Building a Central Indiana STEM Education Pipeline

Jeffrey X. Watt, Department of Mathematical Sciences
Charles R. Feldhaus, School of Engineering and Technology
Kathleen A. Marrs, Department of Biology

Indiana University-Purdue University Indianapolis

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Abstract

Increasing the retention and persistence to graduation for science, technology, engineering, and mathematics (STEM) students is challenging. A recent report by the President’s Council of Advisors on Science and Technology (PCAST) calls for the nation to produce approximately 1 million more STEM professionals during the next decade to meet demand (PCAST, 2012). The PCAST (2012) report, titled Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics, implores universities and community colleges to (a) catalyze widespread adoption of empirically validated teaching practices, (b) advocate and provide support for replacing standard laboratory courses with discovery-based research courses, (c) launch a national experiment in postsecondary math education to address the math preparation gap, and (d) encourage partnerships among stakeholders to diversify pathways to STEM Careers. Yet, the U.S. Department of Labor projects that jobs requiring technical degrees will grow to an estimated 6 million job openings by the end of the decade - the majority being in computer sciences, mathematics, medical and health technology, and engineering. Given this talent gap, it is crucial for universities to develop strategies that encourage more students to successfully complete degree programs in STEM degrees. This paper discusses the building of a Central Indiana STEM Talent Expansion Pipeline (CI-STEP), through adopting and adapting high-impact best practices in STEM education, and the resulting increase in the number of students graduating with a STEM degree.

Introduction

A National Center for Educational Statistics study of six-year graduation data indicates that nationally, 59% of STEM majors fail to complete their degree, with 21% of those changing majors to a non-STEM field (NCES, 2000, 2009). The National Science Board's Science and Engineering Indicators 2000 report reinforces these conclusions: STEM degrees granted today remain below levels reached in the early 1990s (NSB, 2000). Yet, the U.S. Department of Labor projects that jobs requiring technical degrees will grow to an estimated 6 million job openings by the end of the decade – the majority being in computer sciences, mathematics, medical and health technology, and engineering (US Bureau of Labor Statistics, 2010). Given this talent gap, it is crucial for universities to develop strategies that encourage more students to successfully complete degree programs in STEM degrees.

CI-STEP is a five-year, $2M project that enhances a central Indiana pipeline to increase the number of students from the greater Indianapolis region (central Indiana) obtaining STEM degrees that will be sustainable after the expiration of this grant. The goals of this project are to
increase the numbers of students of all demographic groups who:

(1) pursue STEM academic and career pathways;
(2) participate in STEM research, industry internships, and honors activities;
(3) graduate with an undergraduate degree in STEM fields;
(4) and transition into industry, graduate and professional programs.

The program has set a target of increasing the number of STEM graduates at IUPUI by 10% per year (an increase of an additional 782 STEM graduates by 2015).

The Institution and Departments

Indiana University-Purdue University Indianapolis (IUPUI) is located in downtown Indianapolis, and is the state's only urban research university, with 22 schools offering over 200 degree programs. IUPUI has a national reputation for its involvement with the City of Indianapolis and the Indianapolis public school systems through the IUPUI UCASE center (Urban Center for the Advancement of STEM Education). Created in 1969 by the legislature of Indiana, IUPUI embodies the unorthodox partnership between Indiana and Purdue Universities to serve the educational needs in the largest metropolitan region of the state, representing one-fifth of the state's population. IUPUI has grown substantially in its 40-year history, becoming the third largest campus in the state, and is the only 4-year public institution of higher education in this region. More than 60% of IUPUI's 31,000 students are first-generation college attendees and 16% of its student body belongs to minority groups.

The Schools of Science, Engineering and Technology

The School of Science and the School of Engineering and Technology are two of the three largest undergraduate schools by headcount at IUPUI: both schools award Purdue University degrees. Together the two schools are known as leaders in undergraduate STEM education. Both schools have leadership roles in implementation of Project Lead the Way (Engineering and Biomedical Sciences) in school districts state-wide and faculty from both schools are principle investigators of the Indiana-STEM Resource Network.

The School of Science is recognized for its innovation in teaching science through the Just-in-Time Teaching (JiTT) and Peer-Led Team Learning (PLTL) projects (Marrs, 2004; Gafney, 2007). The Math Assistance Center provides a technology-rich environment for collaborative learning, peer-mentoring, and supplemental instruction for students in all levels of mathematics. The School’s Project SEAM, a collaborative effort involving fifteen central Indiana school districts and five postsecondary institutions teamed to create a "seamless" transition
between high school and college for all students, has a strong record of providing science and mathematics professional development to hundreds of local high school teachers since the partnership was established in 1999.

**The Central Indiana STEM Talent Expansion Program (CI-STEP)**

CI-STEP involves undergraduate majors in the School of Science’s six degree-granting STEM departments (Biology, Chemistry, Computer Science, Geology, Physics, and Mathematics), and in the School of Engineering’s and Technology’s six engineering degrees (Biomedical, Computer, Electrical, Energy, Mechanical, and Motorsports), plus the six technology degrees (Biomedical Engineering Technology, Computer Engineering Technology, Computer Information Technology, Construction Engineering Management Technology, Electrical Engineering Technology, and Mechanical Engineering Technology). In addition, the Central Indiana STEM Talent Expansion Program is collaborating with Ivy Tech Community College Central Indiana, as part of the pipeline to increase the number of students graduating with STEM degrees. This collaboration between Ivy Tech and IUPUI is building on the articulation agreements and programs already established, including the creation of new seamless pathways for students pursuing STEM programs between the two- and four-year institutions. These two campuses have the largest number of African American and Hispanic students of any post-secondary institutions in Indiana. Moreover, the largest number of students transferring from an Indiana community college to a 4-year institution was from Ivy Tech Central Indiana to IUPUI.

In addition, the School of Engineering and Technology has developed articulation agreements with other 4-year institutions, allowing students at these institutions the opportunity to transition seamlessly to the ABET accredited engineering and technology programs at IUPUI or earn a dual degree at both institutions. For example, Engineering has partnered with Butler University, a private institution, to establish the Engineering Dual Degree Program (EDDP). The EDDP allows students to study at Butler and also have access to the engineering programs at IUPUI. Completion of this program results in two degrees, one in Engineering from Purdue University, and another from Butler University in another major. This is not a 2+2 program where students are expected to transfer after three years to IUPUI to complete their studies. Instead, the EDDP has a curriculum that integrates the engineering courses into the students' plan of study, which allows students to be full-time residents at Butler for the duration of the program.

**Challenges**

Retention and persistence to graduation are particularly challenging for STEM students
Building a Central Indiana STEM Education Pipeline

on urban campuses. Recognized nationally as one of the largest urban campuses in the country, IUPUI enrolls over 31,000 students, of whom 21,000 are undergraduates, with a diverse blend of traditional full-time, part-time, returning adult, and transfer students. Most students must work at least part-time, and many have family obligations. Approximately 97% of students commute to campus, and many are first generation, both known factors affecting graduation success.

In addition, thousands of students each year transfer out of IUPUI, and thousands more transfer in as upper classmen. In 2008, the IUPUI freshman class was: 46% first-time full-time (FT/FT) non-international students, 23% transfers students, 12% returning adult students, 9% non-degree seeking students, 7% inter-campus transfers, 2% FT/FT international students, and 1% all others. Finally, despite recent improvements in IUPUI’s admissions criteria, many students enter as “conditional admits.” Predictably, the overall campus 1-year retention rate among freshmen is much lower than our sister campus, IU Bloomington, and our campus 6-year graduation rate, a traditional measure of persistence, is only 32% (see Table 1). A problem facing many urban institutions is the number of hours per week that students work off-campus, often four times the number of hours on a residential campus like IU Bloomington. Although, over 21,000 undergraduate students were enrolled at IUPUI in 2008, only 3,356 degrees were awarded.

<table>
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<tr>
<th>Table 1: Student Profile Compared to a Traditional Campus</th>
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<td><strong>Hours employed</strong></td>
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Source: Student retention at IUPUI: Enrollment report and analysis, Fall 2008

In a typical year, the total number of STEM majors at IUPUI is approximately 2,800. In the baseline year, 2008-09, the School of Science had 1,108 and the School of Engineering and Technology had 1,775 declared STEM majors. Clearly, STEM enrollments at IUPUI are strong, accounting for over 2,800 students at the institution. Yet, the overall graduation numbers are low. Thus, a strategic approach to increasing the number of STEM degrees at IUPUI was developed by creating a STEM pipeline to focus on retention and persistence to graduation. To do so, CI-STEP adopted and adapted best practice initiatives, dramatically expanding academic and extra-curricular programs that have proven to be successful at IUPUI and elsewhere.
Adopt and Adapt Best Practice Interventions

The Central Indiana STEM Talent Expansion Program is creating a pipeline and a university culture change to increase the number of IUPUI students obtaining undergraduate STEM degrees: Transition to College → STEM Curriculum → Student Services → Career Placement. The project addresses initiatives needed for transforming undergraduate STEM education by propagating, expanding, and creating new research-based educational innovations and interventions. The program focuses on four main types of activities:

1. Student Success,
2. Career Services,
3. Articulation with IVYTech, and
4. Student-Centered.

Student Success Interventions

Student success interventions include: Orientation and Summer Bridge Programs, STEM Freshman Dormitory, Women in Science Residential House, and First-Year STEM Experience courses drawing on best practices (Gordon et al, 2008; Kirst and Venezia, 2004). Newly-admitted STEM majors receive early, proactive academic advising and placement opportunities throughout summer orientation. This includes scheduling for classes, connecting with campus resources, and facilitating a seamless transition to IUPUI. In addition, Summer Bridge Programs that are known to be an effective way to achieve first-year student success, particularly for first generation, female, and minority students were developed (Fletcher et al, 2001; Hicks, 2003).

A two-week Summer STEM Bridge Program was developed, which helps students explore their major, assess their Strengths Based Assessment report, develop individualized Personal Development Plans, review prerequisite math skills for college level-work, and participate in other activities that build successful transition into their major. A growing body of research links Summer Bridge Programs to a learning community in the fall semester, helps build on the peer-support groups formed during the summer to increase retention (Erickson, Peters et al, 2006; Laufgraben and Shapiro, 2004). Thus, the STEM Bridge has been linked a dedicated learning community course in the fall semester of the freshman year.

Career Services Interventions

Career service components that prepare students to be engaged employees through early career development and guidance is well documented (Hughey et al, 2009; Hundley et al, 2009). Thus, targeted workshops for freshman in the spring semester to introduce key career preparation
strategies and resources, including internship opportunities, have been implemented. The timing of the workshops is particularly salient, as it extends community building from the fall/summer activities and provides students the ability to proactively plan for classes and competencies needed for upper-level classes and high-impact educational practices, including internships.

Preparation for careers and graduate school upon graduation draws on the work of Gardner and others (Gardner et al., 1997; Henscheid, 2008). Through enhancement of the senior year experiences to provide STEM majors with a series of professional development opportunities to synthesize, summarize, and integrate their personal, academic, and professional learning. Also, the program has implemented résumé preparation and review sessions, mock and real interview opportunities, career development advice, and a platform for professional networking with industry partners. In collaboration with IUPUI’s Center for Research and Learning, we are offering preparation and guidance in exploring graduate and professional school opportunities, assistance in applying for targeted educational opportunities, referrals to appropriate funding sources and mechanisms to continue their education, and the ability to network with graduate representatives at IUPUI and elsewhere.

Articulation Interventions

As noted, there are several feeder institutions and affiliated with this project, including the public community college system, a private 2-year institution, and other private 4-year institutions in close proximity to IUPUI. These stakeholders play an important role in populating the STEM pipeline at their respective institution, and specific agreements have been created to explicitly articulate courses between the feeder institution and IUPUI to make a seamless transition for students. Furthermore, other elements have been put in place, such as joint faculty development initiatives and sharing of course/curricular resources, in order to standardize and strengthen the preparation and performance of STEM students across institutions.

Student Centered Pedagogy Interventions

STEM curriculum and pedagogical interventions research has established that students who take courses that use active learning outperform students in traditional classes and develop a greater conceptual knowledge of the course content (Austin, 1993; Hake, 1998; Watt, 2013). Thus, the program is expanding and implementing Peer-Led Team Learning (PLTL) and Just-in-Time Teaching (JiTT) in introductory and upper-level courses throughout the STEM majors.

The PLTL concept is straightforward: recruit recent successful students from the course to serve as peer leaders that coach small student groups in a workshop setting devoted to
problem-solving. Attendance is mandatory. The students and the peer leader meet together once a week for two hours. Prior to the workshop, students complete a Self-Test demonstrating knowledge of required work. During the session, students complete a series of problems with the peer leader providing additional direction, not as content expert, but as an academic coach who suggests meaningful directions for problem solving and understanding concepts. The workshops usually have 8 students, allowing for individual attention. The peer leaders meet as a group for an additional 2 hours each week with the course instructor to prepare for the upcoming workshop, as well as to learn techniques for small group instruction – group facilitation skills, pedagogical techniques, and additional content knowledge.

JiTT is an innovative method that has significant effects on student learning and retention. The idea behind JiTT is to use the internet to create a continuous feedback loop between the web and the classroom. Faculty post web-based “Warm Up” assignments on the course website prior to class and students complete the Warm Up assignments on-line within a few hours of class. The instructor previews student Warm Up responses on-line prior to class, and shows selected student responses in class to set the stage for deeper discussion. This creates an interactive classroom that emphasizes cooperative learning and formative assessment (continuous feedback), and decreases the use of rote lecture (Marrs and Novak, 2004; Gavrin, Watt, Marrs, and Blake, 2004).

In addition to expanding the use of PLTL and JiTT, to target DFW rates in specific STEM courses. A call for STEM-oriented curriculum-and-instruction proposals seeking field-generated ideas that have potential to positively impact the program's scope was made to faculty. Those proposals rated most highly of having promise were funded with mini-grants. The mini-grants funded faculty to work on their proposals during the summer, and then to implement the curricular and instruction changes in the fall semester. Eight such proposals were funded.

Results

The Central Indiana STEM Talent Expansion Program has completed its fourth year of work. The primary goal of the project is to increase the total number of IUPUI STEM degrees awarded by 10% per year. The chart below shows the number of STEM students graduating by each discipline of S-T-E-M and total STEM graduates compared to the goal set for that year starting in 2008. It is clear that IUPUI was flat in its production of graduates from before 2004 to 2008. Then, the number of graduates per year increased by 10% from 2009 to 2012, then the number was flat for 2013. However, there was a more than 10% increase (12.6%) in 2012, which offsets the 2013 numbers. Therefore, the five-year cumulative has been a 10% increase per year.
The noticeable drop in the number of technology degrees from 2006 to 2009, was the result of agreements that transferred the associate degree programs to the community college. This had a disproportionate effect on technology that was not seen in the other STEM disciplines.

**Remarks and Conclusions**

The data show that the graduation numbers at IUPUI were flat for a number of years. The fact that the numbers began to rise in 2009, was due in part to administration, faculty, and staff awareness that: (1) the majority of the seniors were taking two and three years to graduate, making them at risk of not being retained; (2) nearly 55% of the first-year STEM students change their major to a non-STEM program after the first year; (3) faculty were complacent with the status quo of graduating the same number of students each year; (4) the DFW rates in many introductory STEM courses were the highest on campus; and (5) the faculty culture centered on research and provided little or no incentives to implement curriculum and instruction changes (specifically, changing from traditional lecture/passive learning paradigm to an active learning/student centered paradigm). Certainly, the positive rise in persistence to graduation at IUPUI after 2009, was due, in part, to CI-STEP initiatives.

**Lessons Learned**

There has been impact made beyond the intended goals of this program. These include: (1) an unexpected increase in socialization and networking opportunities among faculty in various STEM disciplines, and between faculty at other institutions and IUPUI. Faculty culture has also been impacted positively and as synergies were built among disciplines and with community
colleges, student success increased; (2) increased awareness of academic resources for faculty and students in STEM disciplines, which included an increased level of interest in studying trends on transfer students and an important element in closing the achievement gap and creating a seamless STEM pipeline; and (3) maintaining low student-to-peer leader ratios is critical for lowering DFW rates.

The most important lessons learned in increasing graduation numbers were: (1) start early getting department chairs support to encourage faculty to buy-in to STEM education and transformative pedagogies, which include reward structure and targeting specific faculty members; (2) evaluators need to work closely and early with each initiative because of the complexity of data collection and in order to make data driven decisions and identify best practices; and (3) stay focused on a single specific goal to determine the merits of adopting or adapting a best practice.

Conclusion

CI-STEP has been hugely successful, meeting its graduation goal for STEM students during its first four years. The increase in the graduation numbers have occurred from retention and persistence interventions, and not from increased recruitment of students. The vast majority of these interventions are now sustained by the departments and schools on campus. This sustainability becomes built into a departments’ budgets based on data-driven evidence that retaining more students in the STEM pipeline to graduation more than pays for the intervention. Although, without increased recruitment of STEM students, a point of diminishing returns will eventually be reached as the leaks in the pipeline are addressed. Therefore, future activities will include STEM outreach activities and experiences for high school students to enter the pipeline.

References


