Using Regional Data Collection to Inform University Led Initiatives: The Case of a STEM Education SWOT Analysis

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ABSTRACT

According to the National Science Foundation (2006), science and engineering jobs are a growing sector of the United States economy, but the number of people earning science and engineering degrees has lagged behind the growth in science and engineering occupations. Increasing the science, technology, engineering, and math (STEM) pipeline in the Midwest is a vital part of increasing and maintaining its economic stature. This objective is perhaps more significant in a specific seven-county region located in a Midwestern state, as this region serves as a vital part of the state’s economy and accounts for 34% of the state’s workforce. According to the census data, this seven-county region is the most racially diverse area of the state, making it of particular importance to develop underrepresented students and professionals in the STEM fields. As such, this manuscript provides a critical analysis of the strengths and weaknesses of STEM programs, as well as an evaluation of potential threats to and opportunities for improvement concerning the recruitment and retention of STEM graduates and professionals in the seven-county region. Specifically, empirical data were collected from diverse constituencies and key stakeholders within the STEM community. Targeted participants included STEM professionals residing in and around the seven-county region of study.

Keywords: STEM-increase, K-16, Outreach

BACKGROUND

While postsecondary enrollment has increased over the past decade, the proportion of students obtaining degrees in science, technology, engineering, and math (STEM) fields has fallen. Approximately 519,000 students obtained STEM degrees in academic year 1994–1995, which represented 32% of all degrees awarded at that time. In academic year 2003–2004, approximately 578,000 students obtained STEM degrees, which represented 27% of all degrees awarded (GAO, 2006). When college and university officials were asked why STEM numbers are falling, they cited subpar teacher quality and poor high school preparation as factors that discouraged the pursuit of STEM degrees. In an effort to combat this issue of STEM enrollments and our global competitive advantage, Congress in addition to establishing new grants to encourage students from low-income families to enroll in STEM fields, established an Academic Competitiveness Council to identify, evaluate, coordinate, and improve federal STEM programs (GAO, 2006).

The federal government is very much invested in providing corrective measures to increasing STEM participation. In fiscal year 2004, the federal government spent approximately $2.8 billion to fund over 200 programs designed to increase the numbers of students in STEM fields and employees in STEM occupations, and to improve related educational programs. The National Institutes of Health and the National Science Foundation account for nearly 50% of all programs. Moreover, women now outnumber men in college enrollment, and minority students are enrolling in record numbers at the postsecondary level. To the extent that these populations have been historically underrepresented in STEM fields, they provide an untapped source of STEM participation in the future. Therefore, the United
States in general, and this region of interest in particular, can benefit from tapping into this untapped source and building a strong STEM workforce within the region.

In response to the state of STEM affairs, a private mid-sized research university established a Regional Task Force on STEM Education to conduct a SWOT analysis in efforts to provide an environmental scan of the readiness of the region to be reframed as a STEM Corridor. The overarching goals of the SWOT analysis were to understand how to: (a) boost student participation in STEM at all educational levels in the region; (b) increase STEM participation in order to bolster industry hiring in the region; (c) convince more STEM graduates to stay as well as attract STEM professionals to the region; and (d) gain a greater understanding of the activities or initiatives that help cement a cooperative relationship among STEM organizations in the region.

**METHOD**

A qualitative inquiry is appropriate for the study of a phenomenon for which researchers have very little previous empirical knowledge (Shank, 2002). Creswell (2002) stated more eloquently that “qualitative research examines a research problem in which the inquirer explores and seeks to understand a central phenomenon” (p. 52). Within this context, an exploration means that little is known in the literature about the phenomenon and the researcher in turn will use data from participants to develop foundational knowledge. In order to achieve this goal, it is often recommended to employ a comprehensive interview protocol using open-ended questions (Brenner, Brown, & Canter, 1985; Flowers & Moore, 2003; Rubin & Rubin, 1995). This study utilized the internet to collect qualitative data.

The internet has become a popular medium for finding, retrieving, and exchanging information for use in research (Crossman, 1997; McFadden, 2000). More recently, researchers (e.g., Flowers & Moore, 2003; Moore & Flowers, 2003) have described the usefulness of the internet for collecting qualitative data. Specifically, Flowers and Moore (2003) found that the benefits of collecting qualitative data on the internet were increased efficiency and accuracy by eliminating the time needed to transcribe audiotapes. This study employed e-mail interviews for data collection. Creswell (2002) states: “E-mail interviews consist of collecting open-ended data through interviews from individuals using computers and Web site or the Internet” (p. 207). This approach is recommended when you need to collect data from a geographically dispersed group of people. Accordingly, e-mail interviews were deemed appropriate for this study.

**Data Collection**

Research data were collected through the use of e-mail interviews. The e-mail interviews were administered via electronic mail and a web-based data collection site. To develop our pool of participants, we sent e-mails to STEM professionals in the region requesting names of appropriate individuals for this study. Upon receiving the names, each potential participant was sent an e-mail explaining the purpose of the study and assuring confidentiality. The e-mail requested participation in the study and included a direct link to the data collection website. If the individual agreed to participate, the link would take them to the e-mail interview protocol. The e-mail interview protocol typically took approximately 20 minutes to complete. This data collection process yielded 192 completed e-mail interviews, out of 350 requests for a 55% response rate.

**Data Analysis**

Using Conrad’s (1982) constant comparison method, emergent themes were analyzed after all data were submitted to the web-based data collection site. Themes of particular interest to the
researchers were those associated with elucidating the research questions for this study. These themes were labeled and described independently by the researchers. These themes and their descriptions were then cross-verified by the researchers together, re-labeled, and defined. Each researcher then re-examined the original transcripts for separate verification of the presence of the emergent themes. Original transcripts from these data were extracted as supportive evidence for the existence of each theme. The researchers together combined findings from the separate analyses to produce a final description of each theme, along with their properties and dimensions.

**Participants**

Participants were 192 STEM professionals employed within the region. Because there is little research on this group of professionals within this specific region, it is difficult to assess the representativeness of our sample. Given the nature of the STEM community within the region and the severe underrepresentation of racial and ethnic minorities, only 20% of the respondents to the survey identified as racial and ethnic minorities (e.g., African American/Black, Asian or Pacific Islander, and Hispanic or Latino). The remaining 80% self-identified as White (i.e., not of Hispanic origin). When examining gender of the professionals in STEM and STEM related disciplines within the region, 57% of the respondents were male while 43% of the respondents were female. Participants were treated in accordance with the “Ethical Principles of Psychologists and Code of Conduct” (American Psychological Association, 2002). No participant names or other identifying characteristics were used in reporting the results of this study.

Approximately 55% of the respondents obtained their degrees outside of the 7 county region under study, and approximately 74% earned degrees within STEM or STEM related disciplines. Accordingly, Mathematics, engineering, chemistry, physics, and nursing were among the most frequently reported disciplines. Additionally, the participants earned their degrees from a variety of institutions, both within and outside of the Midwestern state under study. The institution types ranged from community and technical colleges, to public, private, and research universities.

**Protocol**

An E-mail Interview Protocol for STEM Education in the region was developed to examine this phenomenon. Items on the e-mail interview protocol were based on a comprehensive review of the literature addressing STEM education and professionals. The aim was to ensure that data were collected on STEM education in the region in order to perform a SWOT analysis. For the most part, the e-mail interview protocol consisted of open-ended questions (except for demographic information) and was arranged in the same manner the researchers would have asked in-person. The e-mail interview protocol is divided into four sections: (a) demographic information; (b) STEM educational opportunities; (c) strengths and weaknesses of STEM education in the region; and (d) opportunities and threats for STEM education in the region.

**FINDINGS**

**Employment Categories**

Of the professionals in STEM and STEM related disciplines within the M7 region that participated in the study, respondents to the survey were categorized within nine employment sectors. There were 192 survey respondents, and approximately 80% were categorized within the education sector—which included higher and continuing education, K-12, distance learning, and extension services within local communities. The second largest concentration
of categorical participation was the health sector. An overwhelming majority (i.e., 96%) of the respondents currently works in a STEM or STEM related discipline. Among these disciplines, those that were the most prominent among respondents were: (1) technology education; (2) engineering; (3) mathematics education; (4) computer science; (5) computer security and systems analysis; (6) nursing; (7) media/broadcasting; (8) chemistry; (9) biotechnology/biomedical research; and (10) medicine.

STEM Organizations/Programming: Strength
When asked to comment on existing relationships among STEM organizations in the M7 region, only 43% of the respondents were knowledgeable about such efforts. The general consensus among those who were knowledgeable was that the STEM relationships were cooperative and substantive in nature. Specifically, respondents were careful to note the strong nature of established relationships among the public school system, the Technical College system and other higher education institutions in the 7 county region, and industry affiliates. One respondent shared, “(the public school system) has been developing relationships for quite some time with business and higher education to improve the educational opportunities in STEM for K-12 students. The partnerships are deep and meaningful.”

The 7 county region has a commitment to providing educational opportunities in STEM for students throughout the pipeline. A shining example of this commitment, as indicated by many of the respondents, is Project Lead the Way. Other programs that were mentioned are Upward Bound, INROADS, the Minority Engineering Program at two key universities in the region, and other articulation agreements between the Technical Colleges and postsecondary institutions located within the region. Programs like Project Lead the Way are successful because they are offered at the middle and high school levels and connect K-12 with higher and continuing education programs within the 7 county region.

As previously mentioned, there are several STEM program initiatives in place to increase the number of STEM students and graduates (e.g., Project Lead the Way, Upward Bound, INROADS, and the Minority Engineering Program). Respondents reported that these initiatives and programs, by and large, have made gains toward increasing the number of students in the STEM pipeline. Of the 49% who were aware of existing STEM programs efforts in the region, approximately 67% of the respondents indicated that these initiatives are efficient in form and capacity.

STEM Organizations/Programming: Weakness
Although the 7 county region has a strong STEM network/infrastructure, there is minimal evidence to show that collaboration among STEM organizations (non-partnership arrangements) are prevalent. Indeed, communication is often non-existent within and among the 7 county’s STEM organizations. As noted by several of the respondents, communication and transparency among different STEM organizations is an integral component of the region’s efforts to reposition itself as a major player within the industry. According to one respondent, “The relationships between the organizations could be better. There needs to be better coordination.” Another respondent offered the following: “I believe that there are strong partnerships, but the community has tended to ignore partnerships already in place and prefers to reinvent the wheel.”

In general, respondents felt that the size and scope of these STEM programs were a major weakness, and therefore needed to be expanded and enhanced. As with any major initiatives, there is always need for progress and improvements. Respondents provided a multitude of suggestions to help sustain and increase the progress that has been made concerning STEM recruitment and retention of students and graduates in the region: (1) expand Project Lead the
Way and other engineering education programs; (2) integrate STEM subjects across the curriculum at K-12 levels; (3) incorporate industry supported work-based programs and youth apprenticeships; (4) offer more competitive graduate school packages to STEM students of color with a built-in incentive package to stay in the 7 county region upon receipt of a STEM degree; (5) offer tax breaks to STEM and development/research firms; (6) create an incentive package for firms that commit to hiring a specific number of STEM professionals/students of color annually; and (7) develop merit scholarships for top high school students with interests in pursuing a STEM degree at an institution within the region.

STEM Organizations/Programming: Opportunity

The 7 county region is poised to become a major player in the STEM revolution in large metropolitan areas across the United States. There are excellent housing and educational opportunities as well as job opportunities for STEM professionals. In addition, the region possesses a large public research institution and a medium-sized private institution with great potential to conduct advanced STEM research and attract high profile technology and development firms to the region. With its geographic proximity to other large metropolitan areas and Lake Michigan, it is a desirable place to live and grow as a STEM professional. By capitalizing on the geographic location, marketing the region as an urban hub for young professionals (especially professionals of color), highlighting key financial opportunities for investment and entrepreneurial growth, and devoting more targeted resources to the cultivation and development of both public and private universities as world-class research centers, the region can compete nationally with other large metropolitan areas where STEM professionals elect to work.

The region is not alone in its endeavors to attract and retain more STEM students and professionals of color. Indeed, it is a national priority, and federal agencies and private entities are all committing millions of dollars in the development of a pool of STEM professionals of color across the country. As such, the region has a unique opportunity to receive earmarked funds that are expressly intended to assist in this endeavor. By creating STEM pipeline programs that tap into the state’s talent pools and students attending HBCUs by way of summer research/intern programs at institutions within the region, the 7 county region can drastically increase the number of STEM professionals and students of color. This, of course, entails a concerted effort to recruit cohorts of students from institutions with a reputation of producing highly qualified STEM students of color (e.g., Tougaloo College in Jackson, MS and Xavier University in New Orleans, LA). It is important to note that there are also non-HBCUs with high concentrations of STEM students of color (e.g., University of Maryland Baltimore County, Meyerhoff Scholars Program) that might provide the region with an increased and steady flow of aspiring STEM professionals of color.

Many of the respondents developed an interest and deep desire to explore STEM subjects early in their education (i.e., junior high and high school, grades 8-10). What is especially encouraging about this finding is that educators, researchers, and policy makers now have a rough estimate of the time frame in which they can develop and cultivate interest in STEM disciplines in a student’s educational career. By targeting 8th, 9th, and 10th graders in the 7 county region (i.e., who are good in math and science and possess a natural curiosity about the world around them) and allowing them opportunities to explore STEM subject(s) within the context of a directed study class (which counts for high school credit or even college credit), it is highly plausible that the number of young citizens within this region who pursue a career in STEM or related disciplines will drastically increase over the course of the next 10 years. This will, in turn, create a steady flow of STEM professionals in the state, but more importantly within the 7 county region.
STEM Organizations/Programming: Threat

Although the quality of living and geographic location/proximity to other major hubs makes the 7 county region a desirable place, the cost of living coupled with low STEM salaries and a lack of diversity regarding STEM jobs makes the region a “death zone” for STEM students and professionals. Respondents were very candid in their comparisons of their city to other major hub centers along the east and west coast lines in terms of STEM salaries. The 7 county region is a non-competitor in this arena. Unless STEM salaries are increased to mirror industry salaries and STEM jobs are diversified to allow for a greater variety, the region will remain a non-competitor in efforts to attract and retain qualified and talented STEM students and professionals.

The region currently does not have a vibrant community of young STEM professionals of color. Emphasis is placed on young professionals, as many of the respondents addressed this issue in their comments and responses. In fact, respondents indicated that there is a severe lack of representation, and that the southeastern part of the state is continually losing potential pools of highly qualified, young STEM professionals/students of color to historically Black colleges and universities (HBCUs) in the southeastern region of the country. While the latter have reported steady increases among STEM alumni of color whom elect to stay in surrounding areas upon receipt of their STEM degrees, the 7 county region has reported steady decreases.

With regards to cultivating the STEM educational trajectory early on, failure to develop and cultivate interest in STEM disciplines during the specified time frame (i.e., grades 8-10) may result in further loss of potential pools of STEM talent. In addition, denial of opportunities for exploration along with an incentive package (i.e., directed study for high school or college credit) of STEM disciplines early on might curtail the general interest in STEM among students and, thus, further reduce the number of potential STEM professionals.

The region must emphasize retention as much as recruitment. “Brain drain” is as much of a concern as “brain gain.” Equal emphasis must be placed on both. Should the 7 county region fail to appeal and cater to existing STEM professionals and students, they will surely compromise their core efforts to revitalize the region and make it more STEM friendly.

CONCLUSION AND RECOMMENDATIONS

The findings of this study parallels national trends in the lagging growth of individuals earning STEM related degrees as compared to the growth of the science and engineering sectors within the U.S. economy. Likewise, a key component in addressing the weaknesses of STEM economic development within the 7 county region is directly related to education, or the lack thereof. This report echoes other economic studies that necessitate change starting with the K-12 education systems (particularly grades 8-10), relative to increased exposure and development in the areas of science, technology, engineering, and mathematical applications.

The STEM programs in place in the region are relatively small and are limited in their ability to increase their representation within academic or industrial circles by a lack of participation and communication about existing programs. In this study, only 49 percent of STEM professionals in the 7 county region were knowledgeable about existing STEM educational programming geared toward increasing the number of students and graduates within the STEM pipeline. Furthermore, only 43 percent of STEM professionals were aware of existing relationships among STEM organizations that focused on increasing the number of students and graduates within STEM related disciplines.

The need for increased participation and increased diversity within the STEM disciplines is critical if the region is to continue to develop and maintain economic competitiveness with
other large metropolitan areas around the country. Communication to the academic community about existing programs within the STEM disciplines is a key and heretofore underutilized component in increasing participation within the target areas. Because there is a major lack of collaboration and communication among STEM organizations within the region, the region cannot effectively maintain its position as an industry leader in STEM related fields. Communication and collaboration must be increased if the 7 county region is to capitalize on already established programs which increase educational opportunities such as the Project Lead the Way and the Minority Engineering Program.

RECOMMENDATIONS

This section offers eight recommendations for improving the STEM workforce in the 7 county region. The recommendations are organized into two categories: (1) Foundational Efforts and (2) Unique Opportunities. Foundational efforts are recommendations that are not likely to be viewed as new contributions regarding STEM discourse in the region; however, they are critical to establishing appropriate baseline efforts in order to move forward on proposed initiatives. Unique opportunities are recommendations that emerged from data collection and analyses that, if implemented, would likely poise the 7 county region as a national center for STEM education and workforce development.

Foundational Efforts: Recommendation One
Need to Increase the Number of Underrepresented Groups in the STEM Workforce in the M7.
The region should take specific steps to increase the participation of women and people of color in STEM within the region. This is a national problem and it affects the 7 county region as well; however, the region has a large pool of people of color that could be STEM participants if provided the proper incentives to pursue such careers. By leverage existing strengths in this area, appropriate steps could be taken to remedy this concern. For example, the private University in the region is a top producer of female engineers, especially in Biomedical Engineering, according to the October 2007 issue of ASEE PRISM Magazine. These current and former students could be strong advocates for recruiting underrepresented groups into Engineering. Establishing mentoring and scholarship programs for women and people of color to participate in STEM initiatives at all levels could be a logical extension of current efforts. These efforts should be done in concert with industry to offer internships, shadow and employee days, and other programs to underrepresented populations.

Foundational Efforts: Recommendation Two
The region needs to retain more of its STEM graduates.
A significant portion of the STEM graduates within the 7 counties leave the region after degree completion. Therefore, it is necessary to retain these graduates in order to avoid brain drain within the region. Offering incentives for graduates of the region’s institutions to stay in the region should be a chief consideration. For example, tuition discounts for those that stay in the region after graduation could be very appealing. More specifically, a forgivable loan program could be established whereby graduates could borrow up to a specified amount of money interest free for 4 to 6 years while they are in school. Upon graduation, 20% of the loan is forgiven each year they are employed within the region. If a graduate stays within the region for 5 years, their entire loan would be forgiven. After 5 years of employment within the region, these STEM professionals would likely be established both within their careers and the region. As such, leaving the region at that time would be less likely.
Foundational Efforts: Recommendation Three
Recruitment from outside of the region is needed.
Current dialog seems to only prioritize retaining STEM graduates; however, recruiting from outside the region is a key component to growing the workforce as well. In order to grow the STEM economy, it is necessary to attract STEM employees from outside the region. The 7 county region should recruit actively outside the region for both STEM professionals and students. This can be accomplished by attending job fairs at institutions outside the region. Additionally, the SWOT analysis suggest that focusing on the recruitment for STEM professionals of color could help to increase the overall size of the STEM workforce. For example, one approach would be to recruit from minority serving institutions in the South and Southeast regions (e.g., Tougaloo College, Spelman College, Florida A & M University, and University of New Mexico). It is essential that these recruitment efforts include people of color to create a familiar climate during the recruitment visit. It is also important that recruiters promote what the region has to offer prospective employees at work and within the community.

Foundational Efforts: Recommendation Four
STEM Education Needs to Start as Early as Possible: K-1.
STEM education needs to start as early as possible. Young children need to be exposed to and develop STEM skills during their initial years of formal education. This can be naturally fostered with young children because of their curiosity with “how things work.” This should be leveraged in the 7 county region to establish a STEM culture for young children. Train non-STEM pre-school and K-6 teachers on how to foster STEM thinking at early ages. For example, Dr. Jeannette Wing talks about computational thinking and the benefits of such thought processing (CACM, 2006). Computational thinking is STEM thinking and these processes can be fostered in children at early stages of their educational training by fostering the innate curiosity about “how things work.”

Unique Opportunities: Recommendation One
Need to Strengthen the Relationship between STEM Organizations.
Results from the SWOT analysis shows that the existing STEM organizations and programs in the 7 county region work and exist in silos. Essentially, STEM organizations within the region have very limited knowledge of each other’s programs and offerings. Likewise, the inventory database shows that there could be better balance between the programs across levels (e.g., education and sector) in order to foster a STEM program pipeline within the region. An eclectic and decentralized set of STEM programs exist from K-16 and beyond; however, no central or single entity has knowledge of the specific activities and initiatives for all the programs and their sponsors. Thus, no evidence of coordinated leadership for STEM programming in the region was found.

Accordingly, it is recommended that the region establish a STEM Federation that provides coordinated leadership for STEM programming. The STEM Federation would serve as a centralized incubator for both STEM innovation and career/professional guidance. A core activity of the STEM Federation would be an annual conference where all STEM organizations and programs would meet to share information. The STEM Federation should be composed of representatives from industry, education and existing programs. Their mission would be to maintain and facilitate knowledge sharing between STEM organizations and projects within the region.
Unique Opportunities: Recommendation Two  

*Need to market STEM programs in the region.*  

An emergent and key finding from the SWOT analysis was that the region needs to market STEM programs to groups (e.g., women and people of color) that are traditionally underrepresented in STEM professions. It is essential that the STEM programs get proper exposure in order to reach all members of the 7 county region. Using the STEM Federation, and/or industry and philanthropic organizations to establish a STEM marketing campaign is one strategy to achieve this goal. Resources such as public television programming (e.g., “Sports Science” and “How it works”) can be used to influence students’ perceptions and understanding of STEM. The underlining goal of these programs is to bring back the “coolness” of STEM. Innovations such as “edutainment” can be used inside and outside the classroom to help deliver and reinforce STEM subjects. There may need to be multiple campaigns that target different groups (e.g., adults and adolescents). These campaigns should use innovative marketing strategies that lure the targeted audience into STEM programs.

Unique Opportunities: Recommendation Three  

*STEM education needs to be a priority.*  

The nation suffers from a shortage of STEM teachers in K-12. There is a need in the nation at-large and 7 county region in particular to address the insufficient number of STEM teachers in K-12. The National Science Foundation has a program called the Graduate Teaching Fellows in K-12 Education (GK-12). This program provides funding to graduate students in STEM disciplines that are supported by the NSF. The program provides these students with additional skills that will adequately prepare them for scientific and professional careers in the 21st century. Therefore, it is recommended that the region create a similar program to fill vacant STEM teacher positions.

Unique Opportunities: Recommendation Four  

*Create a Research Institute for the Theory and Practice of STEM Entrepreneurial Wealth Creation.*  

In an effort to connect the STEM corporate community with the academic community, we are recommending the creation of a Research Institute for the Theory and Practice of STEM Entrepreneurial Wealth Creation. This Institute would be modeled after the IC² Institute at the University of Texas at Austin, (http://www.ic2.utexas.edu), with a few adjustments. This Institute would be housed at the local private or public research university. The Institute would create programs in entrepreneurship with an emphasis on STEM. For example, we recommend a Masters of Science degree in Science and Technology Commercialization. The program could also have incentives for graduates to create businesses within the region. Endowed Faculty Fellows would be created as part of the Institute as well. The Institute would conduct scholarly research in the areas of STEM entrepreneurship, commercialization, and innovation. Initially, the Institute will need a significant amount of seed money. The hosting Institution will be required to obtain funding from various sources at the State and local levels. The vision and purpose of the Institute is to create more STEM research, practice, and policies within the region.

In closing, it is important to actively and aggressively cultivate interest in the STEM disciplines from an early age by gaining students’ interest prior to their matriculation in and through the 10th grade. The region must market its strengths, minimize its weaknesses, and take advantage of its opportunities by sparking students’ interest while they are still young, cultivating their interest through pre-college, enrichment, internship and coop programs, and
finally, creating a welcoming environment that would retain and cater to individuals’ health, financial, and cultural needs. While the rest of the national economy is moving forward with regard to STEM related initiatives, the challenge that this 7 county Midwestern region will have to overcome is its slow implementation of the necessary components to ensure a successful STEM economy.

REFERENCES


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