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Campus STEM Innovation from a Foothold in Mathematics: Lessons Learned from a Place Where it Happened

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Abstract

A metropolitan university, has had a productive journey in science, technology, engineering, and mathematics (STEM), which eventually led to a campus STEM priority, endowed STEM Community Chairs, an increase in external grants, disciplinary degree pathways for high school teachers and even a Citywide STEM Ecosystem organization. Much of this journey surfaced from collaborations originating in mathematics education, which then synergized into campus wide efforts. This article describes one campus' journey into STEM and how transforming the mathematics teacher education program represented a "springboard" for formalizing STEM collaboration and innovation. It is offered to aid other institutions who want to make STEM more of a priority on campus and to assist in their institutional journey toward a collaborative STEM effort both on and off campus.

Introduction

For universities, there continues to be a critical need for workforce pathways into STEM careers, with the U.S. Bureau of Labor Statistics reporting that the number of jobs in STEM areas will steadily increase by an estimated 1 million jobs from 2012-2022 (Bureau of Labor Statistics, 2014). Many of these jobs will require sophisticated uses of computers, and it is estimated that nearly 71% of all new STEM jobs will be computing-related within an interdisciplinary context (Chen, 2013). The need to produce college graduates with expertise in STEM fields is imperative for the United States to compete in the world market. The Committee on Prospering in the Global Economy of the 21st Century released findings that indicated schools must take action in order for this to happen. Hanuschek (2005) asserted that long-term economic gains could result from improvement in school systems. Additionally, the National Commission on Mathematics and Science Teaching for the 21st Century reported in Before It's Too Late (2000), "that the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically" (p.4). The critical lack of a strong technical workforce can also be traced directly to poor K-12 mathematics and science instruction (Bybee, 2013).

While universities are continuing to ramp up STEM pathways to create just such jobs, they also have to be concerned about the readiness of high school students entering the universities for these STEM related courses and to work with their communities to build coursework pathways from high schools to colleges (Pike & Saupe, 2012). The high school pipeline into STEM careers is an important consideration for both P12 schools and universities. In the U.S., high school students rank 27th in science readiness and 35th in mathematics readiness among industrialized nations (National Center for Education Statistics, 2015). Many state educational systems struggle in terms of student academic performance in science and mathematics (Traphagen & Traill, 2014). Currently, for example, in the state where our university is located only 72% of K-12 students are proficient in science and the same statistic (72%) represents their overall proficiency in mathematics (Department of Education, 2015). Cumulatively, only 42% of graduating seniors in our state are ready for college STEM content courses as identified by ACT statistics (American College Testing, 2014). The Midwestern university discussed in this paper currently prepares nearly 60% of the new teachers for its metropolitan area and many local districts are in a constant search for teachers in the STEM areas, with unfilled in STEM positions each year.

This lack of readiness certainly impacts students' success in university STEM related programs; therefore, a focus on STEM teacher preparation can proactively help to address STEM workforce challenges as students grow into these educational pathways. In this paper, we provide a detailed case study of one university's creation of a successful interdisciplinary STEM pathway inspired and modeled after mathematics education initiatives. The authors' experiences are highlighted within the case study by collectively reflecting upon the journey using copious notes from the case study's progression.

Background and Context

STEM: Breaking down silos

Universities are trying various strategies to help break down some pretty entrenched silos that represent the individual STEM departments (National Academies of Science, Engineering and Medicine, 2016b), in order to be more representative of the collaborativeproblem solving environments common to the STEM workforce. Many researchers have thus identified that STEM educational pathways need to be more reflective of the workplace (Dostis, 2013; Hoachlander &Yanofsky, 2011; National Governors Association, 2011) and to help students to practice problem solving, inquiry, and team work within an interdisciplinary and project context. For faculty and students alike, the understanding of the interdisciplinary aspects of each content area can produce more relevant and connected learning experiences for students to later apply to interconnected workplace environments.

Mathematics as the center of change…again

In many ways, mathematics is the language that crosses all STEM disciplines, and has for many years, as science, engineering, and technology departments (such as computer science), have recognized the importance of a solid mathematics background in their programs. This "language of STEM" recognition was certainly the case at our university, and the mathematics department was well known for supporting various interdisciplinary efforts, where for example work between biology and mathematics departments led to new coursework that crossed those two disciplines. This campus recognition helped the mathematics department to become more interdisciplinary, by eventually hiring various interdisciplinary specialists, such as in mathematical physics, combinatorics, scientific computing, data visualization, biomathematics, dynamical systems, statistics, and specialists in mathematics education. In many ways, this allowed the mathematics department to build natural liaisons to other departments and to become a foundation for later STEM collaborations and institutional pathways.

The mathematics community, as a discipline, is not new to innovation in education. For example, the National Council of Teachers of Mathematics (NCTM) was the first national content-specific organization to identify a need for curriculum standards. In the 1980's, NCTM published an "Agenda for Action" after two decades of attempts to reform mathematics instruction and curriculum across the country. The recommendations in the agenda were the result of information gathered through surveys of many sectors of society, representing both lay people and professionals. The following is a summary of those recommendations:

- Problem solving should be the focus of school mathematics.
- Basic skills in mathematics should be defined to encompass more than computational facility.
- Mathematics programs should take full advantage of the power of calculators and computers at all grade levels.
- Stringent standards of both effectiveness and efficiency should be applied to the teaching of mathematics.
- The success of mathematics programs and student learning should be evaluated by a wider range of measures than conventional testing.
- More mathematics study should be required for all students and a flexible curriculum with a greater range of options be designed to accommodate the diverse needs of the student population.
- Mathematics teachers should demand of themselves and their colleagues a high level of professionalism.
- Public support for mathematics instruction should be raised to a level commensurate with the importance of mathematical understanding to individuals and society (NCTM, 1989).

NCTM followed this agenda with the launching of the first standards-based education movement in 1989. They released the Curriculum and Evaluation Standards for School Mathematics as an unprecedented initiative to promote systemic improvement in mathematics education. Colleges and universities throughout the country considered how they could join in this movement and respond with high quality mathematics teacher education programs. At the time, the university represented in this case study was well-poised to take on the challenges and opportunities of the reform climate. Various timely hires in key positions to create change through powerful collaborations occurred in conjunction with the national reform efforts. A close relationship among the four new faculty hires (two mathematics education professors; one mathematics teacher educator; and one mathematics professor) established a proactive avenue for communication and set the stage for productive change efforts in mathematics education and teacher preparation; later influencing campus-wide STEM initiatives.

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Context of the study

The case study university described in this study is a metropolitan university (a university located in an urban area with the mission of educating its urban citizens). In this context, STEM crosses considerable city interests and represents an opportunity for citywide innovation and leadership. The interdisciplinary nature of STEM and the need for close partnerships both within an institution and within its community make STEM a challenging endeavor for many universities across the nation (National Academies of Science, Engineering and Medicine, 2016b). The partnership described in this paper between the mathematics and teacher education departments involves faculty with deep understandings of both mathematics and teaching. Working together, they created initiatives and programs to produce highly qualified mathematics teachers. At our university, these past STEM successes have strengthened our existing learning strategies and inspired new innovative STEM educational models in research, teaching and service opportunities.

Maintaining a balanced focus between strengthening the core disciplines of STEM while also supporting interdisciplinary STEM initiatives and efforts have continued to be important. In this context, it evolved that the campus would mainly focus on STEM innovations for student learning and particularly associated with student success in P16 pathways into STEM careers, including P12 teaching. Thus, it was felt that the scientific research elements of STEM at our university would also be served by strengthening the overall P16 STEM pipeline and developing a more effective STEM learning environment. An improved STEM learning environment is thought to provide increased opportunities for engaging STEM undergraduates, graduates, and community partners in teaching, research, and service, thereby facilitating the broader impacts of STEM for our metropolitan area, state, and nation.

The journey into prioritizing STEM at our university was certainly not immediate, but most importantly it was wanted by the faculty members. Like STEM on many university campuses across the country (National Academies of Sciences, Engineering, and Medicine, 2016a; Grandgenett, Edick, Boocker, Ali, Hodge, Dorn, Cutucache, 2015, Business-Higher Education Forum, 2013), the reforms, collaborations, and innovations, came from many different faculty members and administrators, that essentially reached out to each other to build trust and shared efforts. Being a metropolitan university, the STEM efforts were also synergistic with the campus mission of transforming and improving the lives of the community. Such work eventually led to a campus STEM priority in 2010, a STEM community chair model for that same year, a STEM strategic plan in 2013, numerous external grants, and a 2015 STEM Citywide STEM Ecosystem effort (led by the university) and eventually, various national awards, such as the 2016 Kellogg Foundation Exemplary Project award from the Association of Public and Land Grant Universities. The mission of a metropolitan university is typically situated within a context of their community and many of our steps toward STEM as a campus priority and strength certainly took that into consideration. The next section talks about these structures and their intermediate steps over time that helped our university to embrace STEM as a campus priority, which also benefited from a wide range of individuals (faculty, administrators, staff, and community) that contributed various ideas and efforts to support such interdisciplinary work.

The University's Journey in Mathematics Education and STEM

It all began in the 1980's when our university started teaching the algebra coursework in a Math Lab (a computer laboratory using computer assisted mathematics software). The mathematics department's first mathematics education faculty member was hired to lead this initiative. The initial format of the Math Lab was individualized instruction in mathematics, facilitated by graduate students and undergraduates. The primary mode of instruction was through tutoring and individual assistance. Throughout the 90's, the instruction changed, under the leadership of the mathematics education faculty member. The need for good instruction in algebra was evident. Small group instruction appeared to bring more attention to the students and to their understanding. Graduate students were trained to deliver small group lectures. Individual tutoring supplemented the group instruction and was available to students throughout the week. Data were collected and revealed that among factors examined, attendance in the Math Lab was the greatest predictor of success for students in the Math Lab. Variables examined were ACT math subscore, and the Mathematics Placement Exam (Mathematical Association of America, 1977). For the sample in this study, the resulting regression equation accounted for 42% of the variance in course grade and indicated that students who earned full attendance credit (attending class each week), the course grade is likely to be at least a C (Rech, Stephens, & Buchalter, 1989).

Most students at the university are required to take algebra as a degree requirement, thus the impact on numbers of students was great. However, the need to utilize the expertise of the faculty member was greater in the area of mathematics content courses for elementary teachers. The Math Lab continued to exist, but the faculty member's assignment was shifted to delivering and developing the courses for prospective teachers. If reform in mathematics education was to take place, it appeared that the changes had to begin with the teachers. Ball (1996) found that if teachers lacked content knowledge, they were not able to carry out educational reform. The focus of the mathematics education faculty was clearly now the mathematics content coursework for future and practicing teachers.

Also, in support of this mathematics education faculty member's role shifting was 1999 research published by Liping Ma. Ma (1999) shared groundbreaking research on teachers' understanding of mathematical concepts. Her book, "Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States" reached sales of 64,000 copies my mid-2007. Her findings caused faculty and researchers at colleges and universities across the country to examine the mathematical preparation of elementary teachers. It has been argued that her book "arrived at a time when both mathematicians and mathematics educators had begun to work together to understand the problems of mathematics education." (Fang and Paine, 2008, p. 196). This was also true at our university. As a result, new coursework was developed for future elementary teachers. Additionally, a second mathematics education faculty member was hired in the mathematics department. The initial impetus for the additional faculty was certainly the focus on the elementary curriculum. However, the efforts quickly expanded into all areas of mathematics education and eventually STEM education.

After the elementary coursework was developed and evolved, focus naturally went to the coursework for middle school and secondary school teachers. Courses focusing on the conceptual understanding of mathematics taught in the K-12 schools were soon initiated for these future teachers. The courses were developed specifically for preservice teachers. Based on positive experiences working with preservice teachers, the need for similar courses offered at the graduate level became clear. Required coursework for graduate students, who were current mathematics teachers, and who could pursue a Master of Arts for Teachers of Mathematics were then developed. As a result, a sequence of courses were designed to enhance the conceptual understanding of mathematics taught at the high school level. The coursework is both challenging and engaging, and it often results in teachers seeing mathematics in a new light.

One of the official interdisciplinary organizational first steps, was a "Content and Pedagogy" committee which evolved in 2004. It was established jointly by the Dean in the College of Education and the Dean for the College of Arts and Sciences who sought to coordinate initiatives that involved mathematics and science teacher preparation, as well as graduate courses for teachers. This was relatively innovative at the time, since it involved interested faculty members and chairpersons in the mathematics and science departments meeting monthly with faculty in the department of teacher education. The group was particularly tasked with looking at teacher preparation in a more collaborative way, and especially, in discussing ways to make coursework for teachers, as appropriate and as innovative as possible. This joint committee was a first step in many ways, in building collaboration and trust across two colleges, which would eventually lead to the trust needed to expand into other colleges and act as a successful springboard into interdisciplinary STEM discussions years later.

The journey to excellence in the preparation of STEM teachers has not been a solitary one. Collaboration with other universities led to the development of a statewide system initiative in mathematics and science instruction in the 1990's. The initiative was part of a national program aimed at developing strong networks of organizations of individuals and institutions all working toward enhanced opportunities for students in STEM fields. This metropolitan university was well-poised once again to engage with a variety of agencies and institutions within the area to create more well-organized and synchronized efforts in STEM education. These efforts led to the engagement of key personnel in leadership positions in STEM education at the national level.

An extremely positive outcome of the systemic initiative was the relationship established between the university and a local community college. The strong individual connections between faculty at the two institutions became the seeds for several citywide mathematics and science efforts. The ability to reach underserved populations was provided by the community college. This enhanced the ability of the university to serve the entire metropolitan area, specifically in the vital area of STEM. These efforts were the precursor for the STEM ecosystem developed that now serves as a national model.

With the numerous programs in place and the commitment to improve mathematics education at all levels, the university awarded the mathematics department a "position of excellence" in elementary mathematics education. The governing body of the institution was keenly aware not only of the vital need for highly qualified mathematics teachers, but it was also aware of this department's ability to meet that need. After an aggressive search, the mathematics department successfully completed those efforts with the hiring of a mathematics educator with an emphasis in elementary education. However, the ability of the mathematics department to be awarded the position of excellence was only realized due to the ongoing cooperation between mathematics educators in the teacher education department and the mathematics department. A team was clearly developing to meet the challenges of creating a strong mathematics teacher preparation program. The teacher education department and mathematics department were true leaders at the university in demonstrating the results coming from a strong and focused partnership. Their pioneering efforts resulted in grant awards, new program development and new course offerings.

One of the STEM related initiatives that surfaced at our university to make STEM and a Campus STEM Priority a reality was an approach that helped to establish a formal mechanism for such leadership, called a Community Chair. The idea came from a local donor, who was originally a mathematics faculty member at our university. In 2010, he approached the Deans in the Colleges of Education and the College of Arts and Sciences with an idea for a new type of leader for the newly established STEM Priority (also established in 2010), that he thought had the advantage of being able to provide leadership across departments and the community, rather than in the context of traditional department chairs currently leading particular departments. His late wife also had been an elementary teacher and he further realized that tremendous impacts for K12 education that could result from universities preparing teachers more collaboratively across departments. He thus donated money to the university to endow a STEM Community Chair, which would be based in the College of Education, but would lead interdisciplinary work across STEM departments. In 2011, he founded a second Community Chair in Mathematics, to further build a basis of STEM collaboration. As established, the Community Chairs receive a significant stipend, operational budget, and reduced teaching load, in order to lead joint initiatives. The model then led to further STEM Community Chairs, including two additional ones in 2014, one in Science (primarily Biology), and one in Computer Science (by Union Pacific). An additional Community Chair in the Physical Sciences was now hired and is based in Physics and began work in 2018. Other disciplines followed suit, and there are a total of 11 Community Chairs across the university, including areas such as Entrepreneurship, Early Childhood, Biomechanics, and Human Rights. These faculty members have focused responsibilities for building collaborative initiatives and set goals both individually and collectively across colleges and the community.

The addition of the Community Chair in the mathematics department complemented the mathematics educators already in place. They now constituted a true team of mathematics educators whose academic "home" was the mathematics department. Focused efforts were immediately undertaken. The previous faculty position was created to develop and strengthen the program for preparing elementary mathematics teachers. The endowed community chair position complemented those efforts, with focus aimed at the increased quantity and quality of secondary mathematics teachers, along with enhanced engagement with community partners.

A teaching method utilized to entice undergraduates to become mathematics teachers was the use of inquiry-based learning (IBL) in the calculus sequence. Rather than showing facts or a clear, smooth path to a solution, in an IBL classroom, the instructor guides students via well-crafted problems through an adventure in mathematical discovery (Kogan & Laursen, 2014). The United States calculus study (Bressoud, Mesa, & Rasmussen, 2015) suggests that the calculus sequence may be the ideal place to provide future teachers with such learning experiences. The Community Chair had extensive experience with IBL in a mathematics classroom and was able to partner with a faculty member who had been using similar techniques with Advanced Placement Calculus teachers. The collaborative efforts between the two faculty members resulted in a two-semester sequence of classes for calculus students with active engagement of students. Students that previously had not declared mathematics or mathematics education as a major are now doing so. The use of IBL instruction has extended to other classes in the mathematics department. More students are being exposed to this student-centered mode of instruction and realizing mathematics can be far more engaging than they previously were aware. Inquiry-based learning in calculus has been shown to be effective, not only with traditional students, but also among first-generation and minority students. (Deshler, Miller, & Pascal, 2016). The faculty are now becoming national leaders in IBL instruction. Connections with faculty at other universities and national networks of IBL instructors and firmly entrenched. Original instructional materials for the classes are being developed with the goal of national dissemination.

Other STEM disciplines are becoming increasingly aware of the impact of IBL in the classroom. The engagement of students with content-specific materials resulting in greater enjoyment and achievement of the subject is a goal for all STEM faculty. IBL training sessions for faculty were presented and faculty from other departments were involved. The outcome of these efforts is a student-focused educational experience in a variety of STEM fields.

The University Journey Expands to STEM as a Campus Priority

The mathematics education "team" was constituted with three faculty in the mathematics department and two in the teacher education department. The expression "There is strength in numbers." was exemplified by this team. These joint efforts resulted in increased grant acquisition and outreach activities. The focus on STEM become a campus priority, with the team leading the way. Clear evidence of the efforts is the successful grant application for a National Science Foundation (NSF) Noyce Teacher preparation program initially in mathematics (2014) and then a second one in science (2017). The $1.2 million awards allow the mathematics education team, as well as a science education team, to expand their efforts to recruit and train future teachers to become teacher leaders.

An extensive mentoring program was developed through the Noyce program for our mathematics teachers (Hodge et al., 2019). We have IRB approval to study this program and report results to the academic community. The members of the mathematics team, as well as the science team, are now actively mentoring future teachers, meeting regularly and guiding them. The experiences afforded to the students in unmatched elsewhere on campus. Once again, the mathematics is leading the way in efforts that are being recognized at the national level.

The preparation of mathematics teachers is no longer the sole responsibility of the teacher education department. The silos that previously existed in the mathematics department and the teacher education department have broken down. Competition that once existed for student majors no longer exists. Great efforts were undertaken to create a more streamlined approach for students to double major in math and in teacher education. Across many campuses, there is competition for students and the notion that teacher preparation is only the interest and business of Colleges of Education. Those myths are being expelled at this progressive institution. The result is a seamless program for students - one that encourages them in mathematics and education. All members of the STEM community should be actively engaged in the development of strong, dedicated, knowledgeable students. These students are the future - not only as scientists and practitioners in STEM fields, but as the leaders in the classroom and in the community. The partnership that has been formed at this university in many ways represents a "functional gold standard" for other departments. The journey for those in the STEM fields is one that requires extensive collaboration. As members of a team at the forefront of these efforts, the mathematics education team has epitomized the level of collaboration needed. The numerous positive outcomes to date provide a glimpse of what can happen when faculty cross boundaries of colleges and departments. STEM fields hold the future for our society. The future is bright when faculty step forward to lead and join efforts for the betterment of students and other constituents.

Summary of Lessons Learned

As we continued on our campus journey from a foundation of mathematics education to STEM as a Priority and strong presence on campus, we realized various "lessons learned" along the way. Here are eight lessons that we have grown to understand and now share and that has grown out of our experiences. There is no "correct order" in which to follow the lessons learned. Instead, we suggest to engage with major stakeholders in STEM at your institution and decide which of the lessons you can springboard from to make lasting changes at your university. For us, it was all about cross-campus collaboration and welcoming an education specialist in the content department that could help promote these collaborative efforts. We suggest you read all of the lessons and prioritize them in an order that is right for your university.

Lesson 1: Education Specialists are Critical in Content Departments

We have realized during on our own campus journey toward STEM that education specialists are critical within STEM content departments, not only to share the important content and pedagogy preparation for K-12 teachers, but also to help to guide educational innovations within particular disciplines. For example, once the Computer Science Department was able to hire an educational specialist (the Computer Science Community Chair) they were able to not only build their program for serving teachers that involved a supplemental endorsement and M.S. in CS Education for teachers, but to also create new innovations in introductory computer science, by creating various instructional flavors (based on career paths) for introductory computer science. Once a strong educational voice and expertise was resident in the department, the faculty felt comfortable in trying to initiate and to pilot various educational reforms.

Lesson 2: Be Responsive to "Moments in Time"

We have certainly used various opportunities to expand STEM efforts and initiatives on campus, and many were tied to external funding opportunities that seemed correct for us at a particular point in time. For example, we were able to secure NSF Noyce awards for enhancing the undergraduate pathways for preparing K12 teachers in the STEM discipline and several NSF ITEST awards were achieved for teacher institutes related to teaching STEM content to teachers at the graduate level using robotics, wearable technologies, and mobile technologies, based upon the interests and strengths of STEM disciplinary departments. At the time of this article, there are now nine NSF awards actively underway for STEM education and student support. We would frequently review new NSF calls for proposals and see if they were a good fit for our current interests and strengths, and we were often successful in identifying those, applying and operationalizing them, increasingly engaging various faculty members across colleges.

Lesson 3: Share Teacher Preparation across Colleges

One of our most important suggestions is one that certainly took internal meetings and conversations at both a faculty and college administrative level. The effective-preparation of K12 teachers of course takes both content and pedagogy contributions, with often Colleges of Education driving the pedagogy related process, and Colleges of Arts and Sciences contributing content coursework. Due to a very strong relationship between the Deans of the two colleges at our institution, there emerged an extended conversation on innovations in coursework where content and pedagogy were combined at times, and in particular, content coursework also included innovative pedagogy, and pedagogy coursework included strong content connections or a flexibility for content. This helped some very specialized courses to emerge, such as courses for elementary mathematics which focused on deep conceptual understanding of the mathematics taught in the elementary classroom, as well as specialized science courses for elementary pre-service teachers. For example, a specialized science course is taught for teachers on prairie ecosystems, a key elementary science topic in our local schools, and it is offered at a newly restored prairie and science facility for the campus.

Lesson 4: Be Inclusive

STEM is certainly about breaking down institutional silos, and we worked diligently at our institution to work across STEM departments but also not to build a bigger silo represented by STEM itself. We set a tone on our campus that everyone was welcome at STEM meetings and that STEM concepts were important across many different disciplines including areas not historically considered as STEM. For example, a business professor became an important collaborator and member of the STEM leadership team, as he began to champion STEM connections in his college. Eventually, the Chancellor designated STEM as a campus priority and would often talk about it being a full campus initiative rather than limited to selected departments or colleges.

Lesson 5: Embrace STEM as an Interdisciplinary Instructional Context

The importance of interdisciplinary STEM instruction is increasingly represented in the professional literature as a critical contribution to modeling workplace environments for students (Hoachlander and Yanofsky. 2011; Traphagen and Traill, 2014). In our institution, we also worked together across colleges to create a STEM prefix that is particularly useful for graduate coursework for teachers. Some very useful courses for teachers such as those for K12 engineering, are hard to recognize that they are appropriate for teachers. For example, several of our graduate courses in Aviation, Bioinformatics, and Biomechanics are for non-majors and are perfect for teachers, but on a transcript look like they are disconnected and inappropriate for a science teacher. With the cross listing of the STEM prefix, courses that both welcome and are seen as appropriate for teachers are more easily identified by potential graduate students. In addition, it is also easier to create interdisciplinary courses for teachers using the prefix, since STEM departments can then acknowledge that the course is for teachers (or a wider audience of graduate students), then say for their own majors, allowing more innovative STEM courses to be created and piloted.

Lesson 6: Collaboration is Essential in Making Forward Progress

Working with other departments is key in building a successful forward progress in STEM education programs. In order to collaborate, one must first build trust. The best way to build trust in collaboration is to collaborate. This may sound cyclic, but it is essential. To do this, start with a small goal that all parties involved are interested in achieving or with a small project. Once relationships develop and trust is established, you can work on larger goals that take more time/effort and that may require a greater risk but could bring about greater rewards. This collaboration could start with colleagues in your own department and could extend as far as working with other universities.

Lesson 7: Communication is Key

When engaging in such collaborative efforts, communication is key. It is vital that clear goals are established. All parties involved must feel as though they have a voice in the mission of whatever project or goal you are working toward. Put procedures and policies in place that all parties are comfortable with and meet regularly to ensure everyone stays on the same page throughout the process. Communicating well and regularly will also assist in the agenda moving forward more rapidly and also in the organization of such progress. At our university the Content-Pedagogy Committee was the forerunner of this strategy. The successes of that group led to the strong efforts and organizations within interdepartmental and intercollegiate STEM groups.

Lesson 8: Grants and Donors Bring Money and Money Brings Change

If you are able to get your interdisciplinary team to have small successes, you can in turn create a pathway to bigger changes. For our university, it was changes such as those made by a mathematics educator in the mathematics department that brought attention to how greatly things could improve with the dedication of one faculty member to a cause (in her case it was to elementary mathematics education). As delineated in this paper, each small change brought about a much larger and more significant change. Eventually, STEM was given a campus priority. This priority allowed faculty members to focus their attention on STEM, knowing they would receive recognition for their efforts. These efforts have brought (and continue to bring) millions of dollars annually in both grant and donor funding to the university. As we all know, money brings about change and focus on what we would like to change. Essentially, the success of our university's STEM progress was all about work development and progress through interdisciplinary communication and collaboration.

Final Thoughts and Conclusions

The journey for innovation in STEM education across our case study university has not been immediate, but it has been well worth the time and effort. These interdisciplinary efforts have resulted in stronger STEM programs and the external funding dollars to make these programs better and conduct research on their success. By following the example of the university described in this paper and fitting it to the specific needs of your country, state, and university, some elements may be catalysts for changing STEM education and teacher education at your university. This paper aims to serve as a reference for a wide audience including administrators, faculty, and those wishing to better understand institutional change in STEM education. We hope that other universities can use benefit from model to help change the stereotype of mathematics being a gatekeeper at their universities (Ross, Guerrero, & Fenton, 2016) to instead a pipeline into the increasingly important STEM disciplines (including STEM education). As stated at the beginning of this paper, there is a critical need for workforce pathways into STEM careers with the number of jobs in STEM fields that need to be filled continually increasing (Bureau of Labor Statistics, 2014). There is a great need nationwide for a well-educated STEM workforce. Both nationally and internationally, we as educators are needed to attend to this call. Most importantly, our students need us to be the change. Their futures depend upon it. We can make a difference if we put the time, research, and effort into it. Set goals and strive to achieve them with a collaborative team for mathematics reform can be a true springboard for STEM initiatives, and become a strong foothold for educational reforms across campus.

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