63% reported that they would be continuing their formal education in STEM fields. Forty-five percent said that they would be studying in a STEM related field and 18% reported that they would be enrolling in medical school. These findings indicate that the project likely contributed to not only the retention of undergraduate STEM majors, but also to the fostering of postgraduate STEM interests.

Research Question #4: Do the SBW math course and CLC participation lead to better math skills and understanding (i.e. math course completion, course grades) relative to non-participating students?

One of the main goals of both the SBW and CLC interventions was to influence math learning outcomes and develop participants' math competencies. The Maplesoft Pre-calculus Test Suite was used as an online assessment to provide a baseline measure of math skills and as a pre-test. At the culmination of the three-week program, the assessment was administered again and participants' scores were used to measure math competency gains. Average pre- and post-test scores for all years are shown in Figure 8. In each year, the post-test scores were significantly higher than pre-test scores ($p<0.001$, paired t-test, sample size varied by year). All cohorts had an increase in normalized gain as well, indicating a substantial increase in their mathematics readiness.

In addition to math pre- and post-test score gains, other data support the claim that the BTV interventions helped to foster participants' mathematical development. Sixty percent of SBW survey respondents from the 2011-2013 cohorts reported that the math course "definitely prepared" them for college level math coursework (See Figure 9). During focus groups and on surveys, many students reported that they felt better prepared for STEM coursework because of the workshop's focus on math. Faculty participants who were interviewed at the end of the workshops also indicated that they felt students had made notable gains in their math skills. In some cases the summer gains were so dramatic that students were placed in a higher math class in the fall. At one of the BTV institutions (BC), students retook the institution's math placement test after successfully completing the SBW. Their performance on the retest allowed over half of the

Project Year	Began as STEM Major	Retained as STEM Major	Percentage
2009	35	18	51%
2010	50	32	64%
2011	49*	31	63%*
2012	47	35	75%
2013	52	46	89%
Total	233*	162	70%*

Table 2: Retention of Summer Workshop Participants (*In 2011, one participant died and is not included in the retention calculation)

Project Year	Began as STEM Major	Retained as STEM Major	Percentage
2009	71	26	36 %
2010	46	20	44%
2011	38	20	53%
2012	30	15	50%
2013	27	26	96%
Total	212	107	51%

Table 3: Retention of CLC Participants

College/University	STEM Majors						Change (%increase)*
	2008	2009	2010	2011	2012	2013	
Bridgewater College	316	332	400	411	456	470	48.7%
Eastern Mennonite University	100	139	150	151	162	158	58.0%
James Madison University	2833	3060	3370	3660	3918	4319	52.4%
TOTALS	3249	3531	3920	3922	4536	4947	52.3%

Table 4 – Increase in Declared STEM majors at BTV Institutions

*Increase reflect the change 2013 relative to 2008

group to be placed into Pre-Calculus instead of their original placement course, College Algebra.

Analysis from the JMU comparison group study also indicated that the SBW program was successful in enhancing the math competency gains of students relative to non-participating students. We used an alpha level of 0.05 for all the statistical tests we conducted. BTV participants' average grade in MATH 231 (Calculus) was 2.78, significantly higher than their control group peers, whose average grade was 2.09 (N=36, $p<0.05$). Program participation was also significantly correlated with taking more STEM courses for math (N=142, $p=0.002$), chemistry (N=142, $p=0.002$), and engineering (N=142, $p=0.02$). However there were no significant differences with respect to higher grades in other STEM classes between the two groups.

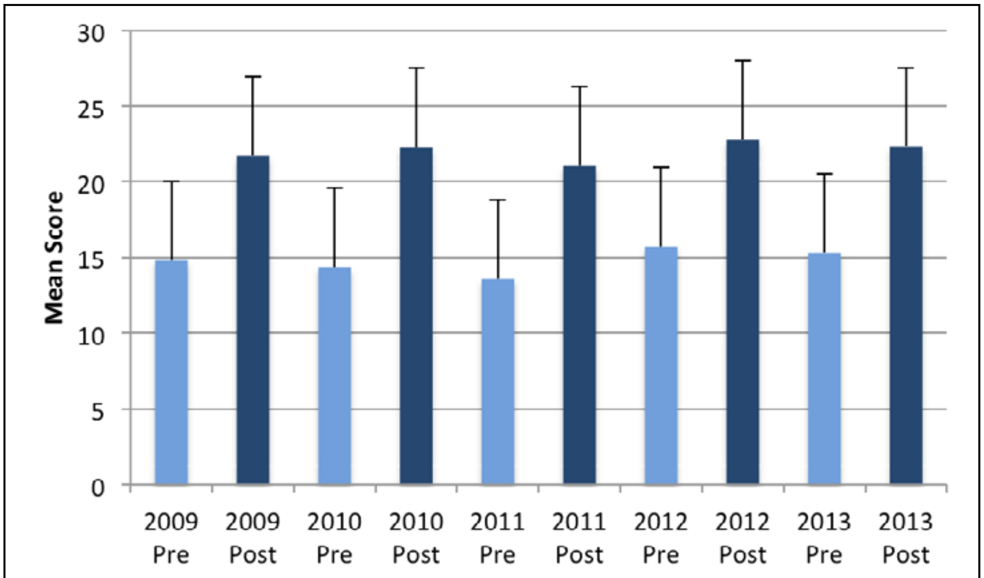

Figure 8: Pre-test/Post-test Mean Math Assessment Scores by Year. The error bars show the standard deviation in each sample.

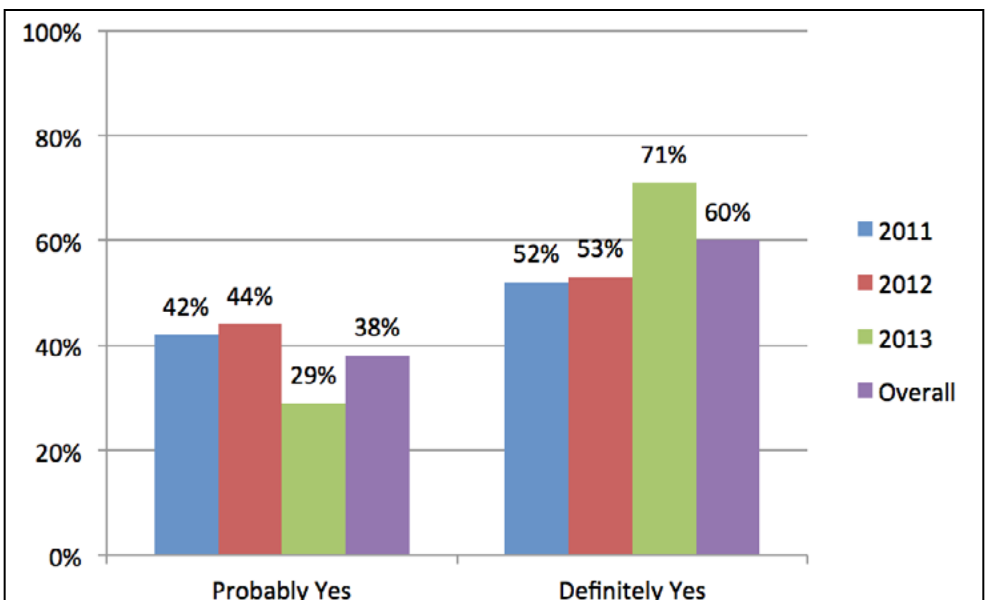

Figure 9: Perceptions of Preparedness for Math Coursework

Discussion and Lessons Learned

This project allowed four distinct institutions to collaborate on an extended project that helped contribute to significant growth in the retention of STEM majors across disciplines. Students' performance on math assessments and participant survey responses indicate that the program's efforts to enhance math competencies were successful. Approximately 60 percent of the program's over 300 participants persisted in their STEM majors. In addition to enhancing the retention of undergraduate STEM majors, survey data also strongly suggest that the project was successful in spurring participants' interests in post-graduate STEM opportunities. A survey of upperclassmen participants indicates that 63% of respondents planned on continuing their formal education in STEM fields. By all indications, these findings suggest that institutional efforts to support STEM retention can be effective.

The combination of the summer workshop and the collaborative learning communities, in particular, proved to be highly effective in supporting students from their freshmen year, setting them on a path of persistence through their STEM major. Our analysis was unable to discern the effect of the two different interventions, which constitutes a limitation of this study. However, the implementation of these two interventions appears to support STEM retention across different institutional types. In particular, SBW participants identified the workshop as an important tool for both enhancing and refining math competencies. Participant survey data also reveal that SBW activities helped students to better understand and link STEM concepts as well as identify with communities of support. These results are supported by the existing literature that emphasizes the importance of these three factors in the retention of STEM majors. Survey and interview data collected from CLC participants also highlight the importance of the component for the project's overall success. Responses from both current participants and upperclassmen emphasized the CLCs' effects on easing the college transition.

In conclusion, we highlight a number of lessons learned that have emerged from this project that may be helpful to other institutions seeking to implement similar efforts to support STEM retention.

Participant Identification. Over the course of the grant's implementation, BTV leaders utilized several different strategies to identify participants for the program. Each strategy produced a variety of results within their respective contexts but a universal formula was not identified. Future implementations should take the variable nature of participant identification into account during both the development and implementation phases.

Inter-institutional Collaboration. Collaboration across institutions proved to have major benefits for the BTV program. By engaging students across campuses, the project was able to develop a regional community of STEM majors, leverage a wide net of campus resources (faculty, facilities, etc.) and engage a diverse set of STEM faculty from a variety of fields. In an era of reduced funding, collaborating with like-minded institutions on STEM retention would multiply efforts and secure scarce resources.

Flexible arrangements with Collaborative Learning Communities. The flexibility institutions needed to create collaborative learning communities to support students in their first year was another lesson learned from this project. We resisted the urge to use a "one size fits all" approach to structuring and organizing these learning communities. Key factors that contributed to the development of successful collaborative learning communities included sensitivity to institutional culture, application processes, and understanding of faculty limits.

Project coordinator engagement. The Project coordinator managed activities at the SBW and implemented a number of CLC activities at each of the schools while also working with each co-PI to adapt programs to the specific needs of each institution. The coordinator delivered time management workshops, hosted career workshops with STEM professionals from the local community, and supported the CLCs by being an active presence on each of the participating campuses. Project leadership frequently noted the good fortune of having a project coordinator who could work across the campuses and provide a sense of cohesion across the different campus communities.

Institutional Commitment and Policy. This project represented an unusual collaboration combined with an institutional commitment on each campus to increase the number of students entering the STEM pipeline. There was an institutional commitment to support this model of community college/college and university interaction that led to a substantial increase in STEM majors. In the final analysis, higher education institutions have an obligation to support STEM retention programs and policy makers have the opportunity to support institutions seeking to provide the support mechanisms necessary for undergraduate student success in STEM.

References

Alston, S., McGowan, J., & Taylor, O. (2008). The Effect of Learning Communities on Achievement in STEM Fields for African Americans across Four Campuses. *The Journal of Negro Education, 77* (3), 190-202.

Astin, A. (1985). *Achieving educational excellence: A critical assessment of priorities and practices in higher education*. San Francisco: Jossey-Bass.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Building Engineering & Science Talent (BEST) (2004). A Bridge for All: Higher Education Design. Principles to Broaden Participation in Science, Technology, Engineering, and Mathematics. Retrieved January 2009, from http://bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdDesignPrincipals.pdf

DeBaise, J. M., & White, J. R. (2004). Amazing Growth at SUNY ESF. *Building and sustaining learning communities: the Syracuse University experience, 43,* 139.

Eagan, K., Hurtado, S. & Chang, M. (2010)."What matters in STEM: Institutional contexts that influence STEM bachelor's degree completion rates." *Annual meeting of the Association for the Study of Higher Education, Indianapolis, IN.*

Hurd and Ruth Federman Stein (Eds.) *Building and Sustaining Learning Communities* (pp. 139-152). Hoboken, NJ: John Wiley and Sons.

Gilmer, T.C. (2007). An Understanding of the Improved Grades, Retention and Graduation Rates of STEM Majors at the Academic Investment in Math and Science (AIMS) Program of Bowling Green State University (BGSU). *Journal of STEM Education 8* (1&2), 11-21.

Grant-Vallone, E. J., & Ensher, E. A. (2000). Effects of Peer Mentoring on Types of Mentor Support, Program Satisfaction and Graduate Student Stress: A Dyadic Perspective. *Journal of College Student Development, 41(*6), 637-42.

Higher Education Research Institute (2010). Degrees of success: Bachelor's degree completion rates among initial STEM majors. Retrieved on March 1, 2010, from http://www.heri.ucla.edu/nih/HERI_ResearchBrief_OL_2010_STEM.pdf

Hunt, S. (2003). Encouraging student involvement: an approach to teaching communication. *Communication Studies, 54,* 133-136. Kezar, A. (2001). Summer Bridge Programs: Supporting All Students. Eric Digest ED 442421.

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2009). Diversifying science: Underrepresented student experiences in structured research programs. *Research in Higher Education, 50*(2), 189-214.

Kardash, C. M. (2000). Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92*(1), 191-201.

Kim, K., Fann, A. and Misa-Escalante, K. (2009). "Engaging women in computer science and engineering: Insights from a national study of undergraduate research experiences." *Center for Embedded Network Sensing.*

Laws, P. W. (1999). New approaches to science and mathematics teaching at liberal arts colleges. *Daedalus, 128* (1), 217-40.

Lent, R.W., Brenner, B., Brown, S.D., Lyons, H., Schmidt, J., Treistman, D. (2003). Relation of Contextual Supports and Barriers to Choice Behavior in Engineering Majors: Test of Alternative Social Cognitive Models. *Journal of Counseling Psychology, 50* (4), 458-465.

Leppel, K. (2001). "The impact of major on college persistence among freshmen. "*Higher Education* 41.3: 327-342.

Marx and Cummings. (2007) Normalized Change. *American Journal of Physics, 75*(1), 87-91.

Matyas, M. L. (1991). Programs for women and minorities: Creating a clear pathway for future scientists and engineers. In M. L. Matyas & S. M. Malcom (Eds.), *Investing in human potential: Science and engineering at the crossroads* (pp. 67-96). Washington, DC: American Association for the Advancement of Science.

Moust, J. C., & Schmidt, H. G. (1994). Effects of staff and students tutors on student achievement. *Higher Education, 28* (4), 471-82.

Rask, K. (2010) Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review, 29* (6), 892 - 900.

Redmond, S. P. (1990). Mentoring and cultural diversity in academic settings. *American Behavioral Scientist, 34* (2), 188-200.

Rendón, L. I. (2002). Community College Puente: A validating model of education. *Educational Policy,* 16, 642-667.

Sabatini, D. A. (1997). Teaching and research synergism: The undergraduate research experience. *Journal of Professional Issues in Engineering Education and Practice,* 123(3), 98-102.

Santa-Rita, E. & Bacote, J. (1996). The benefits of college discovery pre-freshmen summer programs for minority and low income students. *Eric Digest* ED 394 536.

Santos, S. J., & Reigadas, E. T. (2002). Latinos in higher education: An evaluation of a university faculty mentoring program. *Journal of Hispanic Higher Education, 1*, 40-50.

Schambach, T. P., & Kephart, D. (1997). Do I/S students value internship experiences? (ERIC Document Reproduction Service No. ED422937).

Schwitzer, A. M., & Thomas, C. (1998). Implementation, utilization, and outcomes of a minority freshman peer mentor program at a predominantly white university. *Journal of the Freshman Year Experience & Students in Transition,* 10 (1), 31-50.

Shaw, E. J., & Barbuti, S. (2010) Patterns of Persistence in Intended College Major with a Focus on STEM Majors. *NACADA Journal:* Fall, Vol. 30, No. 2, pp. 19-34.

Stein, Ruth Federman (2004). Learning Communities: Overview. In Sandra Hurd and Ruth Federman Stein (Eds.) *Building and Sustaining Learning Communities* (pp. 3-18). Hoboken, NJ: John Wiley and Sons.

Murphy, T.E. Gaughan, M., Hume, R. and Moore Jr., S. Gordon. (2010). "College Graduation Rates for Minority Students in a Selective Technical University: Will Participation in a Summer Bridge Program Contribute to Success?" *Educational Evaluation and Policy Analysis* Vol. 32, No. 1: pp. 70-83. Published by: American Educational Research Association. Stable URL: http://www.jstor.org/stable/40732410

Texas Higher Education Coordinating Board (2009). Best Practices: Success and Retention. Retrieved January 15, 2009, from www.thecb.state.tx.us/os/URRS/BPSR.cfm?ActivityID=1419.

Thile, E. L., & Matt, G. E. (1995). The ethnic mentor undergraduate program: A brief description and preliminary findings. *Journal of Multicultural Counseling and Development, 23* (2), 116-126.

Tinto, V. (1999). "Taking retention seriously: Rethinking the first year of college." *NACADA Journal* 19.2; 5-9.

Watkins, J., & Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching, 42*(5), 36-41.

Waldron, V. R., and Yungbluth, S.C. (2007). "Assessing student outcomes in communication-intensive learning communities: A two-year longitudinal study of academic performance and retention." *Southern Communication Journal* 72.3:285-302.

Wilson, Zakiya S., et al. (2012) "Hierarchical mentoring: a transformative strategy for improving diversity and retention in undergraduate STEM disciplines." *Journal of Science Education and Technology* 21.1: 148-156.

Dr. Bob Kolvoord is a professor of Integrated Science and Technology at James Madison University in Harrisonburg, VA, where he also serves as the dean of the College of Integrated Science and Engineering. Dr. Kolvoord served as the PI for the Bridging the Valley project. He holds a B.A. in Physics and an M.S. in Materials Science from the University of Virginia, and a Ph.D. in Theoretical and Applied Mechanics from Cornell University. Dr. Kolvoord's research interest focus on the use of geospatial technologies and their impact on students' spatial thinking skills.

Dr. Robyn Puffenbarger is an associate professor of Biology at Bridgewater College in Bridgewater, VA. She received her bachelors of science in biology from Virginia Tech and PhD in molecular immunology from the Medical College of Virginia. She also conducted post-doctoral research at SUNY-Stony Brook. She attended the Biology Scholars Program hosted by the American Society for Microbiology and funded by the National Science Foundation to begin her work on the scholarship of teaching and learning (SoTL).

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Dr. Ray McGhee is a senior research scientist in SRI's Education division. For nearly two decades, he has conducted and directed research and program evaluations on efforts to improve students' transition from secondary school to postsecondary school and to the workforce. McGhee has worked on projects examining informal learning in out-of-school settings and high school reform, and he has worked with states, districts, community-based organizations, and schools to plan and implement formative and summative evaluations. He has also studied recruitment, retention, and induction programs designed to prepare postsecondary students for careers in STEM. Dr. McGhee received his doctorate in education from the University of California, Los Angeles.

Dr. Roman J. Miller, is the Suter Endowed Professor of Biology and Director of the MA in Biomedicine program at Eastern Mennonite University (EMU), Harrisonburg, Virginia. He received his Ph.D. in Biomedical Science from Kent State University, and completed a postdoctoral fellowship in physiology/pharmacology at West Virginia University. During the past 31 years at EMU, Dr. Miller has taught courses in physiology, developmental biology, bioethics, and biomedicine. Current research interests include organic blueberry production and the beneficial role of blueberry anthocyanins in mitigating deleterious effects of alcohol in developing embryos.

Ken Overway is an associate professor and chair of the chemistry department at Bridgewater College in Bridgewater, VA. He received his Ph.D. in analytical chemistry from Purdue University in 1997 and a B.S. from Hope College in 1993. His professional interests include soil kinetics, spectroscopy, instrument design and computer interfacing.

Mr. Kenneth Phillips is an instructor of Physics at Blue Ridge Community College in Weyers Cave, VA. He graduated from George Mason University with a Bachelor of Science Degree in physics and from the University of Arkansas with a Masters of Science degree in physics. For the past twenty years he has been teaching physics at various community colleges. He has imparts a sense of enjoyment and understanding of science in general, and physics in particular, to his students, along with improving their problem solving and critical thinking skills. He also helps them achieve their career goals beyond the community college setting.

Ms. Lynne Ryan is an associate professor of mathematics at Blue Ridge Community College in Weyers Cave, VA. She holds a B.A. in Philosophy and an M.A. in Mathematics from Virginia Tech. She has worked within the Virginia Community College System since 1990, and joined the faculty at Blue Ridge in 2004. She currently serves as the faculty program coordinator for the College's transfer degrees. She is committed to fostering the success of her students at all levels, not just in the classroom, but in their progression through BRCC and transition to the next stage in their education.

Ms. Jennifer Sowers is as an adjunct professor in Communications Studies and Theatre at Blue Ridge Community College. She holds a MA in Radio, Television and Film from the University of Maryland and a BA in Urban Studies from Roanoke College. Her college administration career includes work in Admissions, Student Affairs, and University Advancement. She served as the Project Coordinator for Bridging the Valley.

Mr. Jordan Brown served as a student associate for SRI International's Center for Education Policy and now works as an analyst in the Washington D.C. Public Schools. He received his BA in Political Science from the University of Notre Dame and his MA in Education Policy Studies from George Washington University. His research interests include STEM education, specialized instruction, educational measurement & assessment, statistics and education data analysis.