White Paper

STEM@SUNY

Increasing the Persistence of Undergraduate Students in STEM at the State University of New York (SUNY)

Prepared by:
The STEM Undergraduate Research and Education Steering Committee

SUNY STEM Undergraduate Research and Education Steering Committee Members

- **Melissa Bartlett**, **PhD (Biology),** Instructor, Mohawk Valley Community College
- **Kathleen Caggiano-Siino, MBA,** Vice President for Human Resources, Research Foundation
- **Kimberly Eck, PhD (Epidemiology),** Manager, Collaborative Proposal Development**,** Research Foundation
- **David Ferguson**, **PhD (Applied Mathematics)**, Academic Chair, Distinguished Service Professor of Technology and Society and Applied Mathematics and Statistics, and Associate Provost for Diversity and Inclusion, Stony Brook University
- **Candice Foley**, **PhD (Chemistry),** Professor of Physical Sciences, Suffolk Community College
- **James Hewlett, MS (Biology),** Professor of Biology, Director of Biotechnology, Finger Lakes Community College
- **Shashi Kanbur**, **PhD (Physics),** Professor of Physics and Earth Science, Oswego
- **Peter Knuepfer**, **PhD (Geology),** President, Faculty Senate, SUNY System Administration
- **Bonita London**, **PhD (Psychology)**, Assistant Professor, Social and Health Psychology, Stony Brook University
- **Carol Long**, **PhD (English),** Interim President, Geneseo
- **Lisa Montiel**, **PhD (Anthropology)**, Director of Strategic Management, SUNY System Administration
- **Phillip Ortiz**, **PhD (Chemistry)**, Mentor/Coordinator, Science, Mathematics and Technology Studies, Empire State College
- **Kim Scalzo**, Director, SUNY Center for Professional Development, SUNY System Administration
- **Joe Skrivanek**, **PhD (Chemistry),** Professor of Chemistry, School of Natural and Social Sciences, Purchase College
- **Jill Singer**, **PhD (Earth Science)**, Director of the Office of Undergraduate Research, Professor of Earth Sciences & Science Education, Buffalo State College
- **James Spiller**, **PhD (History),** Assistant Provost for Research & Education, Dean of the Graduate School, Brockport
- **Timothy A. Tryjankowski**, Director, Center for Undergraduate Research and Creative Activities, University at Buffalo
- **Daniel White**, **PhD (Anthropology),** Associate Vice President for Student Affairs and Professional and Corporate Recruitment and Outreach, Director of Academic Advisement, CNSE
- **Nancy Willie-Schiff**, **PhD (Higher Education),** Assistant Provost, SUNY System Administration
- **Angela Wright,** Director, Government Relations, Research Foundation

Table of Contents

A. Executive Summary

STEM literate college graduates enter the real world with the tools necessary to lead enriched and empowered lives. STEM literacy is essential to providing college graduates the ability to thrive in and bring value to the workforce. Today's global economy has increased the need for workers with STEM skills. Technological innovation improves the competitive position of U.S. industries, drives export growth, and supports high-quality jobs. Additionally, as a result of the diffusion of technology across industries and occupations, the demand for STEM-capable workers has increased even in traditionally non-STEM fields.

The President's Council of Advisors on Science and Technology (PCAST) asserts that the U.S. is putting its future at risk by forfeiting its historical strengths in STEM education. In their seminal report *Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics,* PCAST challenges U.S. colleges and universities to prepare one million more STEM college graduates over the next decade. To meet the goal of an additional 1 million STEM college graduates in the next decade, the U.S. would need to graduate an additional 100,000 per year – a 33% increase over current rates.

SUNY has the unique ability to make a positive impact on this national goal. As the largest integrated university in the U.S., its 64 campuses provide access to almost every field of academic or professional study educating nearly 463,000 students in more than 7,500 degree and certificate programs.

In 2013, consistent with State University of New York Chancellor Nancy L. Zimpher's goals for enhancing experiential learning across the SUNY system and building upon the initiatives being implemented by the SUNY Office of the Provost and the Office of the Education Pipeline as a part of the Power of SUNY strategic plan, Timothy Killeen, PhD President of the Research Foundation and SUNY Vice Chancellor for Research articulated a bold goal: By 2019, double the number of undergraduate STEM degrees conferred throughout the SUNY system – increasing the number of undergraduate STEM degrees conferred each year from 10,482 to 20,800.

Currently, across the SUNY system, approximately 10,300 full-time first-time undergraduate students matriculate in a STEM program each year. After their first year, 24% leave SUNY and another 11% will switch to a non-STEM program, meaning 3,600 students abandon their STEM education after one year. Achieving Dr. Killeen's goal will require attracting more students to STEM fields and enabling them to persist. The Provost's office, along with the Research Foundation for SUNY and Office of the Education Pipeline are working together to achieve this goal.

Administrators, faculty, and leadership from across the SUNY system were invited to join a SUNY STEM Undergraduate Research and Education Steering Committee. Our Committee was charged with creating a plan that featured experiential learning and research experiences to increase the number of STEM degrees conferred to undergraduates throughout the SUNY system, in addition to increasing STEM literacy, which will provide these students with the tools necessary to thrive and bring value to a number of jobs, as they enter the workforce. The

Committee quickly recommended an appropriate leadership structure and identified several potential solutions for reaching our goal: mentored research experiences, evidence-based teaching, and supplemental supports. Plus, the Committee emphasized the importance of increasing the diversity of STEM students, especially underrepresented minorities and women.

This document, and the recommendations that follow, form a conceptual framework, rather than a proposal. We aim to identify and emulate best practices from within the SUNY system and in other systems of higher education across the country. We anticipate adopting a range of programs that will be tailored to leverage each campus's strengths.In alignment with the PCAST report, our recommendations are as follows:

Leadership
Purpose: Create an appropriate leadership structure to support the goal of doubling the number of SUNY STEM graduates by implementing the recommendations below.

- **Recommendation 1: System Leadership -** The Committee suggests that the SUNY Chancellor identify and support a qualified expert (at System Administration or on a campus) to champion STEM@SUNY in partnership with other leaders and the Committee. This expert would collaborate with the multiple offices and units within System Administration that currently support undergraduate STEM efforts, and be responsible for coordinating communications, professional development initiatives, data collection, and analysis. This leader would work with SUNY System colleagues to allocate resources for STEM education (from internal and external sources) to achieve campus and system goals as well as publicly report on initiatives and progress.
- **Recommendation 2: Campus Leadership -** The Committee suggests that each campus convene a STEM Undergraduate Research and Education Committee to lead the implementation of this report's recommendations. We encourage campuses to tap existing committees and reporting structures to avoid unnecessary duplication of efforts. In some cases, multiple campuses might consider creating one joint committee, if they are geographically proximate or have similar needs and resources. Using a collaborative approach to managing the responsibilities related to planning, customization, implementation, accountability, and evaluation will allow campuses to leverage their unique strengths while participating in a system-wide effort with system-wide recourse

Mentored Undergraduate Research
Purpose: Increase the number of students participating in mentored undergraduate research experiences.

- **Recommendation 3**: Campuses should identify, enumerate, and categorize their funded and unfunded positions for undergraduate mentored research experiences in STEM for the ultimate goal of creating an integrated, electronic system through which any SUNY students can apply for mentored research experiences throughout the SUNY system and beyond.
- **Recommendation 4**: Campuses should strive to create an environment that is fully supportive of undergraduate research by identifying and pursuing transformative opportunities related to their mission and culture, administrative support, research infrastructure, and/or faculty recognition.

Evidence-Based Teaching

Purpose: Implement curriculum redesign solutions to increase the percentage of introductory STEM gateway courses that include applied, active, and experiential learning opportunities.

- **Recommendation 5**: Campuses should increase the use of evidence-based teaching strategies, specifically inquiry-based, research-like activities, into introductory STEM courses and laboratory requirements, and to the extent possible, add more research-based STEM courses.
- **Recommendation 6**: Each campus's STEM Undergraduate Research and Education Committee should consider how to best address the "math gap." We suggest that Committees begin pursuing alternative, evidence-based approaches to enable students to complete mathematics requirements and ensure that mathematics is not a barrier to pursuing STEM majors.

Supplemental Supports

Purpose: Increase the availability and use of supplemental supports, such as professional development opportunities, mentoring, and presentation/publishing opportunities, to support STEM students' persistence in STEM.

- **Recommendation 7**: Campuses should include supplemental supports in all evidence-based teaching initiatives and research experiences for undergraduates. The extent to which supplemental supports are incorporated into existing initiatives should be reviewed and enhanced as appropriate; plus, as new initiatives are created, supplemental supports should be included.
- **Recommendation 8**: Each campus's STEM Undergraduate Research and Education Committee should consider how to increase the number of students receiving supplemental supports that extend beyond the classroom and research laboratory by leverage existing opportunities and creating new ones.

To support these recommendations, the STEM Undergraduate Research and Education Steering Committee identified several important needs, including:

- **Faculty support and incentives**, including a comprehensive electronic resource and professional development plan to provide faculty and staff with the knowledge, evidence, and tools to implement the above recommendations; and honorary and financial awards, decreased teaching loads, and/or favorable tenure review in recognition of faculty commitment to undergraduate STEM persistence.
- An **electronic collaboration platform** where students can connect with potential mentors among faculty, peer students, and alumni professionals within and across SUNY institutions, and where they can review, compare, and apply to mentored research experiences available throughout the SUNY system.
- Funding to directly **support STEM students**, especially for mentored research.

The Committee emphasized that these initiatives require evaluation, quality improvement and sustainability plans at the campus and system level. These recommendations are not meant to minimize or undermine the many innovative projects and efforts being implemented throughout SUNY; rather, the Committee aims to build on the ongoing work with a shared vision for and system-wide dialogue about enhancing STEM literacy and increasing the numbers and persistence of SUNY STEM undergraduate students.

B. Background and Need

What is STEM?

The acronym STEM stands for science, technology, engineering, and math. However, there is no consensus about precisely which degrees and occupations count as STEM. In general, for the purposes of this paper, the State University of New York (SUNY) System Administration Office of Institutional Research (which supplied data on SUNY STEM enrollments and degrees conferred) considers STEM to include life sciences (except some health professions), physical sciences, mathematics and statistics, computing, and engineering. More specifically, the Office uses the Department of Homeland Security (DHS) definition of STEM based on the Classification of Instructional Programs (CIP) codes established by the National Center for Education Statistics. Notably, this definition is broader than the definition that was used to prepare SUNY's report cards and define targets included in the Power of SUNY strategic plan.

As of 2013, SUNY has approximately 7,400 credit-bearing academic programs, of which 1,344 meet the DHS STEM definition. A list of the number of degrees granted in each of those STEM programs is included in Appendix A. However, sources referenced in this document have differing definitions of STEM. These differences in definitions across sources can complicate comparisons or analyses of trends in STEM.

I. STEM undergraduate education in the U.S.

a. The national challenge

Achieving excellence in science, technology, engineering, and mathematics (STEM) has been a national priority, both formally and informally, for most of our country's history. From the establishment of land grant universities in the 1862 to the launch of Sputnik in 1957 to the 1983 *A Nation at Risk: The Imperative for Educational Reform* report, STEM has risen to the forefront of our national consciousness again and again. STEM is an integral part of our national identity.

In 2012, the President's Council of Advisors on Science and Technology (PCAST) asserted that the U.S. is putting its future at risk by forfeiting its historical strengths in STEM education.[1] In its seminal report *Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics,* PCAST explains that our past reliance on foreign-born STEM professionals to satisfy unmet workforce needs places the U.S. in an increasingly precarious position. With rising STEM employment opportunities throughout the world, there is no guarantee that the supply of international STEM workers will continue to adequately meet U.S. needs.

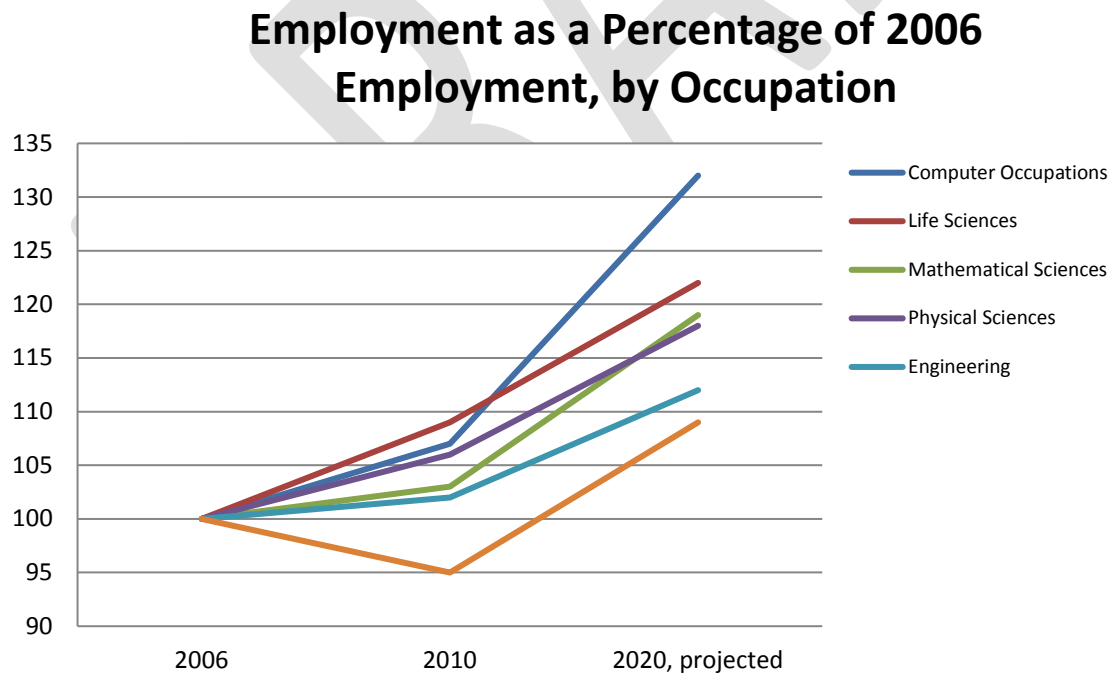
To address STEM workforce needs domestically, PCAST challenged U.S. colleges and universities to prepare one million more STEM college undergraduates over the next decade. To meet this goal, the U.S. would need an additional 100,000 STEM graduates per year. This represents a 33% increase over current degree production - increasing the number of students graduating with associate's and bachelor's degrees from 300,000 to 400,000 per year.

However, transforming the typical college campus using traditional STEM education model to one that provides a comprehensive and highly supportive environment for STEM student is not easy. Even for highly motivated faculty, there are substantial institutional barriers. Faculty time, departmental norms, physical space and layout of classrooms, tenure guidelines, curriculum requirements, and even student expectations are barriers that must be simultaneously addressed.

b. The importance of STEM

STEM literate college graduates enter the real world with the tools necessary to lead enriched and empowered lives. STEM literacy is essential to providing college graduates the ability to thrive in and bring value to the workforce. Today's global economy has increased the need for workers with STEM skills. Technological innovation improves the competitive position of U.S. industries, drives export growth, and supports high-quality jobs.[2] Additionally, as a result of the diffusion of technology across industries and occupations, the demand for STEM-capable workers has increased even in traditionally non-STEM fields.[3]

The demand for STEM-skilled workers is expected to continue to increase in the future. Business organizations and other groups have issued numerous reports and surveys that suggest that there is a heightening need for qualified STEM workers – both those with highly specialized skills as well as those with a more general knowledge of STEM concepts.[4, 5] Data from the Bureau of Labor Statistics show that employment in STEM occupations is expected to expand faster than employment in non-STEM occupations from 2010 to 2020 (by 17 versus 14 percent).[6]



Source: Chairman's staff of the Joint Economic Committee based on data from the Bureau of Labor Statistics. The BLS does not project employment for individual years from 2010-20. For purposes of this chart, Life Sciences excludes Medical Sciences.

Figure 1: Sustained growth in project for STEM occupations

Lower unemployment rates and higher relative wages in STEM occupations indicate the strong demand for STEM workers. The relative strength of the labor market for STEM workers pre-dated the recent recession, and it persisted during and after it. The STEM unemployment rate peaked at 5.5 percent in 2009, while the unemployment rate in non-STEM occupations was still climbing, reaching nearly 10 percent in 2010.[7] In 2010, STEM workers earned 26 percent more than non-STEM workers, even after accounting for other factors that affect pay, such as age, gender, race, location, industry, and union status.[8] While the size of this premium varies with education, it exists for all levels of education. The differential is greatest among workers with less than a bachelor's degree, who make, on average, over 30% more per hour than non-STEM workers with a similar level of education.[9] Among graduates with a bachelor's degree, STEM graduates make about 23 percent more.[10]

The demand for employees with STEM degrees in New York State is high today and will continue to grow. Currently, there are an estimated 25,000 STEM job openings each year in New York State - nearly number the number of degrees conferred by SUNY annually.[11] Within the next ten years, over 8% of all job openings in New York State will be in STEM fields and require a postsecondary education.[12]

c. The leaky STEM pipeline

Despite the clear demand for STEM talent by domestic employers, the U.S. is failing to produce an ample supply of workers to meet the growing need. For decades, educators and policy makers have recognized the influence that early learning experiences have on the students' progression through advancing levels of STEM education, a concept referred to as the STEM pipeline. However, as many researchers have observed, this pipeline is leaky – inadequate preparation and disinterest erode the potential STEM workforce at each educational milestone especially among underrepresented minorities and women.[13] During middle and high school, many students struggle with math and science, falling short of age-appropriate benchmarks on achievement tests. Upon leaving high school, too few students are ready for college-level math and science. In college, there are more bottlenecks and diversions. In the U.S., fewer than 40% of the students who enter college with the intention of majoring in a STEM field complete a STEM degree.[14] Of the students that begin to pursue STEM majors few will complete a STEM degree - among students first enrolled in STEM fields, 35% of students will attain a STEM degree.[15] Most of the students who leave STEM fields switch to non-STEM majors after taking introductory science, math, and engineering courses.[16]

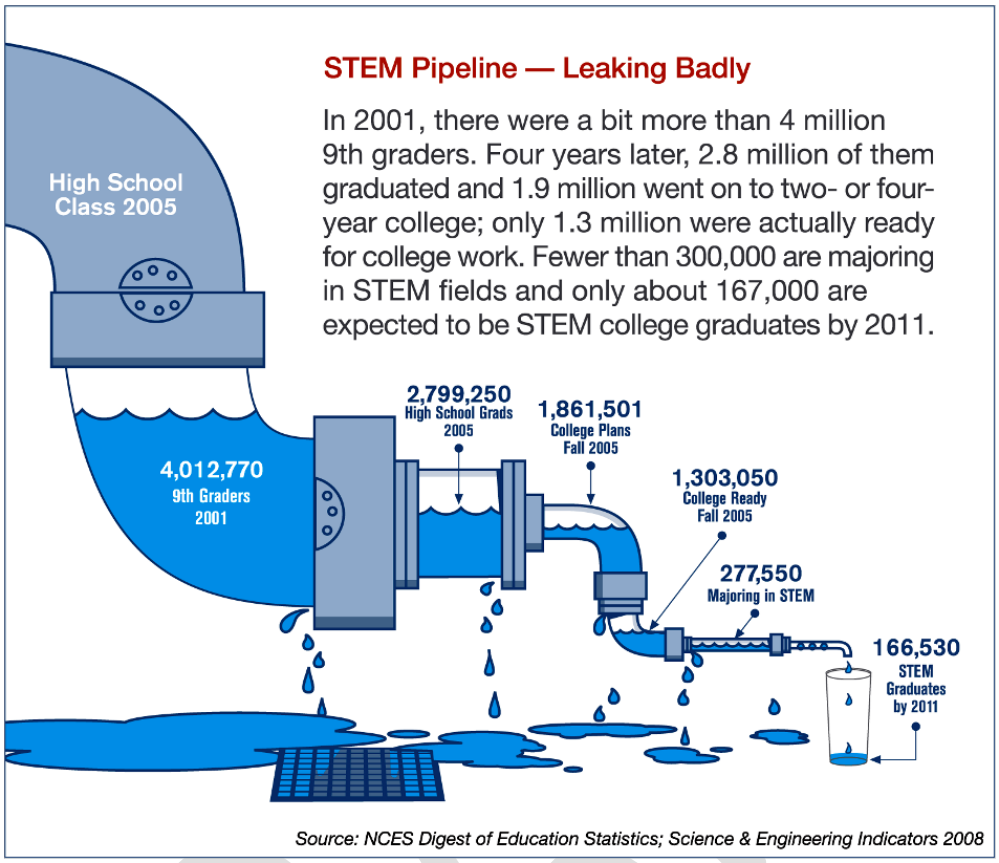


Figure 2: Depiction of leaky STEM education pipeline

The factors that influence enrollment and persistence (also called retention) in STEM majors are diverse and interconnected. Many researchers have described a push-pull effect. The benefits of non-STEM majors attract students while the challenges of being a STEM major and a lack of engagement push students away.[17] Some students that leave STEM fields do so because they do not perform well. Inadequate academic preparation, limited academic and social engagement, and costs are substantial barriers to persisting in STEM.[18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28] Many high-performing students leave their STEM majors because they are unengaged by the ineffective and uninspiring teaching methods and atmosphere typical of introductory STEM classes.[29,30]

Since 2009, the number of STEM associate's and bachelor's degrees conferred has remained stable while the total increased substantially. Therefore, STEM degrees have become a smaller proportion of total degrees.

The PCAST warns that without action, the proportion of STEM degrees among college graduates will continue to drop.[31]

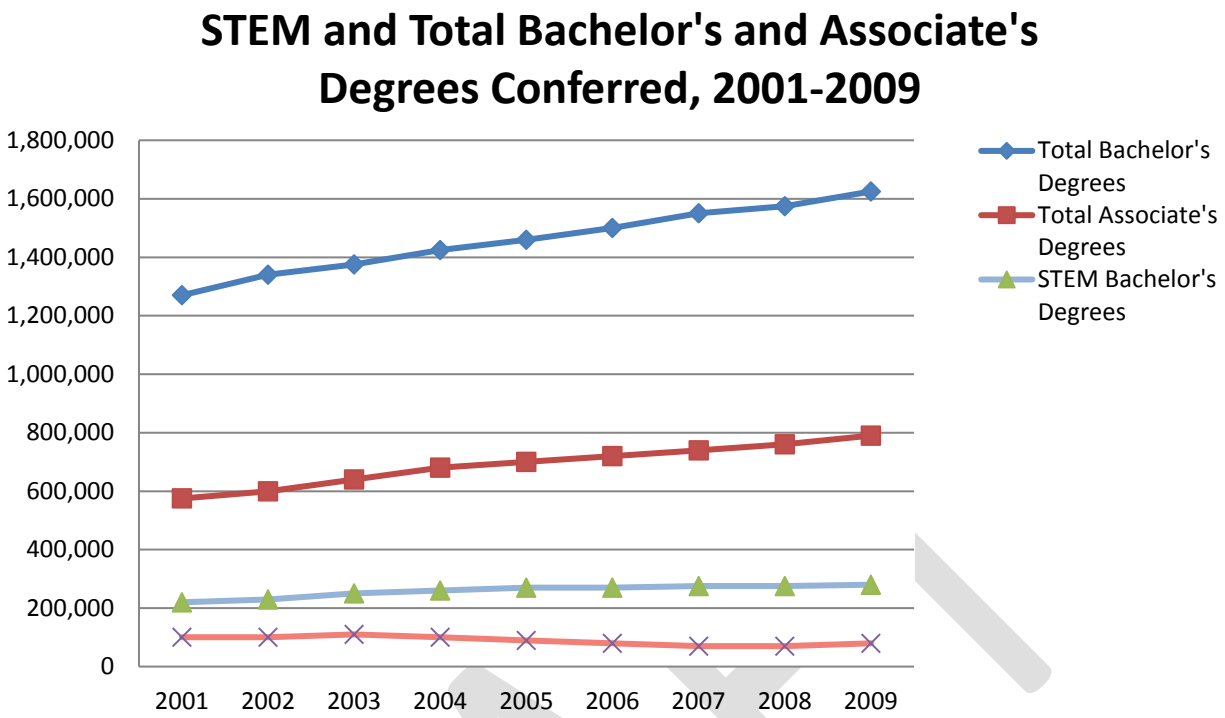


Figure 3: STEM and Total Bachelor's and Associate's Degrees Conferred, 2001-2009 [32]

II. STEM undergraduate education in New York State and at SUNY

a. State University of New York (SUNY)

The nation's largest and most comprehensive state university system, whose roots date back to 1816, the State University of New York (SUNY) was officially established in February 1948 when New York became the 48th state, of the then 48 states, to create a state university system. SUNY initially represented a consolidation of 29 unaffiliated institutions, including 11 teachers colleges. All of these colleges, with their unique histories and backgrounds, united for a common goal: To serve New York State. Since 1948, SUNY has grown to include 64 individual colleges and universities that were either formerly independent institutions or directly founded as part of SUNY.

Today, SUNY's 64 geographically-dispersed campuses, their branch campuses, and other locations bring educational opportunity within commuting distance of virtually all New Yorkers and comprise the nation's largest comprehensive system of public higher education. SUNY's 64 campuses are classified into four categories, based on educational mission, types of academic opportunities available and degrees offered. These include doctoral, comprehensive, and technology institutions, as well as community colleges. SUNY offers students a wide diversity of

educational options including short-term vocational/technical courses, certificate, associate, and baccalaureate degree programs, graduate degrees and post-doctoral studies. SUNY provides access to almost every field of academic or professional study. As of fall 2012, it served nearly 463,000 students – including almost 423,000 undergraduates – in more than 7,500 degree and certificate programs, and more than 1.8 million NYS citizens in professional development and personal enrichment programs.

SUNY students represent New York's diversity: one-quarter of its students are minorities. While SUNY students are predominantly New York State residents, representing every one of the state's 62 counties, they also hail from every other state in the United States, the District of Columbia, four U.S. territories, and 160 nations. Nearly 40% of New York State high school graduates choose SUNY and 99.8% of New York residents live within 30 miles of a SUNY campus. SUNY alumni number over 2.7 million graduates residing in New York State, the nation, and throughout the world.

The Power of SUNY Strategic Plan prioritizes the development of an inclusive and seamless education pipeline as an imperative to fuel the economic revitalization of New York State and enhance the quality of life for New Yorkers. As the nation's largest comprehensive system of public higher education, SUNY is aggressively pursuing "systemness". By planning and implementing initiatives, such as STEM@SUNY, that are comprised of multiple, coordinated components and involve virtually all of its campuses, SUNY will be able catalyze measureable, state-level improvements. The network of activity created through system initiatives such as this has the potential to be larger in scope and scale than any other system of higher education in the U.S.

b. STEM undergraduate education at SUNY

Over the past decade, enrollment and degrees granted in SUNY's STEM programs have increased.

Enrollment and degrees

Currently, SUNY exceeds national benchmarks but there is room for improvement. From 2002 to 2012 while total SUNY undergraduate enrollment increased by 15%, STEM undergraduate enrollments have increased from 41,054 to 52,949 – a nearly 29% increase. Enrollments in STEM academic programs now comprise 15% of SUNY's total undergraduate and graduate enrollment.

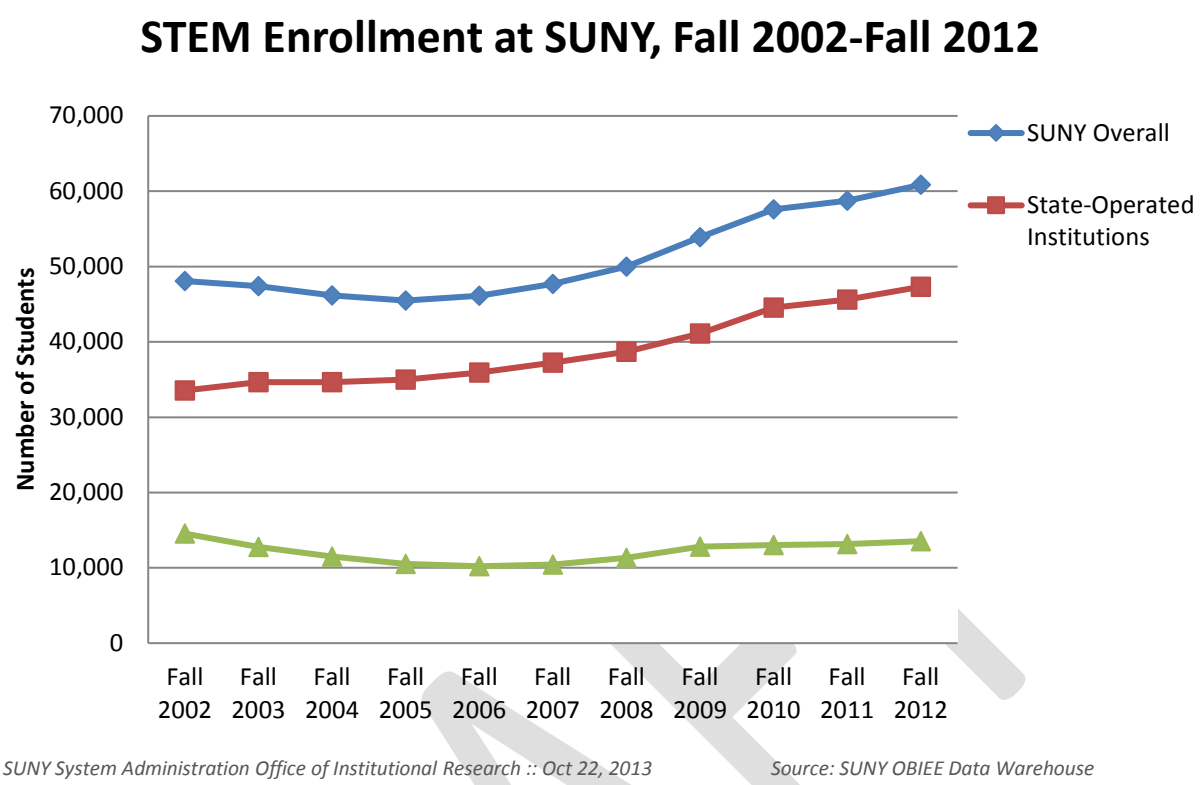


Figure 4: STEM Enrollment at SUNY, Fall 2002 - Fall 2012

SUNY STEM degree production at the undergraduate and graduate levels has increased 23% from 10,716 in 2002-2003 to 13,169 in 2011-2012. Most STEM degrees are undergraduate degrees. In 2011-2012, 2,922 STEM associate's and 7,560 bachelor's degrees were granted, for a total of 10,482 undergraduate STEM degrees.

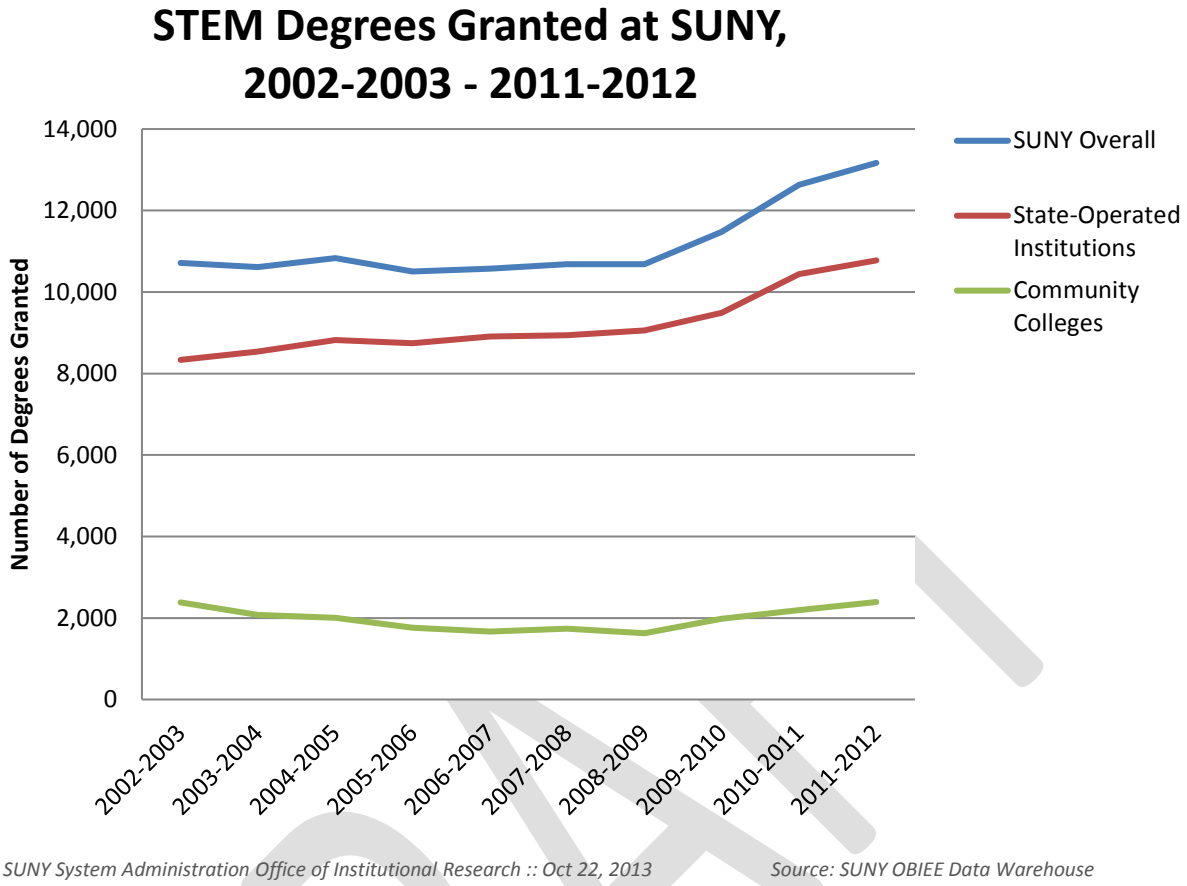
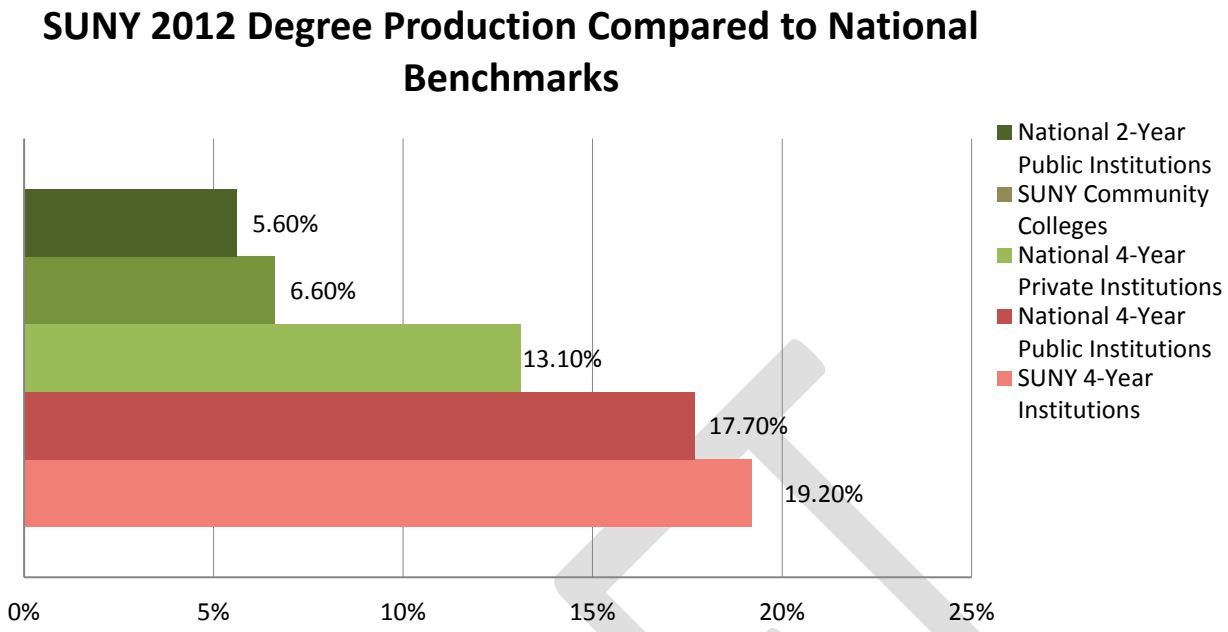


Figure 5: STEM Degrees Granted at SUNY, 2002-2003 - 2011-2012

SUNY four-year institution degree production in STEM fields as a percent of total degrees (19%) exceeds that of national four-year public and privates (18%) and national 4-year private institutions (13%). SUNY's community colleges also had a higher proportion of STEM degrees (6.6%) than national two-year public institutions (5.6%).



SUNY System Administration Office of Institutional Research :: Oct 22, 2013 *Source: National Center for Education Statisticss (NCES)*

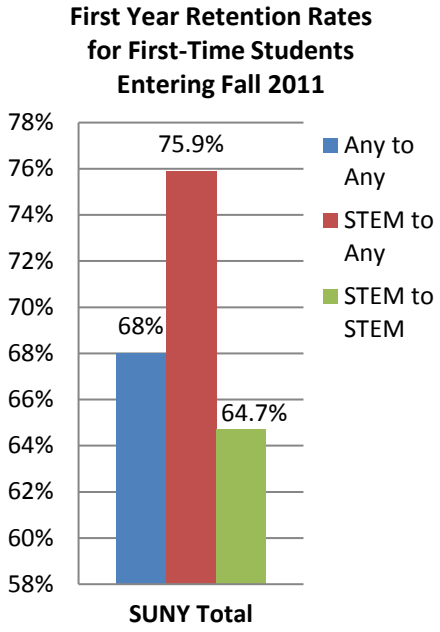
Figure 6: SUNY 2012 degree production compared to national benchmarks

Over the past decade, SUNY saw progress among women and underrepresented minorities in STEM. Women enrolled in STEM programs as percent of the total matriculated female enrollments increased from 7.8% in 2002 to 9.4% in 2012. Enrollments of under-represented minorities in STEM programs more than doubled at SUNY's state-operated institutions (which do not include community colleges) from 3,111 in 2002 to 6,908 in 2012.

Persistence in STEM

Although SUNY outperforms national benchmarks in degree production, the persistence of its undergraduate STEM students could be improved.

Across the SUNY system, approximately 10,300 full-time, first-time undergraduate students enroll in a STEM program each year. (Persistence data on part-time students are not available at this time.) After their first year, 24% of them will leave SUNY and another 11% will switch to a non-STEM program. This represents a loss of 34% or 3,600 students from SUNY STEM after one year, although some of them may return.



SUNY System Administration Office of Institutional Research :: Oct 22, 2013

Figure 7: First Year Retention Rates for First-Time Students Entering Fall 2011 and Enrolled in a Program at SUNY, Indicating Students Initial Program and Second Year Program

Current persistence rates are shown in the table, below.

Persistence rates for undergraduates, women, and underrepresented minorities (2011-2012)

	Enroll in STEM[a]	Leave SUNY[b]	Leave STEM [b]	Persist in STEM [b]
All Undergraduates	9,700	24%	11%	65%
Women	3,000	17%	13%	70%
Underrepresented Minorities	1,700	32%	10%	58%

c. STEM pipeline initiatives at SUNY

SUNY views education in New York State as a pipeline that begins long before a student reaches college and is dedicated to closing the gaps that impede success. The SUNY Office of the Education Pipeline's vision is for more students to complete high school and college prepared for a career in the 21st-century workforce. The Office seeks ways to minimize attrition throughout the 'cradle to career' continuum, with particular emphasis on developing highly-effective teachers and providing cooperative education experiences to adult learners.

The SUNY Office of the Education Pipeline is leading transformational initiatives that are grounded in research, focused on improving outcomes of the system of education in New York State, and provide statewide frameworks to accelerate progress on the ground in all ten economic regions of the state. These initiatives include:

- **Statewide and Local Cradle to Career Partnerships** to build the civic infrastructures that will allow our communities to better serve New York's children and youth
- **Strengthening Teacher Education** to better prepare the higher education faculty and PK-12 teachers who prepare students for success in college and career
- **Smart Scholars Early High Schools** to expand opportunities across the state for students in grade 9-12 to participate in early college high schools, a proven model for increasing graduation rates and post-secondary success
- **STEM Afterschool Mentoring Program** to improve the science and math literacy of middle school children throughout the state
- **Empire State STEM Learning Network** regional community collaborations to increase the number of STEM graduates from community colleges and four-year colleges and universities to fuel research and innovation in a diverse entrepreneurial economy
- **SUNY Works** to increase experiential learning opportunities that are essential to preparing today's students for tomorrow's careers and reducing the amount of time it takes adult students to earn a post-secondary degree
- **Remediation Reform** at the community college-level to increase the effectiveness of developmental education and reduce the cost of college for many New Yorkers

Similarly, the SUNY Office of the Provost, which oversees academic affairs, is committed to student completion and success. It leads a wide range of system-wide initiatives with implications for STEM, such as:

- Curricular reform (e.g., credits to degree, general education, teacher preparation)

- Student mobility and seamless transfer, including replication of the nationally-recognized Baccalaureate and Beyond program for seamless transfer from community colleges to four-year colleges for STEM students
- Degree planning and audit tools for students
- Online college orientation tools
- Undergraduate and graduate research and creativity showcases (in partnership with faculty governance organizations)
- Pathways to STEM graduate education, such as the Professional Science Masters
- Open SUNY, Innovative Instructional Technology Grants, SUNY Connect library services, and the SUNY Learning Network for supporting online courses and programs
- Strategic enrollment planning and funding for high need programs, primarily in STEM

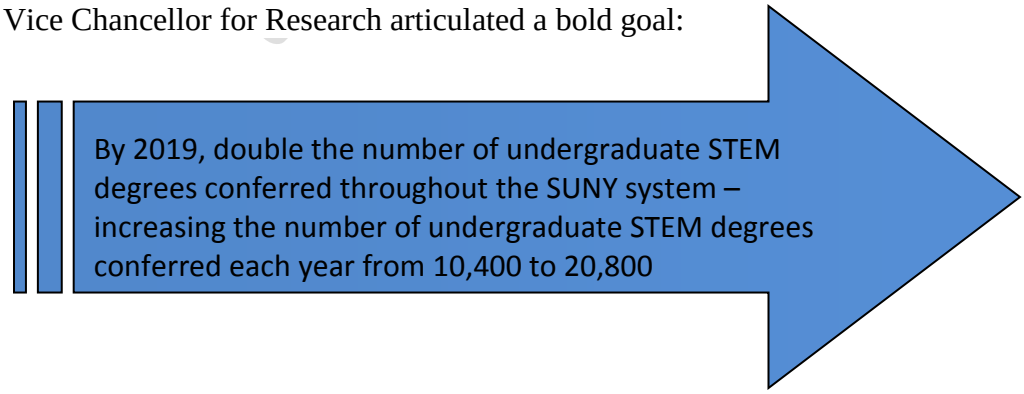
This paper focuses on the undergraduate education part of the pipeline where SUNY has the potential to make a huge impact.

d. The Power of SUNY

The Power of SUNY refers to SUNY's strategic plan whose development was led by Chancellor Nancy L. Zimpher in 2010. The plan envisions that SUNY will be an engine of revitalization for New York State's economy and enhance the quality of life for the state's citizens. The plan acknowledges that diversity counts and aims to create a more competitive SUNY and more competitive New York through six big ideas, one of which is the creation of a seamless education pipeline. *The Power of SUNY* identifies one key goal for STEM education: In 2016-2017, produce 15,738 STEM graduates. Compared to the 2011-2012 academic year which produced 11,772 STEM graduates, this goal represents an increase of 34%.

Notably, these numbers were generated using a narrower definition of STEM that excluded subfields of psychology, economics, pharmaceutical science, medical science, and other fields that are included in the Department of Homeland Security (DHS) definition.[33] Using the more expansive DHS definition, there were 13,169 STEM graduates in 2011-2012. A 34% increase would result in 17,606 STEM graduates in 2016-2017.

In 2013, consistent with State University of New York Chancellor Nancy L. Zimpher's goals for enhancing experiential learning across the SUNY system and building upon the initiatives being implemented by the SUNY Office of the Education Pipeline and Office of the Provost as a part of the strategic plan, Timothy Killeen, PhD, President of the SUNY Research Foundation and SUNY Vice Chancellor for Research articulated a bold goal:



As the largest integrated system of higher education in the U.S., SUNY is uniquely positioned to positively impact the goal defined by PCAST to increase STEM undergraduate degrees by 100,000 per year. If SUNY achieves Dr. Killeen's goal of doubling the number of undergraduate STEM degrees it confers, the additional 10,000 degrees will grow to account for more than 10% of the annualized PCAST goal.

Critically important to achieving this goal is the scope of SUNY's research agenda. Diverse research opportunities are needed on campuses to provide experiential learning and mentored research experiences that are likely to increase persistence of undergraduates in STEM. Annually, more than 2,000 SUNY faculty and staff serving as principal investigators submit more than 5,000 proposals to 1,500 funding agencies. In the 2011-2012 academic year alone, the SUNY Research Foundation Sponsored Program Administration administered more than $930 million, plus facilitated 305 invention disclosures and 223 patent filings. Although not exclusively related to STEM, these unparalleled resources are essential to helping undergraduates persist in STEM at SUNY. Similarly, SUNY's partners in the research community, such as the U.S. Department of Energy Brookhaven National Laboratory on Long Island, have the potential (and interest) to expand STEM research opportunities for SUNY's undergraduates.

e. SUNY STEM Research and Education Committee

To achieve the ambitious goal of doubling the number of STEM undergraduate degrees conferred by SUNY, in mid 2013, administrators, faculty, and leadership from across the SUNY system were invited to join a SUNY STEM Undergraduate Research and Education Steering Committee. The Committee was charged with creating a plan that featured research-based approaches, such as experiential learning and research experiences, to increase persistence in STEM and the number of STEM degrees conferred to undergraduates throughout the SUNY system.

In the subsequent months, the Committee had three meetings. During the first and second meetings, Committee members openly shared their thoughts and experiences about undergraduate student recruitment, and enrollment and persistence in STEM degrees. The Committee quickly identified several potential solutions that warranted further exploration: mentored research experiences, evidence-based teaching, supplemental supports, and network/system-wide supports.

During the third meeting, these solutions were discussed in more detail. The Committee agreed that due to their inextricable nature, network/system-wide supports would be embedded into each solution rather than proposed as a separate approach. The Committee also emphasized the inter-connectedness of the three other approaches – mentored research experiences, evidence-based teaching, and supplemental supports – but determined that they should be described separately for the purpose of clarity.

The Committee created four Workgroups to develop the plan. Workgroups of 3-5 Committee members were formed to address each of the three solutions (mentored research experiences, evidence-based teaching, and supplemental supports); plus one additional workgroup focused on

the background, need, and leadership issues. This paper is the product of the administrators and faculty that dedicated their substantial efforts to these Workgroups.

C. Leadership

The SUNY STEM Undergraduate Research and Education Steering Committee suggests a layered approach to the activities necessary to achieve the goal of doubling the number of undergraduate STEM degrees conferred across the SUNY system. These recommendations acknowledge that although SUNY is an integrated system, its constituent campuses are diverse and that one-size-fits-all solutions are not desirable because they are not likely to be effective.

Purpose: Create an appropriate leadership structure to support the goal of doubling the number of SUNY STEM graduates by implementing the recommendations below.

- **Recommendation 1: System Leadership** - The Committee suggests that the SUNY Chancellor identify and support a qualified expert (at System Administration or on a campus) to champion STEM@SUNY in partnership with other leaders and the Committee. This expert would collaborate with the multiple offices and units within System Administration that currently support undergraduate STEM efforts, and be responsible for coordinating communications, professional development initiatives, data collection, and analysis. This leader would work with SUNY System colleagues to allocate resources for STEM education (from internal and external sources) to achieve campus and system goals as well as publicly report on initiatives and progress.
- **Recommendation 2: Campus Leadership** - The Committee suggests that each campus convene a STEM Undergraduate Research and Education Committee to lead the implementation of this report's recommendations. We encourage campuses to tap existing committees and reporting structures to avoid unnecessary duplication of efforts. In some cases, multiple campuses might consider creating one joint committee, if they are geographically proximate or have similar needs and resources. Using a collaborative approach to managing the responsibilities related to planning, customization, implementation, accountability, and evaluation will allow campuses to leverage their unique strengths while participating in a system-wide effort with system-wide recourse

In general, we view these recommendations as the first steps of a long journey. Regarding leadership, we suggest that the structure for leadership become more formalized as we move forward. We anticipate that our Committee, the SUNY System Administration, University Faculty Senate, Faculty Council on Community Colleges, and – at the campus level – Undergraduate Research Council and Offices, Vice Presents of Research, program administrators, and individual faculty members will continue to play a critical role in shaping and advancing STEM initiatives. Additional specific offices, such as Information Technology teams and offices and the Center for Professional Development, will undoubtedly be involved in the initiatives that focus on building the robust resources and infrastructure that will be needed to achieve the overarching goal of doubling the number of STEM undergraduate degrees in five years. With many stakeholders and influential partners, it will be vital to publically describe and abide by a plan for communication, management, implementation, evaluation, and dissemination. Activities related to creating this more formalized plan include: forming a named,

visible community of practice; creating a list of community members and enabling them to communicate among themselves; creating a sustainable leadership structure for the community that will lead specific initiatives; face-to-face meetings at the onset and throughout long-term initiatives to sustain engagement; identifying resources for the community, including a staff/liaison role at the system level, even if it is located on a campus; having a formal process for working with the Provost and Vice Chancellor of Research to align with community's work with evolving system priorities and opportunities; and identifying specific metrics for measuring progress and success.

D. Solutions

Theoretical models

The solutions recommended below by the SUNY STEM Undergraduate Research and Education Committee were informed by several theoretical models. Vincent Tinto's (1975) seminal student integration model marks the beginning of the current, national dialogue on undergraduate retention.[34] The model theorizes that students who socially integrate into the campus community increase their commitment to the institution and are more likely to graduate.[35] Over time, using empirical evidence Tinto expanded his theory to include additional concepts. Further, other researchers have developed and tested related theories that highlight several important processes associated with academic engagement and achievement. These theories include:

- **Expectancy Theory**: Valence, expectancy and instrumentality are three beliefs which influence motivation. Valence involves an individual's value of an expected outcome. Expectancy is one's belief in the likelihood that effort will lead to performance. Instrumentality is the belief that performance will lead to desired rewards. [36, 37]
- **Expectancy-Value Theory**: Expectancies and values are influenced by beliefs about specific tasks. These beliefs include ability beliefs, perceived difficulty of task, individual goals and affective memories. Perceptions of prior experiences and social influences also play an important role.[38, 39]
- **Goal Setting Theory:** Goal setting theory is premised on the idea that individuals who set goals are more likely to perform at higher levels than individuals who do not set goals. Performance is influenced by goal specificity, challenge, commitment, feedback, and task complexity. According to this theory, individuals perform best when goals are challenging and specific.[40, 41, 42]
- **Self-Efficacy Beliefs**: Self-efficacy beliefs refer to an individual's beliefs concerning whether or not he or she can perform a course of action resulting in a desired outcome. [43, 44, 45, 46]
- **Academic Self-Concept:** Academic self-concept encompasses a student's perception of his or her ability or competence in an academic realm.[47, 48, 49, 50, 51]
- **Motivational Orientations:** Motivational orientations can influence college student performance as well as ability and desire to stay in college.[52, 53, 54]
- **Optimism:** Optimistic individuals perceive positive outcomes as possible and are motivated to invest effort to achieve goals.[55, 56, 57, 58]
- **Identity:** Identifying with one's major and integrating that identity into one's self-concept related to sustained motivation, interest, social engagement, and achievement.[59 60 61 62 63 64]

These interconnected theories consistently point to key modifiable factors that, if inadequate or deficient, act as barriers to undergraduate enrollment and persistence in STEM. These potential barriers include: [65]

- **Academic Preparation**: The quality of a student's prior instruction and his or her preparedness for college-level work can significantly influence whether or not a student will succeed at an institution of higher education.[66, 67, 68]
- **Academic Engagement**: Students' connection to the academic life of an institution has been related to undergraduate persistence.[69, 70, 71, 72]
- **Social Engagement**: Successful social integration is important for a student's success.[73]
- **Financing College**: Working while attending college, paying tuition through loans or grants, and being financially dependent or independent are all factors related to undergraduate persistence.[74, 75, 76]
- **Stereotyping or Stereotype Threat**: the extent to which students' performance and belonging in a field is affected by prevailing stereotypes about their lack of ability in that domain.

These theories can be applied in an endless number of ways. For example, a real-world research program that allows the undergraduate student to experience and overcome a setback (such as the delayed delivery of needed supplies) builds self-efficacy and academic self-concept, thus promoting academic engagement. A course that includes group projects with supportive peers improves concepts in expectancy-value theory and social engagement.

I. Mentored Undergraduate Experience

a. Summary of Literature

Defining Undergraduate Research

The Council for Undergraduate Research defines undergraduate research as an inquiry or investigation conducted by an undergraduate that makes an original intellectual or creative contribution to the discipline.[77] The organization emphasizes the two features of this definition, noting that: 1) The work is aimed at creating new knowledge and 2) The work is intended to contribute to the discipline and should be disseminated through established channels.[78]

The SUNY STEM Undergraduate Research and Education Steering Committee agrees with this definition adding that importantly, the undergraduate research experience is facilitated by a mentor.

The Undergraduate Research Experience

During the past two decades, undergraduate research experience has emerged as a best practice in STEM undergraduate education. Researchers have demonstrated that undergraduate research experiences, especially early experiences, result in increased technical and personal skills, higher grades, shorter time to degree, increased persistence in STEM degrees programs, increased placement in STEM careers, and increased pursuit of STEM graduate degrees. [79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109,110, 111, 112, 113, 114, 115, 116, 117, 118, 119]

Notably, early research experiences, especially in the first two years of undergraduate coursework, increase academic engagement and therefore improve persistence of students in STEM majors and improve students' attitudes toward STEM fields.[120, 121,122] The effects of research experiences are quite positive for all students but have especially high impact for women and members of other groups currently underrepresented in STEM disciplines.

Mentoring

As noted in above, the SUNY STEM Undergraduate Research and Education Committee contends that the undergraduate research experience is incomplete without appropriate mentoring. The research project and mentoring are virtually inseparable; many of the successful undergraduate research programs referenced above include mentoring.

Mentors (whether faculty, independent researchers, graduate students, or qualified peers) are pivotal in ensuring the success of the student's experience, acting as teachers, coaches, and gatekeepers.[123] Although challenging to define precisely, a key characteristic of a mentor-mentee relationship that is it personal as well as professional.[124] The National Research Council's emphasizes the personal aspect of mentoring and encourages mentors to ask students about themselves and interests outside of research.[125] By providing effective mentoring, students are able to realize that they, like the faculty they have come to know and identify with, can be develop an interest in and successfully pursue careers as future STEM faculty or professionals.

From a student's perspective, mentors can be incredibly influential. Using illustrative qualitative data, author D. Lopatto (2007) emphasizes undergraduate students' perceived centrality of the mentor-mentee relationship to the success of their research experience:

> "In the current SURE data, student evaluations of their supervisors moderately correlated (0.39) with their overall evaluation of their experience. Examples of the importance of mentoring emerged in the follow-up survey, in which respondents were free to volunteer remarks. Twelve students wrote about their mentors. The 10 positive comments included the following: "The most important part of my summer research experience was my amazing mentor. She guided me through the planning, execution, and analysis of my work while allowing me enough space to work independently."The two negative comments included the following: "My professor seemed to forget how to relate to undergrads and even tended not to give us as much work. When deadlines didn't allow for even the slightest mistakes, I pretty much did menial tasks or just sat around reading papers and such while a grad student did the work."[126]

In a more recent publication, D. Lopatto (2009) asserts, "Good mentoring is an essential element of undergraduate research, and the failure of the mentor is the most acute reason why dissatisfied students leave." [127]

D. Lopatto confirmed these results quantitatively. He found that overall satisfaction with the research experience and gains in technical and personal skills were associated with mentoring characteristics. Among mentoring characteristics, "Treats you [the student] like a colleague was the strongest positive predictor of satisfaction and learning gains; while "unresponsive to your

[the student's] questions" was the strongest negative predictor.[128] Other researchers have found similar results.[129, 130]

Participating in a mentoring relationship also results in significant gains in student skills as reported by the student and mentor. These skills include using professional and discipline-specific language, expressing ideas clearly, bringing new insights to the problem at hand, combining information in new ways, working independently, accepting constructive feedback, formulating questions and hypotheses, and applying relevant research methods.[131, 132]

b. Identification of Best Practices

With uniformly encouraging results supporting the notion that undergraduate research leads to positive outcomes for undergraduates and persistence in STEM degrees, recent research has focused on how to best incorporate undergraduate research into institutions of higher learning.

Characteristics of Excellence in Undergraduate Research
There is a long list of successful undergraduate research programs. Many programs incorporate features that extend research beyond the laboratory, such as mentoring and opportunities for students to present their research, and most would be unable to function without integral institutional supports, such as training in mentorship and faculty incentives. In 2011, we had 21 undergraduates, 2012, 47 undergraduates and in 2013 we had 55 undergraduates take part. These students undertook research projects at research driven institutions in Brazil, Costa Rica, Democratic Republic of Congo, France, India, Sweden, Switzerland, and Taiwan. Although not all students were freshmen, retention is 100% amongst this cohort.

Fortunately, these characteristics and supports have recently been itemized. In 2012, using results published by highly-regarded researchers, input from leaders and administrators at universities throughout the world, and its 30 years of experience, the Council for Undergraduate Research identified Characteristics of Excellence in Undergraduate Research.[133] The Characteristics of Excellence in Undergraduate Research provides an excellent summary of current best practices, many of which overlap and act synergistically to support and sustain highly effective undergraduate research environments. The SUNY STEM Undergraduate Research and Education Steering Committee notes that successful, sustained, widespread undergraduate research programs do not include all components from the list below; rather, incorporate one or more elements from the majority of the categories below:

Characteristics of Excellence in Undergraduate Research

- Campus mission and culture
- Administrative support
- Research Infrastructure
- Professional development opportunities
- Recognition
- External funding
- Dissemination
- Student-centered issues
- Curriculum
- Summer research program
- Assessment activities
- Strategic planning

c. Current Best Practices at SUNY

Throughout the SUNY network, STEM undergraduates research program have been implemented throughout the system, including:

STEM Research Opportunities for Undergraduates
In March 2013, the SUNY Research Foundation announced awards totaling nearly $300,000 to support and enhance STEM research opportunities for undergraduates at SUNY's State-Operated campuses. These funds complemented existing programs, such as:
• University at Buffalo's Center for Undergraduate Research and Creative Activities
• Buffalo State College's Undergraduate Research Office
• SUNY Brockport's undergraduate research program
• SUNY Cortland's Undergraduate Research Council
• SUNY New Paltz's programs for undergraduate and graduate research and creativity
• SUNY Oswego's Undergraduate Research program, which includes an Office of Research and Individualized Student Experiences (RISE) and a Global Lab experience
• SUNY Potsdam's Center for Student Research

SUNY Replication Project: Baccalaureate and Beyond Community College Mentoring Program
This STEM seamless transfer program is modeled on the nationally recognized Baccalaureate and Beyond Community College Mentoring Program established at Purchase College. SUNY is replicating Purchase College's ideas for seamless STEM transfer throughout the SUNY System in the SUNY Replication Project, led by the founder of the Purchase program, Dr. Joseph Skrivanek, Professor of Chemistry and Biochemistry. To date, 11 four-year institutions and 18 community colleges are participating.

SUNY Louis Stokes Alliance for Minority Participation (LSAMP)
Since 1996, the SUNY LSAMP, which is coordinated by Stony Brook University and funded by the National Science Foundation (NSF), has been helping to change the basic shape of STEM education and forging new opportunities for underrepresented minority (URM) students in New York State. The infrastructure, research base, and replicable models that have been developed are the result of the aggressive and sustained efforts of the Alliance partners. These efforts have resulted in a substantial increase in bachelor's degrees awarded to URM students in STEM fields, and have lead to an increase in the number of URM students enrolled in STEM programs. The 16 campuses in the SUNY alliance are Albany, Binghamton, Buffalo, Buffalo State, New Paltz, Old Westbury, Stony Brook, Farmingdale, as well as Schenectady, Broome, Tompkins-Cortland, Dutchess, Orange, Ulster, Nassau and Suffolk community colleges. Other Alliance partners are the Brookhaven National Laboratory, the NSF funded SUNY Alliance for Graduate Education and the Professoriate (AGEP), and the New York State Education Department's CSTEP program.

Collegiate Science and Technology Entry Program (CSTEP) - In 2012-13, 22 SUNY campuses participated in CSTEP, a New York State program designed to increase the number of students from under-represented minority groups who are pursuing professional licensure and careers in mathematics, science, technology and health-related fields.

Community College Undergraduate Research Initiative (CCURI)
With a $4-million NSF grant and 26 institutional partners from across the U.S., CCURI is based at Finger Lakes Community College, and includes two other SUNY campuses, Tompkins-Cortland Community College and Jamestown Community College. The CCURI model of incorporating undergraduate research (UR) into community college curricula involves engaging students from the moment they enter the classroom. The model employs a case study method of instruction in freshman coursework. The CCURI writing team develops cases that instructors can use to teach basic scientific concepts within the context of an ongoing research project. Students are then given an opportunity to explore those projects as either a CURE (Course Undergraduate Research Experience), a SURE (Summer Undergraduate Research Experience) or PURE (Program Undergraduate Research Experience). The growing CCURI network has become a rich source of collaboration on both the curricular and research side of the CCURI model.

Ronald E. McNair Post-Baccalaureate Achievement Program
SUNY institutions receive federal McNair funds to prepare eligible participants for doctoral studies through involvement in research and other scholarly activities. Participants are from disadvantaged backgrounds and have demonstrated strong academic potential. Institutions work closely with participants as they complete their undergraduate requirements and encourage participants to enroll in graduate programs, and then track their progress through to the successful completion of advanced degrees. The goal is to increase the attainment of Ph.D. degrees by students from underrepresented segments of society. In July 2013, the University at Buffalo hosted its 19th annual McNair Research Conference, a national event that includes workshops and research presentations

Research Experience for Undergraduates (REU)
The NSF's REU program supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation. REU projects involve students in meaningful ways in ongoing research programs or in research projects specifically designed for the REU program. Within SUNY, recent REU awards have been made to Albany, Binghamton, Buffalo, Stony Brook, ESF, New Paltz, Oswego, Plattsburgh, Potsdam, and other campuses.

Global Laboratory at SUNY Oswego
The Global Laboratory is an innovative undergraduate research experience offering students hands-on, immersive problem-solving opportunities in international laboratories in the most promising fields of study STEM. The Global Laboratory combines the international connections of SUNY Oswego faculty with the scientific talents, research proficiency, and intellectual curiosity of undergraduates to advance scientific knowledge, design solutions to the many intractable challenges of our time, and to improve the quality of life for humans worldwide. This pioneering laboratory empowers and uplifts students through the knowledge they gain and the life-changing experiences they encounter. Qualifying undergraduates spend two to ten weeks on any of the world's seven continents conducting community-based research with leading scientists on projects designed to discover solutions to pressing global problems while promoting international understanding.

d. Recommendations

As described in the leadership section, responsibilities related to oversight, accountability, implementation, and evaluation of STEM@SUNY will be layered. The SUNY STEM Undergraduate Research and Education Committee, a multi-disciplinary committee comprised of representatives from SUNY universities and community colleges throughout New York, has been and will continue to be focused on the system-wide initiatives and supports; while Campus-Specific STEM Undergraduate Research and Education Committees (to be created at each university and community college campus) will focus on adapting and implementing these system-wide initiatives to leverage their specific campus's strengths and target areas in need of improvement.

Vision and Goal

The SUNY STEM Undergraduate Research and Education Steering Committee envisions developing a campus and system-wide culture that is more supportive of undergraduate research complete with the appropriate faculty and student supports. We hope to create an integrated, electronic system through which students from all campuses can apply to participate in mentored research experiences that are available throughout the SUNY system and beyond. We readily acknowledge that achieving this vision will be a multi-year process that requires buy-in from many partners and stakeholders. Plus, by the nature of the necessary activities, it cannot possibly be limited only to STEM disciplines. We believe that the development of this white paper is this first step of a long journey.

We aim to ensure that every undergraduate student pursuing a STEM degree who is interested in having a research experience is able to do so, with a special emphasis on allowing students to experience "early" research experiences for first and second-year students. Many students will be able to participate in research and "research-like" experiences through introductory STEM classroom and laboratory courses. These active learning techniques focus on the development of research skills and are discussed in the following section on evidence-based teaching.

Although a smaller group of students will be able to participate in a true mentored research experiences, our goal is to increase the number of students that participate; increase the diversity of experiences available; and enhance all research programs by providing appropriate supports to faculty and students. Additionally, we are particularly focused on increasing the opportunities available for students at SUNY community colleges and students who are underrepresented minorities and women. To achieve these goals, the SUNY STEM Undergraduate Research and Education Steering Committee recommends several system-wide initiatives and supports.

Planning

First, we recommend that the Campus-Specific STEM Undergraduate Research and Education Committees review inventories and other existing assessments to identify opportunities to provide undergraduates with mentored research experiences and, more globally, create an environment that is more supportive of undergraduate research. Additionally, determine how best to scale up research experiences that already occur throughout the SUNY system. Frameworks, such as the A Council for Undergraduate Research's Characteristics of Excellence in Undergraduate Research as a framework for institutional self-assessment may also be useful to supplement previously-conducted assessments.

Recommended Network Supports and Initiatives
Purpose: Increase the number of students participating in mentored undergraduate research experiences.

Our recommendations focus on next steps and supports that would complement new and existing initiatives. These recommendations admittedly lack specificity. This was a conscious decision made to accommodate the diverse constituents of the SUNY system but we believe these recommendations are universally necessary to begin connecting the discussions, ideas, and projects ongoing across the state.

Recommendation 3: Campuses should identify, enumerate, and categorize their funded and unfunded positions for undergraduate mentored research experiences in STEM for the ultimate goal of creating an integrated, electronic system through which any SUNY students can apply for mentored research experiences throughout the SUNY system and beyond.

The purpose of this recommendation is to gain a better understanding of existing capacity for the purpose of planning large-scale initiatives. Knowing how much capacity exists in the system under current programs and could exist with additional funding is critical to moving forward. Many campuses actively encourage and operate programs featuring undergraduate research but, to date, no effort has been made to create a system-wide catalog of opportunities. Anecdotally, we understand that most ongoing programs operate at funding capacity but some could accommodate more students if more funding was available. Both academic year opportunities and summer programs should be included in the catalog. Additionally, we recommend that opportunities outside of the SUNY system in which SUNY student have regularly engaged (such as Brookhaven National Laboratory) be cataloged as a part of this effort.

Looking ahead, it will be essential that the electronic system to be developed is maintainable. Clear reporting and updating responsibilities will need to be defined and appropriate access points and linkages created.

Recommendation 4: Campuses should strive to create an environment that is fully supportive of undergraduate research by identifying and pursuing transformative opportunities related to their mission and culture, administrative support, research infrastructure, and/or faculty recognition.

The purpose of this recommendation is to acknowledge the importance of factors outside of the laboratory that make undergraduate research on a large scale possible and empower campus-specific committees to have productive conversations about these issues. We know that this recommendation is cannot possibly be limited to STEM and is not achievable in the short-term or without buy-in from campus and system administrators. Still we encourage campus-specific committees to begin (or continue) this discussion.

We suggest the conversation focus on how to improve factors such as:

- Institutional and faculty commitment
- Multidisciplinary participation
- Integration with existing programs

- Funding
- Faculty load credit for supervising undergraduate research
- Reassigned time for research-related tasks for faculty
- Undergraduate research administrative support
- Promotion and tenure guidelines
- Salary review
- Campus awards
- Research infrastructure and oversight to create a culture conducive to mentored undergraduate research

Additionally, to the extent possible, funding to directly support student participation in mentored research (such as research supplies and stipends) will enable SUNY to provide more opportunities.

One of the most important resources to achieve our vision is an electronic platform through which students can connect with faculty to form and grow mentoring relationships, as well as review, compare, and apply to mentored research experiences available throughout the SUNY system and possibly beyond. This type of platform and level of integration is the essence of "systemness." For example, this type of platform could connect STEM students at two-year colleges with limited research opportunities to university research centers operating dozens of multi-million dollar research centers. Throughout the SUNY system platforms with the potential to provide this functionality exist and we hope will be explored by SUNY leadership.

The STEM Undergraduate Research and Education Steering Committee asserts that appropriate faculty support is critical to achieving these recommendations. Providing mentorship through research experiences requires substantial time and dedication from faculty. We suggest that faculty have access to professional development opportunities to learn how to better implementing mentored research programs. For example, few faculty members have ever received training in how to be a mentor.

II. Evidence-Based Teaching

a. Review of Literature

Definition of Evidence-Based Teaching

"Evidence-based" teaching involves utilizing theoretically-based, proven teaching methods in combination with regular assessment of student's progress toward learning goals.[134] There are hundreds of publications describing successful programs that re-conceptualize pedagogical frameworks and redesign curricula and individual courses in undergraduate education that, support engagement and persistence in STEM by helping to effectively educate students so that they are interested, inspired, and equipped with the foundational knowledge and skills to succeed in further STEM study. However, for a variety of reasons, these programs are underutilized. Below, the SUNY Undergraduate STEM Research and Education Steering Committee outlines several methods to better incorporate evidence-based teaching into STEM education.

Pedagogies of Engagement

A focus on pedagogy, or the practice and theory of teaching, is an important concept in evidence-based teaching. Educational research has highlighted the need to reexamine our traditional "sage on the stage" methodology in higher education. One of the accepted and essential learning outcomes for students of higher education is the process and ability to think critically. Critical thinking and problem solving are important in all academic pursuits, including STEM fields.[135] Advancements in pedagogical practice have shown that lecture-based learning is less effective in achieving the learning outcomes desired in science and mathematics fields yet most introductory STEM courses taken in the first two years of college are dominated by lectures. Although the lecture has been a standard method of teaching in higher learning for centuries, cognitive research on how students learn indicates that hands-on and problem-based teaching methods enhance critical thinking skills, long-term retention of information, and student persistence in STEM majors.[136, 137, 138, 139, 140, 141, 142, 143, 144] Hands –on and problem-based lessons can be woven effectively into lecture format classes. The use of lectures as a standard method of teaching is not the problem, but instead that some lecture classes do not incorporate these experiential learning exercises. These approaches are "student-centered" approaches that link learning outcomes, learning styles, evaluative, and formative assessment strategies to guide students through a "process" of learning. These student centered approaches also take into account the diverse developmental and intellectual starting points of individual students without sacrificing the efficiency of lecture and test method. Generally, approaches that most effectively transmit information and build critical thinking skills require that students are actively engaged in the process of learning and receive feedback during the process.[145]

Curriculum Redesign

Effective curriculum redesign has included methods such as changing course sequences, adding or removing courses, and restructuring the content of multiple courses. The "math gap" is a commonly discussed reason for considering curriculum redesign in STEM undergraduate programs.

Mathematics is an essential tool and potential gateway to success in STEM fields however many students who enter college/university programs have not mastered the basics of pre-calculus and algebra to be successful in college-level calculus and statistics courses. Mastery of mathematics leads to success in STEM courses, for example, algebra is essential to be able to apply concepts in introductory chemistry courses. In 2005, 57% of the students enrolled in 4-year colleges and universities were enrolled in pre-college algebra, trigonometry, or other pre-calculus courses – largely material covered in high school.[146] Developmental classes can be uninspiring leaving students with the impression that mathematics is dull and unimaginative. Unfortunately, these feelings may spill over to other STEM disciplines causing students to seek alternate fields for training.[147] Redesigning STEM field curricula with an appreciation of these lacunae in student knowledge and with an understanding of what type of mathematical tools are required to be success in Chemistry, Physics, Biology, etc. can go a long way in retaining students in science majors and enabling them to graduate within a four or five year time frame. In this area, we advocate for breaking down silos between mathematics and the applications of mathematics that are needed in other science and engineering fields.

b. Identification of Best Practices

Too often, science is taught in a fact-based vacuum devoid of any sense of how scientists work and how the process of science is unfolds. In essence science is discovery while science courses, on the whole, are memorization. This disconnect drives away students. Adding inquiry-based elements to introductory STEM courses is critical keeping students engaged in STEM courses, despite the extensive and often difficult course material.

Pedagogies of Engagement

When implemented at the institutional level, active learning pedagogies move the locus of transformation away from the individual faculty member and reframe instruction as a means to support student achievement and learning outcomes. Funded by the National Science Foundation, Project Kaleidoscope identified a variety of pedagogies used by institutions to actively engage students in the classroom and improve key STEM indicators of enrollment and persistence.[148] The pedagogies of engagement include:

- **Calibrated Peer Review** is web-based management of writing with peer review in classes of any size
- **Cooperative Learning** involves students working in groups to accomplish learning goals
- **Interactive Lectures** engage students with course material through short individual, pair, or small-group activities
- **Investigative Case-Based Learning** involves students in addressing real world problems
- **Just-in-Time Teaching** encourages students to read assigned material outside of class, respond to short questions online, then participate in discussion and collaborative exercises in the following class period
- **Peer-Led Team Learning** engages teams of six to eight students in learning sciences, mathematics and other undergraduate disciplines guided by a peer leader. Peer leaders are drawn from the pool of students who have done well in the course previously
- **Process-Oriented Guided Inquiry Learning** (POGIL) is a research based learning environment where students are actively engaged in mastering course content and in developing essential skills by working in self-managed teams on guided inquiry activities

These pedagogies and others, such as the flipped classroom, all utilize active learning activities. Active learning teaching activities that have been successfully implemented in a range of classroom sizes, include: small group discussion, peer instructions, testing, one-minute papers, clickers, problem-based learning, case studies, analytical challenge before lecture, group test, problem sets in groups, concept mapping, writing with peer review, and computer simulations/games, have been shown in enhance learning.[149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184]

Research and Research-Like Experiences

Experiential "research-like" learning is another approach to active learning. Curriculum must be carefully designed to ensure that students have the basic knowledge and skills necessary to actively participate in research-like exercises and move on to pursue semi-independent research. Through research-like or research-infused courses, students participate in inquiry-based activities such as group work, read primary literature, follow a research process, shape the research methodology, collect and analyze data, and draw conclusions. Students in research-like courses experience gains in STEM knowledge and skills and develop the ability to transfer those skills to

other science and engineering problems.[185] Traditional laboratory courses can be transformed into discovery-based courses or research courses that allow students to investigate issues they identify and define. Research courses have been shown to improve key STEM indicators.[186, 187]

Curriculum Redesign
Curricular redesign must be done in a way that allows faculty to identify, create, and use curriculum that allow for maximum capacity and ensures transferability of credits across the SUNY system and. Promising practices include:

- **Summer and other bridge programs** for high school students entering college
- **Enhanced pre-STEM courses** for students in college, including approaches that rely on computer technology
- **"Math in context"** college curricula developed and delivered in class by faculty from mathematics-intensive disciplines such as physics, engineering, and computer science. These science faculty must recognize that mathematics education is not simply the work of mathematics professors.

c. Current Best Practices at SUNY

Long Island Alternative Energy Consortium (LIAEC)
The Long Island Alternative Energy Consortium is an interdisciplinary, cooperative effort by seven public and private colleges and universities (Stony Brook University, Farmingdale State College, SUNY Old Westbury, SUNY Maritime, New York Institute of Technology, Suffolk County Community College and Nassau Community College), working with public entities (including Brookhaven National Laboratory) and private companies, to prepare undergraduate students to professionally thrive in renewable and alternative energy industries and to help create high tech jobs on Long Island. The LIAEC received an NSF Transforming Undergraduate Education in STEM grant in September 2013, to support curricular development of the seven participating colleges, including and support a variety of majors at different institutions by:

1. Creating a minor at the undergraduate level, incorporating core courses in energy science and policy available through distance learning and online resources and a choice of complementary multidisciplinary electives offered across institutional boundaries.
2. Facilitating cooperative, active learning through internships and independent research courses through public/private partnerships.
3. Recruiting and retaining non-traditional and under-represented students.
4. Leveraging best practices and current programs.

Community College Undergraduate Research Initiative (CCURI)
With a $4-million NSF grant and 26 institutional partners from across the U.S., CCURI is based at Finger Lakes Community College, and includes two other SUNY campuses, Tompkins-Cortland Community College and Jamestown Community College. The CCURI model of incorporating undergraduate research (UR) into community college curricula involves engaging students from the moment they enter the classroom. The model employs a case study method of instruction in freshman coursework. The CCURI writing team develops cases that instructors can use to teach basic scientific concepts within the context of an ongoing research project. Students are then given an opportunity to explore those projects as either a CURE (Course Undergraduate Research Experience), a SURE (Summer Undergraduate Research Experience) or PURE

(Program Undergraduate Research Experience). The growing CCURI network has become a rich source of collaboration on both the curricular and research side of the CCURI model.

National Center for Case Study Teaching in Science
Based at the University of Buffalo, the mission of the National Center for Case Study Teaching in Science is to promote the development and dissemination of materials and practices for case teaching in the sciences. Its website provides access to an award-winning collection of peer-reviewed case studies. It also offers a five-day summer workshop and a two-day fall conference to train faculty in the case method of teaching science. In addition, it is actively engaged in educational research to assess the impact of the case method on student learning. Over the years, the Center has been generously supported by the National Science Foundation, The Pew Charitable Trusts, and the U.S. Department of Education. These excellent programs may be a source of an "online materials" available as free open share for use by SUNY faculty.

Northeast Advanced Technology Education Center
This NSF-funded partnership between the SUNY College of Nanoscale Science and Engineering, Hudson Valley Community College, Rensselaer Polytechnic Institute, and Mohawk Valley Community College works to develop critical workforce training for the burgeoning nanotechnology sector in the Capital Region and beyond. The partners develop curricula, outreach, and experiential learning opportunities for community college students and local teachers to recruit and educate the next generation of nanotechnology-savvy workers. Students apply classroom learning to hands-on workshops in CNSE's world-class Nano-Complex and HVCC's high tech TEC-SMART campus.

d. Recommendations

As described in the leadership section, responsibilities related to oversight, accountability, implementation, and evaluation of the STEM@SUNY will be layered. The SUNY STEM Undergraduate Research and Education Steering Committee, a multi-disciplinary committee comprised of representatives from SUNY universities and community colleges throughout New York, has been and will continue to be focused on the system-wide initiatives and supports; while Campus-Specific STEM Undergraduate Research and Education Committees (to be created at each university and community college campus) will focus on adapting and implementing these system-wide initiatives to leverage their specific campus's strengths and target areas in need of improvement.

Vision and Goal
The SUNY STEM Undergraduate Research and Education Steering Committee encourage the SUNY system to strive to make STEM curriculum engaging and mitigate or remove curriculum-related barriers to entering STEM fields. We understand that research and research-like experiences in introductory courses are critical to engaging students early and facilitating their persistence in STEM. We also see great opportunity to increase STEM literacy among non-STEM majors through cross-disciplinary courses. The SUNY STEM Undergraduate Research and Education Steering Committee aims to ensure that all introductory STEM courses for first and second-year students use evidence-based teaching strategies, especially research and research-like learning experiences. To achieve this goal, the SUNY STEM Undergraduate Research and Education Steering Committee makes the following recommendations.

Planning
First, we recommend that the Campus-Specific STEM Undergraduate Research and Education Committees review self-studies and other existing assessments to determine which introductory, gateway STEM courses could be better infused with experiential learning and other evidence-based teaching strategies. Frameworks, such as the Association of American Universities Framework for Systemic Change in Undergraduate STEM Teaching and Learning may also be useful to supplement previously-conducted assessments.[188]

Recommended Network Supports and Initiatives
Purpose: Implement curriculum redesign solutions to increase the percentage of introductory STEM gateway courses that include applied, active, and experiential learning opportunities

Recommendation 5: Campuses should increase the use of evidence-based teaching strategies, specifically inquiry-based, research-like activities, into introductory STEM courses and laboratory requirements, and to the extent possible, add more research-based STEM courses.

We know this is an ambitious recommendation. Thus we encourage campus-specific committees to approach it incrementally, starting perhaps with the largest, bottle-neck courses or those courses led by particularly motivated and skilled instructors. Regardless of the sequence of curricular analysis and revision,, there are many approaches to infusing research components into introductory STEM and laboratory courses and there is a spectrum of potential transformations. We encourage campus-specific committees to empower faculty to incorporate research components into their courses in ways that accommodate faculty preferences and highlight their strengths.

An illustrative initiative that integrates research-like components into two introductory courses is summarized below:

> The exercise involves students from two different departments to work together on a research project, a study of drinking water quality. Students in introductory Geology and Chemistry classes are involved in the interdisciplinary study. The goals of this project are to introduce the students to the scientific method, get them to actually "do" relevant science, and show how science affects their lives. This activity is part of the Geology courses, with at least one class time (two is better) dedicated to discussion of the project. It is usually scheduled to occur when we are discussing water topics in the Geology courses. For the Chemistry course, it comprises one of the labs, specifically the one on ion chromatography and capillary electrophoresis. These courses are mainly populated by first or second year students with more than 50 students per class.
>
> Students from an introductory Geology course collect drinking water samples from the area. They collect multiple samples if their homes have water softening systems, water filtration systems, or from the same source, to serve as a replicate analysis. Samples of well water are also collected to compare to the municipal water. These samples are taken to the Chemistry class, where students analyze the samples using ion chromatography in one of their labs. The results of these analyses are sent in spread-sheet form to the

Geology class, who analyzes the results. Questions asked are: What is the effect of water-softening on water composition?; What is the effect of filtering on water quality?; Is there any geographic control on the composition of the drinking water?; and What is the difference between municipal water and well water? These questions lead to the discussion of how water-softeners work (zeolites) and filtering systems work, what geologic factors control the composition of drinking water, and why there might be a variation geographically in drinking water composition. The class is divided up into teams to discuss one of these topics. A volunteer then presents the results to the rest of the class and then a discussion ensues. Finally, volunteer teams from Geology and Chemistry develop presentations to deliver to the other classes. The Chemistry presentation involves ion chromatography, analytical methods, and analytical error. The Geology student presentation involves the analysis of the data.

Learning objectives include:

- Have students learn the scientific method and learn how scientific research studies are designed and carried out.
- Teach students the interdisciplinary nature of science and scientific research (that there is a reason for them to take Chemistry classes).
- Teach students about sample collection protocols.
- Develop data handling and analysis skills.
- Develop an appreciation for the power and dynamics of working in groups.
- Develop discussion and presentation skills.
- Have students learn about how to handle various types of error and uncertainty in data.
- Incite interest and enthusiasm for science and possible choice of science as a career.

Recommendation 6: Each campus's STEM Undergraduate Research and Education Committee should consider how to best address the "math gap." We suggest that Committees begin pursuing alternative, evidence-based approaches to enable students to complete mathematics requirements and ensure that mathematics is not a barrier to pursuing STEM majors.

Math is too often a barrier to persisting in STEM. Introductory college-level mathematics is a gateway to STEM majors and mastery of math concepts helps students succeed in STEM courses. For example, algebra is essential to applying chemistry concepts routinely taught in introductory chemistry courses. SUNY institutions might consider: summer and other bridge programs for high school students entering college; enhanced remedial courses; and "math in context" courses that feature math skills training in STEM disciplines such as physics, engineering, and computer science.

The SUNY STEM Undergraduate Research and Education Steering Committee asserts that supporting faculty in these recommendations is critical. Infusing research and research-like experience into introductory STEM courses requires faculty time, dedication, and financial commitments by academic leaders. We encourage campus-specific committees to connect faculty to existing resources such as Innovative Instruction Technology Grants, a grant program open to SUNY faculty and support staff across all disciplines that supports instruction techniques

that use technology in new ways, and Open SUNY, a system-wide effort designed to maximize online-enabled learning opportunities for all SUNY students.

We suggest

- That Faculty have access to professional development opportunities to learn how to utilize evidence-based teaching pedagogies and to efficiently create research and research-like opportunities in the classroom and laboratory,
- A comprehensive electronic resource with planning and implementation tools to help faculty members incorporate research, research-like, and other active learning activities into lessons would be extremely useful and efficient,
- Faculty and administrators are given professional development opportunities and an electronic resource to address the math gap, and
- The participation in these opportunities should be considered favorably during tenure and promotion deliberations.
- Additionally, to the extent possible, funding to directly support student participation in research and research-like activities (such as funding for supplies) will enable SUNY to provide more diverse activities for students.

III. Supplemental Supports

a. Review of Literature

Defining supplementary supports

Nationally, many researchers and leaders have published formal calls for additional supports to increase enrollment and persistence in STEM fields among underrepresented populations. Women and members of minority groups constitute approximately 70% of college students but are underrepresented among students who receive undergraduate STEM degrees (approximately 45%).[189] These calls for supplementary supports, meaning experiences that extend beyond the acquisition of STEM knowledge to positively influence theoretical concepts (such as motivation), are needed to improve enrollment and persistence among these populations. Activities such as the following can be considered supplemental supports:

- Faculty mentoring
- Professional development seminars for students
- STEM workplace visits
- Research conferences
- Student presentations
- Peer tutoring for fellow college and high school students
- Peer mentoring/ ambassador programs

Such supplementary supports are important not only for women and underrepresented minorities, *but for all students*. Further, supplementary supports are not separable from classroom-based and research experiences. Rather, supplementary supports should be designed to serve undergraduates in STEM classrooms and laboratories.

b. Identification of Best Practices

Best practices indicate that supplementary supports should be integrated into comprehensive STEM enrollment and persistence initiatives that include research experiences and evidence-based teaching. For example, the Council for Undergraduate Research Characteristics of Excellence in Undergraduate Research includes factors that extend far beyond the research laboratory itself. These wrap-around factors student-centered issues, such as financial support and mentoring.[190] Several examples of multi-faceted, comprehensive STEM enrollment and persistence initiatives include:

A summer program in computer science that included a meaningful research experience, plus the opportunity to interact with role models and other undergraduate students, forming a "community" and overcoming social engagement barriers.[191]

A computer-information systems program that includes four initiatives: 1) Re-assigned time for faculty to engage students in research during the academic year and summer; 2) Help for faculty to develop new courses in their research areas; 3) Aid to the department in purchasing needed hardware and software to support research and instructional activities; and 4) Focus on student professional-development activities, enrollment in special topics, and summer research.[192]

Another research program targeting freshman and sophomore students at a research university allowed students to work with faculty members to conduct bibliographic research, literature reviews, and lab experiments. The program involved monthly meetings, peer mentoring, and skills workshops.[193]

In an assessment of the Ronald E. McNair program, program directors reported that the most important components of the McNair program were seminars, faculty-mentored research projects, and visits to graduate schools.[194]

A successful program at a state university to support engineering students included activities, such as giving merit-based financial aid, having a freshman-orientation program, recruiting research-active faculty members, involving students early in research, and having group activities (e.g., peer mentors in a support network, tutoring).[195]

The National Study of Living-Learning Programs indicates that these programs create comprehensive in- and out-of-class learning environments that engender the effective student engagement with faculty, qualified peers, and curricula.[196]

c. Current Best Practices at SUNY

Throughout the SUNY system, programs that include or act as supplemental supports for STEM undergraduates include:

SUNY Replication Project: Baccalaureate and Beyond Community College Mentoring Program
This STEM seamless transfer program is modeled on the nationally recognized Baccalaureate and Beyond Community College Mentoring Program established at Purchase College. The goal of the program is to aid underrepresented minority, financially disadvantaged, and first generation community college students in completing a Bachelor's degree in various fields. The

program includes workshops and community building activities throughout the academic year, emphasizing mentorship and social engagement. SUNY is replicating Purchase College's ideas for seamless STEM transfer throughout the SUNY System in the SUNY Replication Project, led by the founder of the Purchase program, Dr. Joseph Skrivanek, Professor of Chemistry and Biochemistry. To date, 11 four-year institutions and 18 community colleges are participating.

Biology Partnership in Research and Education Program (BioPREP)
This National Institutes of Health program at Stonybrook University was developed to encourage underrepresented students at two-year institutions who want to transfer to four-year schools and prepare for careers in the biological sciences. Participants receive a small salary for participating in BioPREP and are responsible for their room and board costs. Students receive mentorship and have the opportunity to participate in a poster session and receive awards.

SUNY Louis Stokes Alliance for Minority Participation (LSAMP)
Since 1996, the SUNY LSAMP, which is coordinated by Stony Brook University and funded by the National Science Foundation (NSF), has been helping to change the basic shape of STEM education and forging new opportunities for underrepresented minority (URM) students in New York State. The core of the LSAMP program at Stony Brook is a four-year curriculum that is also an integral part of the CSTEP program. It offers a semester by semester program of courses and seminars to enhance students' academic, research and life skills, improving self-efficacy, academic self-concept, and concepts related to the theories of expectancy and expectancy-value. The infrastructure, research base, and replicable models that have been developed are the result of the aggressive and sustained efforts of the Alliance partners. These efforts have resulted in a substantial increase in bachelor's degrees awarded to URM students in STEM fields, and have lead to an increase in the number of URM students enrolled in STEM programs. The 16 campuses in the SUNY alliance are Albany, Binghamton, Buffalo, Buffalo State, New Paltz, Old Westbury, Stony Brook, Farmingdale, as well as Schenectady, Broome, Tompkins-Cortland, Dutchess, Orange, Ulster, Nassau and Suffolk community colleges. Other Alliance partners are the Brookhaven National Laboratory, the NSF funded SUNY Alliance for Graduate Education and the Professoriate (AGEP), and the New York State Education Department's CSTEP program.

Collegiate Science and Technology Entry Program (CSTEP)
In 2012-13, 22 SUNY campuses participated in CSTEP, a New York State program designed to increase the number of students from under-represented minority groups who are pursuing professional licensure and careers in mathematics, science, technology and health-related fields. The CSTEP programs include undergraduate research, enrichment activities, field trips, as well as seminars and workshops designed to enhance skills needed for graduate study, such as application tips, computer technology training, and presentation skills. These supports increase self-efficacy, academic self-concept, and concepts related to the theories of expectancy and expectancy-value.

Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM)
This NSF program makes grants to institutions of higher education to support scholarships for academically talented students demonstrating financial need, enabling them to enter the STEM workforce or STEM graduate school following completion of an associate, baccalaureate, or

graduate-level degree in science, technology, engineering or mathematics disciplines. Grantee institutions are responsible for selecting scholarship recipients, reporting demographic information about student scholars, and managing the SSTEM project at the institution. Grantees create a community of STEM scholars via targeted student support activities including mentoring, internship opportunities, field trips, tutoring, transfer assistance and monthly meetings featuring renown scientists. The list of SUNY campuses receiving one or more recent S-STEM awards includes – but is not limited to – Albany, Binghamton, Buffalo, Stony Brook, Fredonia, Oneonta, Oswego, Fulton- Montgomery, Hudson Valley, Jamestown and Suffolk Community College.

Ronald E. McNair Post-Baccalaureate Achievement Program
SUNY institutions receive federal McNair funds to prepare eligible participants for doctoral studies through involvement in research and other scholarly activities. Participants are from disadvantaged backgrounds and have demonstrated strong academic potential. Institutions work closely with participants as they complete their undergraduate requirements and encourage participants to enroll in graduate programs, and then track their progress through to the successful completion of advanced degrees. The goal is to increase the attainment of Ph.D. degrees by students from underrepresented segments of society. In July 2013, the University at Buffalo hosted its 19th annual McNair Research Conference, a national event that includes workshops and research presentations.

Educational Opportunity Program (EOP)
Although not limited to STEM, the SUNY Educational Opportunity Program provides access, academic support and financial aid to students who show promise for succeeding in college but who may not have otherwise been offered admission. The program supports students throughout their college careers within the University. Educational Opportunity Program students may receive support services, such as academic, career, and personal counseling; tutoring and supplemental instruction. As part of a student's overall financial aid package, the Educational Opportunity Program provides financial assistance for non-tuition related expenses (e.g. books, supplies, etc.)

d. Recommendations

As described in the leadership section, responsibilities related to oversight, accountability, implementation, and evaluation of the STEM@SUNY will be layered. The SUNY STEM Undergraduate Research and Education Steering Committee has and will continue to be focused on system-wide initiatives and supports, while campus-specific STEM Undergraduate Research and Education committees (to be created at each SUNY campus) are encouraged to adapt and implement these system-wide initiatives to leverage their campuses' strengths and target areas for improvement.

Vision and Goal
The SUNY STEM Undergraduate Research and Education Steering Committee views supplemental supports as a constellation of efforts or "wrap-around" activities that interact synergistically with classroom-based and research experiences to create a culture in which STEM students can thrive. We aim to ensure that all undergraduates in or considering STEM majors who are open to participating in supplementary supports have the opportunity to do so.

We acknowledge that most STEM students will only be able to participate in low cost activities such as in-class presentations, and relatively few students will be able to participate in resource-intensive activities, such as presenting at national conferences. We have a special focus on insuring that STEM students and future professionals reflect an increasingly diverse society by supporting women and underrepresented minorities and encouraging each campus to include supports tailored to these populations. To achieve this goal, the SUNY STEM Undergraduate Research and Education Steering Committee proposes several system-wide initiatives and supports.

Planning
We reiterate our recommendation that the campus-specific STEM Undergraduate Research and Education committees build on existing campus assessment policies and procedures to conduct institutional supplementary support For undergraduate students in STEM classes and majors.

Recommended Network Supports and Initiatives
Purpose: Increase the availability and use of supplemental supports, such as professional development opportunities, mentoring, and presentation/publishing opportunities, to support STEM students' persistence in STEM.

Given the diversity of supplemental supports and SUNY constituents; we have declined to recommend specific activities. Instead, our recommendations focus on system-wide initiative that would complement campus efforts to provide supplemental supports to STEM students.

Recommendation 7: Campuses should include supplemental supports in all evidence-based teaching initiatives and research experiences for undergraduates. The extent to which supplemental supports are incorporated into existing initiatives should be reviewed and enhanced as appropriate; plus, as new initiatives are created, supplemental supports should be included.

For example: 1. An existing mentored undergraduate research program could incorporate as a supplemental support an opportunity for participating students to visit a commercial facility which conducts related applied research; or 2. An introductory STEM course could utilize discussion groups, which culminate their work with group members making in-class presentations.

Recommendation 8: Each campus's STEM Undergraduate Research and Education Committee should consider how to increase the number of students receiving supplemental supports that extend beyond the classroom and research laboratory by leverage existing opportunities and creating new ones.

There are many forms of supplemental supports that enable students from different classes, majors, and research projects to engage with one another, faculty, and industry representatives, as well as present their scholarship and engage in peer tutoring and mentorship. Such activities can include:

- **Research Café**s: The goal of a Research Café series is to bridge academic connections by providing a platform for students to share their research experiences and results in an informal but organized setting. Research Cafes allow students to develop peer supports

and increase academic engagement. Anecdotally, we know that many departments and schools have created Research Cafés or similar programs for students pursuing graduate degrees and hope similar programs can be developed for undergraduates.

- **Symposiums:** Symposiums typically include oral and poster presentation sessions. There are several institutions throughout the SUNY system that host local and regional symposiums for undergraduates. We encourage campuses-specific committees to focus on increasing participation among undergraduates for both presenters and attendees.
- **Online research conferences**: Online research conferences featuring undergraduate presenters are an excellent alternative to in-person conferences. Barriers related to cost and travel are eliminated. We encourage campuses-specific committees to focus on increasing participating in existing online conferences and consider how to support student participation, for example allowing students to use teleconferencing equipment.
- **Student Ambassadors**: Student ambassadors are near-peers who informally or formally share their experiences in STEM and describe the opportunities available to them as a STEM major with potential STEM majors. We suggest campuses-specific committees consider how they can connect Student Ambassadors with pre-freshmen and freshmen early in their matriculation or before students have declared a major. Not only would this activity increase interest in STEM but it also increases Student Ambassadors' academic engagement and strengthens their identity as a STEM major.
- **High School Tutoring**: There are many programs through which STEM students tutor or otherwise engage middle and high school students in STEM projects and activities. Like Student Ambassadors programs, tutoring increases interest in STEM among high school students and increases tutors' academic engagement and strengthens their identity as a STEM major.
- **Academic Program-Based Clubs:** Academic-based clubs, such as Women in Engineering, exist on many campuses throughout the SUNY system but are not uniformly active. We encourage campus-specific committees to consider how they can support existing clubs implement meaningful activities.
- **Scholarships:** Scholarships for students, especially underrepresented minorities and women who are at-risk of leaving school because of unmet financial need.

The STEM Undergraduate Research and Education Steering Committee asserts that appropriate faculty support is critical to achieving these recommendations. Implementing supplemental supports requires faculty time and dedication. We suggest that faculty have access to professional development opportunities to learn how to better implementing supplement supports in the classroom, laboratory, and beyond. For example, mentoring is a critical supplementary support but few faculty members have ever received training or guidance. Additionally, a comprehensive, electronic resource and collaboration platform with planning and implementation tools to help faculty members incorporate supplemental supports into lessons, work, and extracurricular activities would be extremely useful and efficient. The collaboration aspect would facilitate cross-disciplinary activities and allow faculty to share innovations and lessons learned.

We suggest that faculty be "rewarded" for using or being a supplemental support. Faculty rewards might include formal awards acknowledging commitment to mentoring students, a decreased teaching load or course release in exchange to supporting students, favorable

consideration of how faculty members are supporting students during tenure review, or monetary incentives.

Additionally, to the extent possible, funding to directly support student participation in supplemental supports (such as funding for student travel to conferences) will enable SUNY to provide more diverse opportunities for students.

E. Resource Needs

Resources
The STEM Undergraduate Research and Education Steering Committee identified several essential resources, many of which currently exist or are in development Institutions need to examine existing resources and leverage them to the greatest extent possible to best meet the needs of faculty, administrations and students. Below is a brief summary of the key resources identified.

Many of these recommended initiatives ultimately rest in the hands of faculty. Therefore, incentivizing and supporting faculty participation is essential, as is rewarding faculty for participating in on campus-specific STEM Undergraduate Research and Education committees and implement their recommendations. Faculty rewards might include honorary and financial awards, decreased teaching loads, or favorable consideration during tenure review

In addition, faculty must have access to relevant and cost-effective professional development, training, and tools. The STEM Undergraduate Research and Education Steering Committee recommends developing a comprehensive electronic resource that includes: evidence, literature reviews, training tools, and lesson and work plans. This online resource would ideally have to capacity to allow faculty to share tools, lessons learned, and adaptations in real-time.

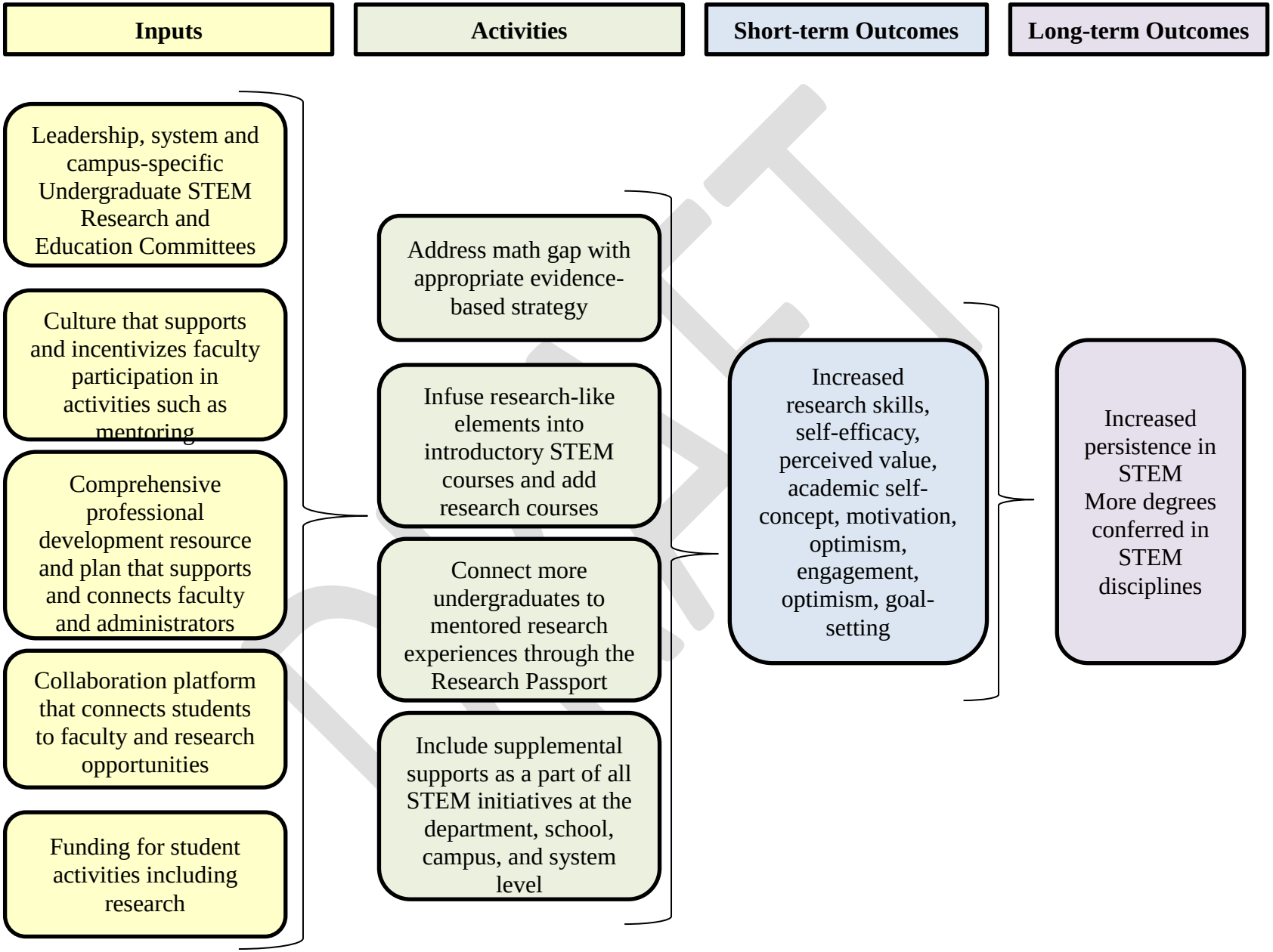
An electronic collaboration platform through which students can connect with potential mentors among SUNY and alumni STEM professionals as well as investigate mentored research opportunities throughout the SUNY system is necessary to better connect and integrate the relatively isolated undergraduate research experiences occurring throughout the system. This online platform must be sustained and managed effectively by clear reporting and defined responsibilities with appropriate access points and linkages.

There should also be a specific quantitative method for evaluation. The use of quantitative methods in statistics (such as multiple regression, logit models, etc) will allow for rigorous study of SUNY-wide data and monitor this over different intervals of time, in order to identify trends.

Funding to directly support student participation in mentored research experiences (such as research supplies and stipends) and other activities, as needed, will be critical.

F. Logic Model and Expected Outcomes

This logic model demonstrates the inputs and activities needed to achieve the short-term and long-term outcomes.



G. Evaluation

The STEM Undergraduate Research and Education Steering Committee recognizes that any initiative to attract STEM students and enhance their persistence will require diligent and coordinated assessment by a SUNY system liaison and campus leaders. These faculty and administrators need to develop:

- Data that indicates why many undergraduate students leave STEM disciplines so as to inform program development.
- A method for understanding system-wide data needs and standardizing data for the purpose of multi-campus evaluation must be developed. Ideally, this collaboration will build on existing systems and resources.
- Valid, easily-obtainable, short-term outcomes that can appropriately serve as proxies for persistence must be identified and utilized. Together with program evaluation, these short-term outcomes will be essential to measuring success and being able to make appropriate midcourse corrections.

H. Moving Forward

Undoubtedly, there are dozens of initiatives being developed and implemented on a small-scale throughout the system. The STEM Undergraduate Research and Education Steering Committee hopes these innovations continue and that successful initiatives are expanded, replicated, and sustained. We applaud the hundreds of faculty, staff, and administrators who have dedicated their time and energy to improving STEM education at SUNY. We encourage the SUNY System Administration to consider how it can create and implement the system-wide supports that we have recommended. We encourage everyone throughout the SUNY system to use document to guide their future planning as we work toward a more integrated system.

I. References

[1] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/administration/eop/ostp/pcast. Accessed November 11, 2013.
[2] Freeman, Richard B. "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic
Leadership?" National Bureau of Economic Research. August 2006. Available at nber.org/chapters/c0207.pdf
[3] Carnevale, Anthony P., Michelle Melton, and Nicole Smith. "STEM." Georgetown University Center on Education and the Workforce. October 2011. Available at www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/stem-complete.pdf
[4] Deloitte Consulting LLP, The Manufacturing Institute, and Oracle Corporation. "People and Profitability: A Time for Change." 2009. Available at deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/us_pip_peoplemanagementreport_100509.pdf.
[5] Deloitte Consulting LLP and The Manufacturing Institute. "2005 Skills Gap Report – A survey of the American Manufacturing Workforce." 2005. Available at doleta.gov/wired/files/us_mfg_talent_management.pdf.
[6] Chairman's Staff of the Joint Economic Committee. Calculations using data from the Bureau of Labor Statistics. "Employment Projections: 2010-20." Table 1.7 Occupational Employment and Job Openings Data, Projected 2010 20, and "Worker Characteristics, 2010." February 2012. Available at bls.gov/emp/. For the purposes of this calculation, STEM occupations are defined as in the U.S. Department of Commerce's Economics and Statistics Administration report, "STEM: Good Jobs Now and for the Future." ESA Issue Brief #03-11. July 2011. Available at esa.doc.gov/sites/default/files/reports/documents/stemfinalyjuly14_1.pdf.
[7] U.S. Department of Commerce, Economics and Statistics Administration. "STEM: Good Jobs Now and for the Future." ESA Issue Brief #03-11. July 2011. Available at esa.doc.gov/sites/default/files/reports/documents/stemfinalyjuly14_1.pdf. The Department of Commerce defined STEM as including professional and technical support occupations in computer science and mathematics, engineering, and life and physical sciences, as well as certain related managerial occupations.
[8] U.S. Department of Commerce. "STEM: Good Jobs Now and for the Future," *supra* note 11.
[9] U.S. Department of Commerce. "STEM: Good Jobs Now and for the Future," *supra* note 11.
[10] U.S. Department of Commerce. "STEM: Good Jobs Now and for the Future," *supra* note 11.
[11] SUNY System Administration Office of the Academic Programs and Planning; NYS department of Labor and OBIEE Data Warehouse
[12] SUNY System Administration Office of the Academic Programs and Planning; NYS department of Labor and OBIEE Data Warehouse
[13] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013
[14] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional

college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013

[15] Preliminary Estimate -U.S. Department of Education, National Center for Education Statistics, 2003-04 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:04/09)

[16] Preliminary Estimate -U.S. Department of Education, National Center for Education Statistics, 2003-04 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:04/09)

[17] Bowling. Bullen, Doyle, Filaseta. "Retention of STEM majors using early undergraduate research experiences." SIGCSE Conference'13 March 6–9, 2013, Boulder, CO USA. Available at http://db.grinnell.edu/sigcse/sigcse2013/Program/viewAcceptedProposal.pdf?sessionType=paper&sessionNumber=196. Accessed November 15, 2013.

[18] Bean, J. (1980). Dropouts and Turnover: The Synthesis and Test of a Causal Model of Student Attrition. Research in Higher Education, 12(2), 155-87.

[19] Swail, W. S. (2004). The art of student retention: A handbook for practitioners and administrators. Austin, TX: Educational Policy Institute.

[20] Adelman, C. (1999). Answers in the tool box: Academic intensity, attendance patterns, and bachelor's degree attainment. Washington, D.C.: Office of Education Research and Improvements, U.S. Department of Education.

[21] Retention Study Group. (2004). Promoting success for Carolina's undergraduates: Factors related to retention and graduation. University of North Carolina at Chapel Hill: Enrollment Policy Advisory Committee

[22] Wyckoff, S. (1998). Retention theories in higher education: Implications for institutional practice. Recruitment and Retention in Higher Education, 12(2), 2-7.

[23] Tinto, V. (2004). Student retention and graduation: Facing the truth, living with the consequences. Washington, D.C.: The Pell Institute.

[24] Adelman, C. (1999). Answers in the tool box: Academic intensity, attendance patterns, and bachelor's degree attainment. Washington, D.C.: Office of Education Research and Improvements, U.S. Department of Education.

[25] Swail, W. S. (2004). The art of student retention: A handbook for practitioners and administrators. Austin, TX: Educational Policy Institute.

[26] Retention Study Group. (2004). Promoting success for Carolina's undergraduates: Factors related to retention and graduation. University of North Carolina at Chapel Hill: Enrollment Policy Advisory Committee

[27] Swail, W. S. (2004). The art of student retention: A handbook for practitioners and administrators. Austin, TX: Educational Policy Institute.

[28] Tinto, V. (2004). Student retention and graduation: Facing the truth, living with the consequences. Washington, D.C.: The Pell Institute.

[29] Seymour, E. and N. M. Hewitt. (1997). *Talking about leaving*. Boulder, CO: Westview Press.

[30] Brainard, S. and L. Carlin. (1998). "A six-year longitudinal study of undergraduate women in engineering and science." *Journal of Engineering Education* 87(4):), 369-375.

[31] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013

[32] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013

[33] Only degrees with CIP2 Code equal to 03, 11, 14, 15, 26, 27, 40 or CIP6 Code equal to 010000, 010902, 010905, 010907, 011001, 011101, 011102, 011199, 301901, 302401 were included in this definition.

[34] Tinto, V. (1975). Dropouts from higher education: A theoretical synthesis of recent literature. A Review of Educational Research, 45, 89-125.

[35] Tinto, V. (1975). Dropouts from higher education: A theoretical synthesis of recent literature. A Review of Educational Research, 45, 89-125.

[36] Vroom, V.C. (1964). Work and motivation. New York: John Wiley Sons.

[37] Friedman, B., & Mandel, R. (2010). The prediction of college student academic performance and retention: Application of expectancy and goal setting theories.Journal of College Student Retention: Research, Theory & Practice, 11(2), 227-246.

[38] Bong, M. (2001). Role of self-efficacy and task-value in predicting college students' course performance and future enrollment intentions. Contemporary Educational Psychology, 26(4), 553-70.

[39] Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. Contemporary Educational Psychology, 25, 68-81.

[40] Locke, E. A., & Latham, G. P. (1990). A theory of goal setting and task performance. Englewood Cliffs, NJ: Prentice Hall.

[41] Kamphoff, C., Hutson, B., Amundsen, S., & Atwood, J. (2007). A Motivational/Empowerment Model Applied to Students on Academic Probation. Journal of College Student Retention: Research, Theory & Practice, 8(4), 397-412.

[42] Sorrentino, D. (2007). The SEEK Mentoring Program: An Application of the Goal-Setting Theory. Journal of College Student Retention: Research, Theory & Practice, 8(2), 241-250

[43] Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84, 191-215.

[44] Bean, J. & Eaton, S. B. (2000). A psychological model of college student retention. In J.M. Braxton (Ed.), Reworking the departure puzzle: New theory and research on college student retention. Nashville: University of Vanderbilt Press.

[45] Bean, J. & Eaton, S. B. (2001). The psychology underlying successful retention practices. Journal of College Student Retention, 3(1), 73-89.

[46] DeWitz, S. J., Woolsey, M. L. & Walsh, W. B. (2009). College student retention: An exploration of the relationship between self-efficacy and purpose in life among college students. Journal of College Student Development, 50(1), 19-34.

[47] Marsh, H.W. & Shavelson, R. J. (1985). Self-concept: Its multifaceted, hierarchical structure. Educational Psychology. 20(3), 107–123.

[48] Komarraju, M., Musulkin, S., & Bhattacharya, G. (2010). Role of Student-Faculty Interactions in Developing College Students' Academic Self-Concept, Motivation, and Achievement. Journal of College Student Development, 51(3), 332-342

[49] Tinto, V. (1975). Dropouts from higher education: A theoretical synthesis of recent literature. A Review of Educational Research, 45, 89-125.

[50] Chickering, A. (1969). Education and identity. San Francisco: Jossey-Bass.

[51] Eli, S. & Bowen, A. (2002). College students' perceptions of student-instructor relationships. Ethics and Behavior, 12(2), 177-190.
[52] Baker, S. R. (2004). Instrinsic, extrinsic and amotivational orientations: Their role in University adjustment, stress, well-being and subsequent academic performance. Current Psychology, 23 (3), 189-202.
[53] Allen, D. (1999). Desire to finish college: An empirical link between motivation and persistence. Research in Higher Education, 40(4), 461-485.
[54] Lin, Y., & McKeachie, W. (1999). College Student Intrinsic and/or Extrinsic Motivation and Learning. Washington, DC: American Psychological Association.
[55] Peterson, C. (2000). The future of optimism. American Psychologist, 55(1), 44-55.
[56] Scheier, M., & Carver, C. (1992). Effects of optimism on psychological and physical well-being: Theoretical overview and empirical update. Cognitive Therapy and Research, 16(2), 201-228. Schunk, D.H. & Zimmerman, B.J. (2006). Competence and control beliefs: Distinguishing the means and ends. In Alexamder, P.A. & Winnie, P.H.(Eds.). Handbook of educational psychology (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.
[57] Aspinwall, L., & Taylor, S. (1992). Modeling cognitive adaptation: A longitudinal investigation of the impact of individual differences and coping on college adjustment and performance. Journal of Personality and Social Psychology, 63(6), 989-1003.
[58] Nes, L., Evans, D., & Segerstrom, S. (2009). Optimism and college retention: Mediation by motivation, performance, and adjustment. Journal of Applied Social Psychology, 39(8), 1887-1912.
[59] Ahlqvist, S., **London, B.,** & *Rosenthal, L. (2013). How gender rejection sensitivity undermines the success of women in science, technology, engineering, and mathematics fields. *Psychological Science.* Online First: DOI: 10.1177/0956797613476048.
[60] Derks, B., Van Laar, C., & Ellemers, N. (2007). The beneficial effects of social identity protection on the performance motivation of members of devalued groups. *Social Issues and Policy Review*, *1*, 217–256.
[61] Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science*, *21*, 1051–1057. doi:10.1177/0956797610377342
[62] London, B., Rosenthal, L., Levy, S., & Lobel, M. (2011). The influences of perceived identity compatibility and social support on women in nontraditional fields during the col- lege transition. *Basic and Applied Social Psychology*, *33*, 304–321. doi:10.1080/01973533.2011.614166
[63] Settles, I. H. (2004). When multiple identities interfere: The role of identity centrality. *Personality and Social Psychology Bulletin*, *30*, 487–500. doi:10.1177/0146167203261885
[64] Settles, I. H., Jellison, W. A., & Pratt-Hyatt, J. S. (2009). Identification with multiple social groups: The moder- ating role of identity change over time among women- scientists. *Journal of Research in Personality*, *43*, 856–867. doi:10.1016/j.jrp.2009.04.005
[65] Demetriou, C. & Schmitz-Sciborski, A. (2011). Integration, motivation, strengths and optimism: Retention theories past, present and future. In R. Hayes (Ed.), Proceedings of the 7th National Symposium on Student Retention, 2011, Charleston. (pp. 300-312). Norman, OK: The University of Oklahoma. Available at https://studentsuccess.unc.edu/files/2012/11/Demetriou-and-Schmitz-Sciborski.pdf
[66] Bean, J. (1980). Dropouts and Turnover: The Synthesis and Test of a Causal Model of Student Attrition. Research in Higher Education, 12(2), 155-87.

[67] Swail, W. S. (2004). The art of student retention: A handbook for practitioners and administrators. Austin, TX: Educational Policy Institute.
[68] Adelman, C. (1999). Answers in the tool box: Academic intensity, attendance patterns, and bachelor's degree attainment. Washington, D.C.: Office of Education Research and Improvements, U.S. Department of Education.
[69] Retention Study Group. (2004). Promoting success for Carolina's undergraduates: Factors related to retention and graduation. University of North Carolina at Chapel Hill: Enrollment Policy Advisory Committee
[70] Wyckoff, S. (1998). Retention theories in higher education: Implications for institutional practice. Recruitment and Retention in Higher Education, 12(2), 2-7.
[71] Tinto, V. (2004). Student retention and graduation: Facing the truth, living with the consequences. Washington, D.C.: The Pell Institute.
[72] Adelman, C. (1999). Answers in the tool box: Academic intensity, attendance patterns, and bachelor's degree attainment. Washington, D.C.: Office of Education Research and Improvements, U.S. Department of Education.
[73] Swail, W. S. (2004). The art of student retention: A handbook for practitioners and administrators. Austin, TX: Educational Policy Institute.
[74] Retention Study Group. (2004). Promoting success for Carolina's undergraduates: Factors related to retention and graduation. University of North Carolina at Chapel Hill: Enrollment Policy Advisory Committee
[75] Swail, W. S. (2004). The art of student retention: A handbook for practitioners and administrators. Austin, TX: Educational Policy Institute.
[76] Tinto, V. (2004). Student retention and graduation: Facing the truth, living with the consequences. Washington, D.C.: The Pell Institute.
[77] Council for Undergraduate Research. (2010) Transformative research at predominantly undergraduate institutions. Available at http://www.cur.org/assets/1/7/TRFull.pdf Accessed November 5, 2013
[78] Council for Undergraduate Research. (2010) Transformative research at predominantly undergraduate institutions. Available at http://www.cur.org/assets/1/7/TRFull.pdf Accessed November 5, 2013
[79] Mogk D.W. Undergraduate research experiences as preparation for graduate study in geology. J. Geol. Educ. 1993;41:126–128.
[80] Tomovic M.M. Undergraduate research—prerequisite for successful lifelong learning. ASEE Annu. Conf. Proc. 1994;1:1469–1470.
[81] Fitzsimmons S.J., Carlson K., Kerpelman L.C., Stoner D. A Preliminary Evaluation of the Research Experiences for Undergraduates (REU) Program of the National Science Foundation. Washington, D.C: National Science Foundation; 1990
[82] Zydney A.L., Bennett J.S., Shahid A., Bauer K.W. Impact of undergraduate research experience in engineering. J. Eng. Educ. 2002;91:151–157
[83] Kremer J.F., Bringle R.G. The effects of an intensive research experience on the careers of talented undergraduates. J. Res. Dev. Educ. 1990;24:1–5
[84] Mabrouk P. A., Peters K. Student perspectives on undergraduate research (UR) experiences in chemistry and biology. CUR Quarterly. 2000;21:25–33
[85] The pipeline. Benefits of undergraduate research experiences. *Russell SH, Hancock MP, McCullough J Science. 2007 Apr 27; 316(5824):548-9.*

[86] Seymour E., Hunter A. B., Laursen S. L., DeAntoni T. Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. Sci. Educ. 2004;88:493–534

[87] Survey of Undergraduate Research Experiences (SURE): first findings. Lopatto D. *Cell Biol Educ. 2004 Winter; 3(4):270-7*

[88] Lopatto D. Undergraduate research experiences support science career decisions and active learning. CBE Life Sci Educ. 2007;6:297–306. doi: 10.1187/cbe.07-06-0039

[89] Lopatto D. "Science in Solutions: the Impact of Undergraduate Research on Student Learning." Research Corpoation for Science Advancement. 2009

[90] Lopatto, D. Undergraduate research as a high-impact student experience. "*Research.* Association of American Colleges and Universities; Spring 2010: 27-30

[91] Alexander B, Foertsch J, Daffinrud S, Tapia R . The "Spend a Summer with a Scientist" (SaS) program at Rice University: A study of program outcomes and essential elements 1991-1997. Council on Undergraduate Research Quarterly. 2000;20(3):127-133.

[92] Bauer KW, Bennett JS. Alumni perceptions used to assess undergraduate research experience. Journal of Higher Education, 2003;74:210-230.

[93] Campbell A, Skoog G. Preparing undergraduate women for science careers. Journal of College Science Teaching, 2004;33(5):24-26.

[94] Chandra U, Stoecklin S, Harmon M. A successful model for introducing research in an undergraduate program. Journal of College Science Teaching , 1998;28(2):116-118.

[95] Chaplin S, Manske J, Cruise J. Introducing freshmen to investigative research: A course for biology majors at Minnesota's University of St. Thomas. Journal of College Science Teaching , 1998;27(5):347-350.

[96] DiBiasio D, Mello N. Multi-level assessment of program outcomes and assessing a nontraditional study abroad program in the engineering discipline. Frontiers: the Interdisciplinary Journal of Study Abroad , 2004;10:237-252.

[97] Foertsch J, Alexander B, Penberthy D. Summer research opportunity programs (SROPs) for minority undergraduates: A longitudinal study of program outcomes 1986-1996. Council of Undergraduate Research Quarterly , 2000;20(3):114-119.

[98] Nagda B, Gregerman S, Jonides J, von Hippel W, Lerner JS. Undergraduate student-faculty research partnerships affect student retention. Review of Higher Education , 1998;22:55-72.

[99] Nnadozie E , Ishimaya J, Chon N. Undergraduate research internships and graduate school success. Journal of College Student Development , 2001;42(2):145-156.

[100] Russell SH, Hancock MP, McCullough J. Benefits of undergraduate research experiences. Science , 2007;316:548-549.

[101] Shellito C, Shea K , Weissmann G, Mueller-Solger A , Davis W. Successful mentoring of undergraduate researchers: Tips for creating positive student research experiences. Journal of College Science Teaching , 2001;30:460-465.

[102] Summers M, Hrabowski F. Preparing minority scientists and engineers. Science 2006;311(5769):1870-187 1.

[103] Ward C, Bauer K , Bennet J. Content analysis of undergraduate student research evaluations. http://www.udel.edu/RAIRE /Content.pdf

[104] Cole F. 1995. Implementation and evaluation of undergraduate research practicum. Journal of Professional Nursing , 1995;11(3):154-160.

[105] Ferrari J, Jason L . Integrating research and community service: Incorporating research skills into service learning experiences. College Student Journal , 1996;30(4):444-451.

[106] Gafney L . The role of the research mentor/teacher: student and faculty views. Journal of College Science Teaching , 2005;34(4):52-57.
[107] Hakim T. 1998. Soft assessment of undergraduate research: Reactions and student perceptions. Council of Undergraduate Research Quarterly , 1998;18:189-1192.
[108] Hunter AB, Laursen SL , Seymour E . Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. Science Education 2006;91(1):36-74.
[109] Ishiyama J. Undergraduate research and the success of first generation, low income college students. Council on Undergraduate Research Quarterly 2001;22:36-41.
[110] Ishiyama J. Does early participation in undergraduate students benefit social science and humanities students? Journal of College Students , 2002;36(3):380-386.
[111] Kardash, CM. Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. Journal of Educational Psychology , 2000;92(1):191-201.
[112] Seymour E , Hunter A , Laursen S, DeAntoni T. Establishing the benefits of research experiences for undergraduates: First findings from a three-year study. Science Education , 2003;88:493-534.
[113] Barlow, A. and M. R. Villarejo (2004). "Making a difference for minorities: Evaluation of an educational enrichment program." *Journal of Research in Science Teaching* 00: 1-2.
[114] Carter, F. D., M. Mandell, and K.I. Maton. (2009). "The Influence of On-Campus, Academic Year Undergraduate Research on STEM Ph.D. Outcomes: Evidence From the Meyerhoff Scholarship Program." *Educational Evaluation and Policy Analysis* 31(4): 441-462.
[115] 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)." *Higher Education* 8: 11-21.
[116] Hathaway, R., B.A. Nagda, and S. Gregerman. (2002). "The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study." *Journal of College Student Development* 43(5): 614-631.
[117] Junge, B., C. Quiñones, J. Kakietek, D. Teodorescu, and P. Marsteller. (2010). "Promoting Undergraduate Interest, Preparedness, and Professional Pursuit in the Sciences: An Outcomes Evaluation of the SURE Program at Emory University." *CBE—Life Sciences Education* 9(2): 119-132.
[118] Kight, S.L., J.J. Gaynor, and S.D. Adams. (2006). "Undergraduate Research Communities: A Powerful Approach to Research Training." *Journal of College Science Teaching* July/August, 34-39.
[119] Kinkel, D. H. and S. E. Henke. (2006). "Impact of undergraduate research on academic performance, educational planning, and career development." *Journal of Natural Resources and Life Sciences Education* 35: 194-201.
[120] Nagda, B. A., S. R. Gregerman, J. Jonides, W. von Hippel, and J.S. Lerner. (1998). "Undergraduate student-faculty research partnerships affect student retention." *The Review of Higher Education* 22: 55-72.
[121] Russell SH, Hancock MP, McCullough J. Benefits of undergraduate research experiences. Science , 2007;316:548-549..
[122] Carter, F. D., M. Mandell, and K.I. Maton. (2009). "The Influence of On-Campus, Academic Year Undergraduate Research on STEM Ph.D. Outcomes: Evidence From the Meyerhoff Scholarship Program." *Educational Evaluation and Policy Analysis* 31(4): 441-462.

[123] Lopatto D. "Science in Solutions: the Impact of Undergraduate Research on Student Learning." Research Corpoation for Science Advancement. 2009
[124] Handelsman, J. Pfund, C., Lauffer, S.M., & Pribbenow, C.M. (2005). Entering mentoring. University of Wisconsin.
[125] National Research Council. (1997). Adviser, teacher, role model, friend: On being a mentor to students in science and engineering. Washington, D.C.: National Academy Press.
[126] Lopatto D. Undergraduate research experiences support science career decisions and active learning. CBE Life Sci Educ. 2007;6:297–306. doi: 10.1187/cbe.07-06-0039
[127] Lopatto D. "Science in Solutions: the Impact of Undergraduate Research on Student Learning." Research Corpoation for Science Advancement. 2009.
[128] Lopatto D. "Science in Solutions: the Impact of Undergraduate Research on Student Learning." Research Corpoation for Science Advancement. 2009
[129] The pipeline. Benefits of undergraduate research experiences. *Russell SH, Hancock MP, McCullough J Science. 2007 Apr 27; 316(5824):548-9.*
[130] Hunter, A-B., Laursen, S.L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. Science Education, 91, 36-74.
[131] Singer, J. and Zimmerman, B., Evaluating a Summer Undergraduate Research Program: Measuring Student Outcomes and Program Impact (Acrobat (PDF) 991kB Mar7 12), CUR Quarterly, Spring 2012, v 32, n 3.
[132] Singer, J. and Weiler, D., A Longitudinal Student Outcomes Evaluation o the Buffalo State College Summer Undergraduate Research Program (Acrobat (PDF) 482kB Mar5 12), CUR Quarterly, Spring 2009, v. 29, n 3.
[133] Council for Undergraduate Research identified Characteristics of Excellence in Undergraduate Research. Available at http://www.cur.org/assets/1/23/COEUR_final.pdf. Accessed November 11, 2013.
[134] J. Handelsman, et al.D. Ebert-May, R. Beichner, P. Bruns, A. Chang, R. DeHaan, J. Gentile, S. Lauffer, J. Stewart, S.Tilghman, W. Wood. (2004). "Scientific Teaching." *Science* 304(5670), 521–522.
[135] National Research Council. (2005). *How Students Learn: Science in the Classroom.* Washington, DC: National Academy Press.
[136] Conway, M. A. and S. J. Anderson. (1994). "The formation of flashbulb memories." *Memory & Cognition* 22: 326.
[137] Weigel, R. H. (1975). "The impact of cooperative learning experiences on cross-ethnic relations and attitudes." *Journal of Social Issues* 31: 219-244.
[138] Schwartz, D. L. and J.D. Bransford (1998). "A time for telling." *Cognition & Instruction* 16: 475-522.
[139] Springer, L., M. E. Stanne, and S.S. Donovan. (1999). "Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis." *Review of Educational Research* 69(1): 21-51.
[140] Rivard, L. P. and S. B. Straw. (2000). "The effect of talk and writing on learning science: An exploratory study." *Science Education* 84: 566-593.
[141] Callender, A. A. and M. A. McDaniel. (2007). "The Benefits of Embedded Question Adjuncts for Low and High Structure Builders." *Journal of Educational Psychology* 99: 339-348.
[142] Chen, J. Y. (2011). "Problem-based learning: Developing resilience in nursing students." *Kaohsiung Journal of Medical Sciences* 27(6): 230-233.

[143] Morgan, R. L., J. E. Whorton, and C. Gunsalas. (2000). "A comparison of short term and long term retention: lecture combined with discussion versus cooperative learning." *Journal of Instructional Psychology* 27: 53-58.
[144] National Research Council. (2005). *How Students Learn: Science in the Classroom.* Washington, DC: National Academy Press.
[145] Ausubel, D. P. (2000). *The Acquisition and Retention of Knowledge: A Cognitive View.* Dordrecht, The Netherlands: Kluwer Academic Publishers.
[146] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013
[147] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013
[148] Project Kaleidoscope. Available at http://serc.carleton.edu/sp/pkal/index.html Accessed November 8, 2013
[149] Almer, E., K. Jones, and C. Moeckel. (1998). "The impact of one-minute papers on learning in an introductory accounting course." *Issues in Accounting Education* 13(3): 485-495.
[150] Anderson, W. L., Mitchell, S. M., and M.P. Osgood. (2005). "Comparison of student performance in cooperative learning and traditional lecture-based biochemistry classes." *Biochemistry and molecular biology education: A bimonthly publication of the International Union of Biochemistry and Molecular Biology* 33(6): 387-93.
[151] Armbruster, P., M. Patel, E. Johnson, and M. Weiss. (2009). "Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology." *Education* 8: 203-213.
[152] Armstrong, N., S. Chang, and M. Brickman. (2007). "Cooperative learning in industrial-sized biology classes." *Education* 6: 163-171.
[153] Beichner, R. J., J.M. Saul, D.S. Abbott, J.J. Morse, D.L. Deardorff, R. J. Allain, et al. (2007). "The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project." In E. F. Redish & P. J. Cooney (Eds.), *Research-Based Reform of University Physics*. College Park, MD: American Association of Physics Teachers.
[154] Born, W. K., W. Revelle, and L.H. Pinto. (2002). "Improving biology performance with workshop groups." *Science Education* 11(4): 347.
[155] Buckley, M., H. Kershner, K. Schindler, C. Alphonce, and J. Braswell. (2004). "Benefits of using socially-relevant projects in computer science and engineering education." *SIGCSE '04: Proceedings of the 35th SIGCSE Technical Symposium on Computer Science Education* 36(1): 482–486.
[156] Capon, N. and D. Kuhn. (2004). "What's so good about problem-based learning?" *Cognition and Instruction* 22(1): 61-79.
[157] Chizmar, J. F. and A.L. Ostrosky. (1998). "The one-minute paper: Some empirical findings." *The Journal of Economic Education* 29(1):3.

[158] Cortright, R. N., H.L. Collins, D.W. Rodenbaugh, and S.E. DiCarlo. (2003). "Student retention of course content Is improved by collaborative-group testing." *AJP: Advances in Physiology Education* 27(3): 102-108.
[159] Cortright, R. N., H.L. Collins, and S.E. DiCarlo. (2005). "Peer instruction enhanced meaningful learning: ability to solve novel problems." *Advances in Physiology Education* 29(2): 107-11.
[160] Crouch, C. H., and Mazur, E. (2001). "Peer Instruction: Ten years of experience and results." *American Journal of Physics* 69(9): 970.
[161] Fagen, A. P. (2002). "Peer instruction: results from a range of classrooms." *The Physics Teacher* 40(4): 206.
[162] Fonseca, A. P., C.I. Extremina, and A.F. Fonseca. (2004). "Concept mapping: A strategy for meaningful learning in medical microbiology." *First International Conference on Concept Mapping*. Pamplona, Spain.
[163] Freeman, S., E. O. Connor, J.W. Parks, M. Cunningham, D. Hurley,D. Haak, C. Dirks, and M.P. Wenderoth. (2007). "Prescribed active learning increases performance in introductory biology." *Education* 6:132-139.
[164] Harris, M. A., R.F. Peck, S. Colton, J. Morris, E.C. Neto, and J. Kallio. (2009). "A combination of hand-held models and computer imaging programs helps students answer oral questions about molecular structure and function: A controlled investigation of student learning." *CBE—Life Sciences Education* 8(1): 29-43.
[165] Klappa, P. (2009). "Promoting active learning through "pub quizzes"— a case study at the University of Kent." *Evaluation* 14 (December), Article C2.
[166] Lasry, N., E. Mazur, and J. Watkins. (2008). "Peer instruction: From Harvard to the two-year college." *American Journal of Physics* 76(11): 1066.
[167] Lewis, S. E. and J.E. Lewis. (2005). "Departing from lectures: An evaluation of a peer-led guided inquiry alternative." *Journal of Chemical Education* 82(1): 135.
[168] McDaniel, C. N., B.C. Lister, M.H. Hanna, and H. Roy. (2007). "Increased learning observed in redesigned introductory biology course that employed web-enhanced, interactive pedagogy." *CBE—Life Sciences Education* 6: 243-249.
[169] McDaniel, M., H. Roediger, and K. McDermott. (2007). "Generalizing test-enhanced learning from the laboratory to the classroom." *Psychonomic Bulletin & Review* 14(2): 200-206.
[170] O'Sullivan, D. W. and C.L. Cooper. (2003). "Evaluating active learning: A new initiative for a general chemistry curriculum." *Journal of College Science Teaching* 32(7): 448-453.
[171] Pelaez, N. J. (2002). "Problem-based writing with peer review improves academic performance in physiology." *Advances in Physiology Education* 26(3): 174-184.
[172] Preszler, R. (2004). "Cooperative concept mapping: Improving performance in undergraduate biology." *Journal of College Science Teaching* 33(6): 30-35.
[173] Preszler, R. W., A. Dawe, and C.B. Shuster. (2007). "Assessment of the Effects of Student Response Systems on Student Learning and Attitudes over a Broad Range of Biology Courses." *CBE—Life Sciences Education* 6(1): 29 -41.
[174] Preszler, R. W. (2009). "Replacing lecture with peer-led workshops improves student learning." *CBE—Life Sciences Education* 8: 182-192.
[175] Rivard, L.P. and S.B. Straw. (2000). "The effect of talk and writing on learning science: An exploratory study." *Science Education* 84: 566-593.
[176] Schwartz, D. L. and J.D. Bransford (1998). "A time for telling." *Cognition & Instruction* 16: 475-522.

[177] Smith, M., W. Wood, W. Adams, C. Wieman, J. Knight, N. Guild, et al. (2009). "Why peer discussion improves student performance on in-class concept questions." *Science* 323: 122-124.
[178] Smith, M.K., W.B. Wood, K. Krauter, and J.K. Knight. (2011) "Combining Peer Discussion with Instructor Explanation Increases Student Learning from In-Class Concept Questions." *CBE—Life Sciences Education* 10: 55-63.
[179] Steele, J. E. (2003). "Effect of essay-style lecture quizzes on student performance on anatomy and physiology exams." *Bioscene: Journal of College Biology Teaching* 29(4): 15-20.
[180] Tessier, J. (2004). "Using peer teaching to promote learning in biology." *Journal of College Science Teaching* 33(6): 16-19.
[181] Tessier, J. (2007). "Small-group peer teaching in an introductory biology classroom." *Journal of College Science Teaching* 36(4): 64-69.
[182] Tien, L.T., V. Roth, and J.A. Kampmeier. (2002). "Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course." *Journal of Research in Science Teaching* 39(7): 606-632.
[183] Traver, H. A., M.J. Kalsher, J.J. Diwan, and J. Warden. (2001). "Student reactions and learning: Evaluation of a biochemistry course that uses web technology and student collaboration." *Biochemistry and Molecular Biology Education* 29: 50-53.
[184] Yarden, H., G. Marbach-ad, and J.M. Gershoni. (2004). "Using the concept map technique in teaching introductory cell biology to college freshmen." *Bioscene: Journal of College Biology Teaching* 30(1): 3-13.
[185] Lopatto, D. (2010). Undergraduate research as a high-impact student experience." Spring 2010. Association of America College and Universities. Accessed November 26, 2013. Available at http://www.niu.edu/engagedlearning/research/pdfs/ugr_high_impact_activity.pdf
[186] Bednarksi, A.E., Elgin, S.C.R., and H.B. Pakrasi. (2005) "An Inquiry into Protein Structure and Genetic Disease:
Introducing Undergraduates to Bioinformatics in a Large Introductory Course." Cell Biology Education Fall 2005.
[187] Pope, W. H., D. Jacobs-Sera, et al. (2011). "Expanding the diversity of mycobacteriophages: insights into genome
architecture and evolution." PLoS One 6(1): e16329.
[188] Association of American Universities. Framework for Systemic Change in Undergraduate STEM Teaching and Learning . Available at http://www.aau.edu/WorkArea/DownloadAsset.aspx?id=14357 . Accessed November 8, 2013
[189] Executive Office of the President. President's Council of Advisors on Science and Technology (February 2012) Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf. Accessed November 11, 2013
[190] Council for Undergraduate Research identified Characteristics of Excellence in Undergraduate Research. Available at http://www.cur.org/assets/1/23/COEUR_final.pdf. Accessed November 11, 2013.
[191] Alexander B, Foertsch J, Daffinrud S, Tapia R . The "Spend a Summer with a Scientist" (SaS) program at Rice University: A study of program outcomes and essential elements 1991-1997. Council on Undergraduate Research Quarterly. 2000;20(3):127-133.
[192] Chandra U, Stoecklin S, Harmon M. A successful model for introducing research in an undergraduate program. Journal of College Science Teaching , 1998;28(2):116-118.

[193] Nagda B, Gregerman S, Jonides J, von Hippel W, Lerner JS. Undergraduate student-faculty research partnerships affect student retention. Review of Higher Education , 1998;22:55-72.
[194] Nnadozie E , Ishimaya J, Chon N. Undergraduate research internships and graduate school success. Journal of College Student Development , 2001;42(2):145-156.
[195] Summers M, Hrabowski F. Preparing minority scientists and engineers. Science 2006;311(5769):1870-187 1.
[196] Brower, A., & Inkelas, K. (2007). Assessing learning community programs and partnerships. In Learning communities and student affairs: Partnering for powerful learning, ed. B. Smith & L. Williams. Washington, D.C.: National Association of Student Personnel Administrators.