Facilitating Collaboration Across Science, Technology, Engineering & Mathematics (STEM) Fields in Program Development

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Abstract

Collaboration plays a major role in interdisciplinary activities among Science, Technology, Engineering & Mathematics (STEM) disciplines or fields. It also affects the relationships among cluster members on the management team. Although effective collaboration does not guarantee success among STEM disciplines, its absence usually assures problems. More specifically, collaboration has the obvious roles of identifying talents coming together for a common purpose of combining knowledge and sharing responsibility, creativity, and experience of others. Facilitating collaboration across Science, Technology, Engineering, and Mathematics (STEM) fields in program development is critical to providing a strong educational foundation to all learners in STEM education. This synergistic effort among educators and other professionals across the STEM fields will enable effective knowledge sharing in program development. This paper addresses leadership and knowledge sharing among collaborators in STEM program development through facilitating collaboration across STEM fields.

Introduction

The recognition is growing in academics and business that collaboration can build a seamless support system across the STEM fields if well harnessed. For a powerful effect in bringing relevance and cohesiveness of STEM fields in program development, the pooling of ideas, resources, commitment and efforts of many is more effective than relying on the few best individuals in program development. This synergism among STEM collaborators will bring a shared understanding of contextual influences from their differing background to their programmatic efforts as well eliminating redundancy and overlapping that results in inefficient use of resources and the duplication of services (Melton, 2001; Gallagher, Clifford, & Maxwell, 2004). More importantly, facilitating collaboration across STEM fields will lead to a successful common goal in program development. While collaboration is the vehicle for combining and sharing resources among STEM fields, it is imperative to understand why collaboration should occur (Melton, 2002; Stowell, 2005). Consequently, it is important to note that collaboration enhances services, increases the quantity of resources available to serve clients or participating disciplines, increases better use of available resources, and increases the quality of available services. More importantly, it enables STEM disciplines to address their common interests and common goals in providing services to cluster constituents, increases opportunities for knowledge sharing and exchange (thereby increasing knowledge awareness, sensitivity and competence), and helps to view everyone as a resource.

An increasing number of jobs at all levels require knowledge of STEM. In addition, several reports have linked K – 12 STEM Education to continued scientific leadership and economic growth in the United States (SEDL, 2012). This new industrial revolution has made it imperative to prepare the present and future workforce with the required skills (soft and technical) and knowledge necessary to compete in the 21st century economy. While it is essential to prepare STEM program graduates with skills necessary to function in the capacity of a technologist, manager or supervisor in any organization that desires to implement emerging technologies, it is necessary for a faculty of STEM disciplines to work collaboratively to develop and propose courses that will enhance needed and necessary skills and experience in the industrial technology undergraduate program. Since hands-on activities of any course will be enhanced through prolific research endeavors, interdisciplinary research clusters utilizing the core research facilities in that institution will help prepare and put our graduates at the forefront of employment in the new industrial revolution.

More importantly, "educators and decision makers must continue to increase their understanding of various STEM education opportunities. They must also realize the need to establish support systems for diverse learners as they relate to STEM education, while at the same time recognize the economic impact of not moving in this direction" (SEDL, 2012). According to Marchand (2009) who reported based on a business academic's point of view from an examination of the way in which 169 countries, 37 funding institutions and 2,500 scientists worked together through effective collaboration, has given an insight into the benefits and characteristics of successful program development and leadership by collaboration. For such a diverse collaboration to produce incredible results, some potential barriers must be identified and broken.

Team Leadership and Management

According to Stowell (2005), a leadership skill development posited that "one of the most important things a leader needs to be able to do is to collaborate with his/her team members and create a culture where members value and listen to alternative views and seek out win-win objectives. This can be accomplished by clearly identifying common needs and objectives; and certainly should occur on multiple occasions over time." Establishing collaborative relationships is not always natural or easy, particularly because people have different lifestyles, backgrounds, and experiences (Stowell, 2005). Since scholars across the STEM fields differ in so many ways given their diverse backgrounds, and being leaders of their respective disciplines, leadership through collaboration and harmony must be fostered.

To this effect, participants in this collaborative effort must learn first–hand to participate without formal authority or bias based on discipline. There should be a consensus on who will lead and with the understanding of all members or participants on the fact that this designated person has no authority beyond that granted to him by the people who would work with him. However, he is recognized as the indisputable leader of the project, keeping all efforts on track to ensure that the collaboration garners the best out of its members. In this capacity, it behooves such a designated leader to bring everybody together, regardless of their field of specialization, not rock the boat, makes sure that everybody feels that they are part of the process with a sense of belonging, and be willing and able to encourage members with the weakest link in the group through motivation and gentle guidance. In this type of forum, the team's leadership style should be more about facilitating stewardship. This is an environment that encourages participation and ideas rather than dictating and directing project evolution (Marchand, 2009).

It is necessary to build consensus and harmony among the participants so as not to lose persons whose talent or financial contributions may be diverted else–where. Marchand (2009) further opined that decisions have to be taken on consensus; keep everybody, with an enormous diversity of skills on board. Without that camaraderie and commitment from participants, it is impossible with a top-down management system. What works is the ability of the leader to know how to collaborate and develop effective partnerships with others (Stowell, 2005).

To fully anticipate collaborative activity and diverse team success, such a diverse team needs emergent interdependence, meaning that members on the team must develop the desire and expectation to work interdependently for the benefit of the team's work (Caruso & Woolley, 2008). In addition, Chi-Ying Cheng, Sanchez-Burks and Lee (2008) proposed that reinforcing the compatibility between functional identities within a team facilitates access to functionally unique knowledge systems, which in turn increases team innovation and provides common ground to promote communication and collaboration among professionals working in STEM disciplines.

Rink and Ellemers (2008) posited a theoretical model to explain under which conditions different insights or approaches within a team do not necessarily undermine team cohesiveness or prevent the development of a common team identity, and can, in fact, reinforce each other. To this effect, they reviewed a program of research that examined the formation of a common identity in new collaborations, as well as the extent to which teams accept newcomers who possess unique resources. The outcome of their research showed that clarity and congruence determine the likelihood that team members will maintain a common identity while they effectively use the differences among them and accommodate to team changes. In this vein, junior faculty should be encouraged to participate in all activities. Even more active roles should be assigned at their early stage on board to discover quickly their potential and areas that they might need help on.

Knowledge sharing through research clusters

As we look at models for 21st century skills and the issue of competitiveness, it is clear that the integration of STEM fields will play an important role given that "groups of people from diverse functional areas become high-collaboration teams" (Jassawalla & Sashittal, 2006). The STEM collaborations signify a good, unified system that has many advantages of facilitating cooperation with little disadvantage. STEM is a unified project, and all the faculty members who are involved in this should help each other. There must be mutual understanding between the faculty members to break all of these barriers. Interaction should be fostered at different levels to make necessary improvements and to solve any problem that may arise between the members amicably so as to implement the collaboration in a disciplined manner. Since there should not be any kind of differences among these members, it behooves each and every member to cooperate and give their best to achieve and maximize the output.

More importantly, collaboration has to take place first at the local level of education and then move up instead of the opposite. It is suggested that departments can come together as clusters to initiate this effort. The potential of the individual members should be quickly identified, trusted respected and encouraged. It should be noted that the contributions of the individual may differ given the nature and knowledge about the project or program to be developed. Regardless, synergism should be fostered by tapping into the individuals' strength rather than focusing on their weaknesses. That is why brainstorming for creativity and new ideas and initiatives should be encouraged so as to pool knowledge. For example, highly interdisciplinary and relevant activities on new industrial revolution at Jackson State University (JSU) have synergized many disciplines such as physics, chemistry, biology, mathematics,

Cluster	*Cluster Subgroups*
Applied Computational Sciences & Engineering/High Performance Computing – This cluster investigates High Performance Computing Modernization	Computational Nanoscience, Molecular Electronic Structure/Computational Quantum, Chemistry Computational Engineering & Technology, Bioinformatics/ Genomics
Environmental Science & Engineering – This cluster conduct research on today's environmental problems and appropriately disseminating research findings.	Bio-Phyto Remediation, Environmental Toxicology, Environmental Impact Assessment, Industrial Waste Management/ Landfill Technology, Biomass/ Alternative Fuel/Renewable Energy, and Genomics
Nanoscale Sciences & Technology This cluster investigates interactions between noble metal, magnetic and organic nanostructures for developing new sensors; modeling visualization; experimentally developing suitable nanomaterials for the construction of integrated optic chemical sensors	Computational Nanoscience, Nanofabrication, visualization modeling, Nanophotonics, Nanosensors, Synthesis and Characterization, and Applied Material Science
Data Information, Security and Management – This cluster conduct research on nanostorage, nanoRFID, computer forensic and data security	Information Assurance and Computer Security, Information and Intelligent Systems Data, Information, Modeling and Visualization

Figure 1. Research Clusters and their subgroups

technology and engineering with focus on the strength of the participants. This has led to the development and implementation of research clusters across the STEM fields (Figure 1) with their subgroups reflecting the interdisciplinary areas of strength of the participants. The diversification of the scholars in their areas of expertise with varying background in the STEM fields has made knowledge sharing and management possible in many emerging fields.

More importantly, the research clusters have made provision for departments to organize instruction and student experiences around broad, cluster categories that encompass virtually all disciplines from entry through professional levels. This is a combination of engineering, physical sciences, electrical engineering, physics, chemistry, molecular biology, and many more in the STEM fields. In addition, examining the program components, resources and eligibility factors can help identify areas of potential among collaborators to maximize resources.

In the same vein, a faculty member of the Department of Physics, Atmospheric and Geosciences with a research interest in the development and characterization of novel advanced materials, focusing on thin films, coatings and nanostructured materials, has developed an undergraduate nanoscience curriculum entitled 'Introduction to Nanoscale Science.' This course aims at enhancing student learning and research opportunities that relate to real-world applications and the use of state-of-the-art instrumentation (Walters, 2005). In addition, this course is meant to introduce undergraduate students to nanoscale processing and analysis techniques in the classroom. Through three consecutive NSF grants for Nanoscience Undergraduate Education (NUE), JSU has acquired four Nanosurf Scanning Probe Microscopes (SPMs), two Atomic Force Microscopes (AFMs) and two Scanning Tunneling Microscopes (STMs). This will enhance the teaching of principles of nanoscience and applications to aid hands-on processing laboratories, interactive microscopy learning experience and early research experiences, at every level of the curriculum.

Most importantly, majors across the university and their faculty will benefit from the existing cross-teaching with the Department of Physics, Atmospheric and Geosciences that offers students a wide range of opportunities in materials processing, the use of advanced instrumentation, and exposure to cutting-edge topics in nanoscience. Experience using the AFM and STM tools has proven to be valuable preparation for entering other research arenas, as shown by feedback from various internship sponsors. Similarly, topics in nanoscale science and other cutting edge research was presented in a weekly seminar series which features a number of presentations by outside speakers, and a forum where students present their research projects. Through these channels, students and faculty members who are new to this field from other departments are eligible to participate in the lectures and seminar series' to enhance the hands-on application of the AFM and STM tools.

Because of the concern for selecting and structuring knowledge about joint effort across the STEM fields, the synthesis of ideas would lead to a consensus on the part of STEM faculty participating. Therefore the challenge of the rapid evolution of technological knowledge base leaning to the side of one discipline will be minimized and importantly STEM faculty members will continue to participate effectively as well be able to place priority on the ability to identify and structure appropriate knowledge for instruction. This will make it possible for the STEM faculty to rely on many sources of curriculum materials and their abilities to synthesize technological information that is integrative to all STEM disciplines (Zuga, 1991). In order to unite knowing and doing in an effort to develop valuing, the expertise of integrating content and practice across STEM fields is one of the major contributions STEM educators will make to knowledge sharing.

Sharing of resources and facilities

According to Melton (2002), "no program can provide all things to those who are in need of services. No budget can provide the resources to assist all of those in need." Collaboration and cooperation is strengthened by sharing resources, especially when there is shortage of required resources and expertise among collaborators. "The essence of collaboration is resource sharing since organizational priorities and institutional pride are based in resource allocation and utilization" (Melton, 2002). Thus, resource sharing represents commitment to something larger than the single-focused discipline goals and objectives, and a shift to enter into relationships with other disciplines or fields to achieve shared goals, visions, and response to mutual interest and obligations, as is evident in STEM disciplines.

Personal and organizational risk factors of collaboration necessitate the need to create an organizational culture that will support collaborative action. Resource sharing requires development and enhancement of relationships and commitment to achieve something through that relationship, which may not otherwise be achievable by an individual agency or organization. STEM fields should work together in a more coordinated way to garner the benefits associated or there in.

Collaboration can eliminate redundancy and overlapping that result in inefficient use of resources and the duplication of services (Gallagher, Clifford & Maxwell, 2004). The core laboratories and facilities at JSU provide researchers with adequate resources such as equipment, technologies, and support functions to enhance research capabilities, as well as for instructional delivery on basic nanofabrication technology. Currently, cross-teaching is a practice among faculty members from Departments of Technology and Physics with the utilization of some of the following facilities and laboratories to enhance nanofabrication hands-on experience. Some of the major laboratories and facilities are:

1) The 3D – Modeling laboratory
2) Nanoscience Core Laboratory
3) Molecular Magnetic Resonance Core Laboratory
4) The Computational Modeling Core Laboratory/Supercomputer Center
5) The Visualization Core Laboratory
6) GIS Remote Sensing Laboratory.

Other core facility resources are:

7) HP (Hewlett Packard) Model 6890/5973 GC-MS (Gas Chromatography /Mass Spectrometer
8) Varian, Model Cary 3E UV-Vis (Ultra Violet-Visible) Spectrometer
9) Instruments S.A. Model FluoroMax-2 Spectrofluorometer
10) Shimadzu Model AA-6701 (atomic absorption) spectrometer
11) Shimadzu Model 17A GC/ECD (Gas Chromatograph/Electron Capture Detector)
12) Spex Model Raman Spectrometer
13) Varian Model Cary 300 Bio UV-Vis Spectrometer
14) HP Model 1100 HPLC with UV absorption and fluorescence detectors
15) Nicolet Model Nexus 870 FT-IR Spectrometer/Auto Image System
16) Finnigan MAT Model Duo-10000 LC/MS/MS System
17) Finnigan LCQ DECA/ESI Bundel with an LCQ NANO Spray Ion Source (CE/MS)
18) Amersham Biosciences ÄKTA FPLC (Model 18-1118-67) with Fraction Collector

Utilizing the existing core laboratories and facilities to enhance basic nanofabrication technology requires participating faculty members:

- To be able to explain concepts in physical science to both non-experts and experts acquiring knowledge of nanoscale science and technology with more emphasis on the "know how"
- To help set the directions and priorities of the use of core facilities to aid further research activities in nano-science and technology
- To facilitate learning by gaining experience in advanced micro- and nano-

fabrication methods as applicable STEM fields

- To assist national users working on their nanofabrication projects in the core facilities
- To establish and maintain baseline fabrication processes as well as intro duce and develop advanced process methods and train users in these methods.
- To support the mutual needs of business, industry, and academia by providing mechanisms for technical exchange and collaboration.

Development of STEM-Based Programs

Given the aforementioned as laid down in the College of Science, Engineering and Technology (CSET) at JSU, there is a need to develop a new academic program that targets a commitment to undergraduate and graduate teaching in the emerging fields. Currently, a new Masters of Science in Technology degree (interdisciplinary curriculum) to be offered at JSU will serve as the pathway to an education in nanotechnology, with nanofabrication as one of the majors as an example. Therefore, there is a further need to hire individuals with demonstrated excellent research potential, teaching ability, and with relevant industrial experience and expertise in the sub group areas.

However, collaboration across STEM fields, disciplines or programs can be successful through the active partnerships between educators, businesses, and students. Educators are responsible for providing students with the necessary tools to become successful and are also responsible for making sure they themselves have the proper training. Entrepreneurship also plays an important role in this effort. What better source is there to find out what is needed for industry growth than to gain information from that particular business? Partnerships with industry will aid in providing schools with the necessary tools to implement in education. Businesses can work with educational institutions in terms of telling them what is needed or required. Businesses can also offer grants and hands–on training. The students are to take advantage of the opportunities provided by the educators and businesses where they can receive hands-on training with mentors and role models.

While the aforementioned are encouraging, the awareness and the minimization of the barriers to the success of collaboration among STEM educators should be identified and dealt with carefully. For a start, these collaborators should "consist of people who come together because they have something in common, rather than because they represent different stakeholders or different points of view" (Cornwall, 2008, p. 275). In addition, the following should be noted:

1. *Building Consensus among participants* - Consensus building among collaborators
has to be guided to ensure that the community as a whole participate in all activities that lead to the conclusive or winning solutions.

2. *Being Open and Inclusive* - Sense of belonging among participants should be promoted with the understanding that the collective wisdom of the collaboration is far greater than that of any one individual.

3. *Leading by encouraging* - There is always another day when all participating members will be able to participate fruitfully. They may be even be offered the opportunity to contribute to the chosen solution. As such, regular meetings should be open to all to facilitate openness and knowledge sharing.

4. *Postponing Decision Making to Manage Risks* - Decision making should not be rushed since accountability is the responsibility of the participants. This is necessary to avoid unnecessary risks that might be costly down the road. So, this process is slow and should be consensus driven. You have to leave the possibility of reducing uncertainty, rather than fixing the risks.

5. *Teams and technology interactions over time* - Implementing new technology in collaboration activities with a shortage in funds and skills is challenging because of the perceived risk of damage or breakage. Understanding the learning process is therefore critical, both for the host of the facilities with technologies and for technological novices seeking to adopt them. However, rules and regulations that guide the way the laboratory equipment is to be used must be strictly adhered to. This includes the necessary safety precautions, and the elimination of unnecessary trials and errors that may lead to breakage or bodily injury leading to unnecessary cost bearing for the host.

6. *Knowledge acquisition in virtual teams* - How individuals acquire knowledge through group experiences and how technologies used by virtual teams will affect this process should be thoroughly investigated so as to promote the success of the collaborative effort. Since there are numerous challenges to knowledge acquisition in distributed groups, it is suggested that all collaborators must be briefed and brought to almost the same level of knowledge of the technological mechanisms to be adopted for enhancing opportunities for learning in virtual teams (Straus & Olivera, 2000).

Jassawalla et al. (2006) noted that "when people with multiple talents are placed in teams, they will interact, cross-fertilize ideas, and collaborate to produce." Given an understanding that STEM as a meta-discipline is relevant, a mindset that allows for the free exchange of ideas, joint policy making, and shelving all complexes (undue proclamation of superiority of a discipline) will help to forge on. Breaking the barriers to marrying these disciplines effectively is necessary so as to be able to bring all the tools you can to building the solution. As such, effective collaborative teams in STEM education should not be limited to identifying barriers (Winship, 2011). In addition, they should work together to create innovative solutions to barriers of student success with the following as examples:

- Barriers can be broken by educators being challenged in their work; getting the task done with accountability for the knowledge implemented with appropriate delivery method and approaches.
- Barriers can be broken by implementing supportive policies and creating organizational structures to facilitate collaboration across STEM disciplines. This will promote teamwork and enhance research with faculty colleagues. To be successful, collaborators must know the potential in the collaboration process, and be prepared to deal with challenges as well as reap the benefits of effective communication and increased student achievement.
- School district educators should meet and collaborate on a local level. Once a unified collaboration is done, then move to the state level and then the national level. This process will attempt to unify everyone. It is impossible to please everyone, but each level will have a voice in the process. Allowing everyone to have a voice brings about unity. Being a democracy, we have to learn to respect the process and buy into whatever decisions are made. I believe this will help to make STEM collaborations successful across disciplines. Taking into consideration the different cultures we have here in the United States, I would also suggest that the program be designed to encompass all children.
- An integration of STEM fields will be effective only when the faculty can work out their differences and the departments can overcome their superiority complexes. In-depth meetings should certainly be held in order to share ideas about the collaboration of these fields. Both cooperation and compromise should be promoted amongst the members in order to produce an effective collaboration.
- Continued patience and support from each member is certainly required in order to create a successful STEM collaboration. Open communication and sufficient time will be necessary to sharing ideas and overcoming

differences before continuing onwards with the collaboration. A conference with numerous individuals from various backgrounds, experiences and educational levels can provide expertise and ideas to form a more unified association. This unity will further the collaboration and present an effective instructional advantage to students.

Conclusion

Collaboration among scholars to form cluster groups in the university will enable further knowledge sharing with effective cost saving in the preparation of the future workforce for the emerging fields that will be developed by the integration of STEM disciplines. Given that the equipment needed in any collaborative facility is expensive, existing core laboratories and facilities could serve as the appropriate starting point. Collaboration in the STEM fields will be effective only if the capacity of all involved work for one another and go beyond personal recognition. Authority should come out of respect from peers and never be used to coerce. Leadership in collaboration should mean stewardship. With all these put together effectively, higher institutions will be able to reduce and manage projects with high uncertainty, complexity and risk.

Business also plays an important role in this effort. What better source is there to find out what is needed for industry growth than to gain the information from that particular business? Partnerships with business will aid in providing schools with the necessary tools to implement in education. Businesses can work with educational institutions in terms of telling them what is needed or required. Businesses can also offer grants and hands–on training. Although educators and businesses are important factors, students are also a key component. Some apprentice program can offer students a salary and benefits while they work toward obtaining their STEM degrees. When opportunities arise, students should take advantage of partnerships and training offered by educators and businesses.

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References

Chi-Ying Cheng, C., Sanchez-Burks, J., & Lee, F. (2008). Taking advantage of differences: Increasing team innovation through identity integration. In E. Mannix & M. Neale (Eds.), *Diversity and Groups (Research on Managing Groups and Teams, Volume 11)*, (pp. 55-73). Emerald Group Publishing Limited.

Cornwall, A. (2008). Unpacking 'participation': Models, meanings and practices. *Community Development Journal, 43*(3), 269 – 283.

Caruso, H. M., & Woolley, A. W. (2008). Harnessing the power of emergent interdependence to promote diverse team collaboration. In E. Mannix & M. Neale (Eds.), *Diversity and Groups (Research on Managing Groups and Teams, Volume 11)*, (pp. 245-266). Emerald Group Publishing Limited.

Ejiwale, J. A. (2012). Tools for collaboration across STEM fields. *Journal of Education and Learning 6(3)*, 177 - 184.

Gallagher, J. J., Clifford, R. M., & Maxwell, K. (2004). Getting from here to there: To an ideal early preschool system. *Early Childhood Research & Practice, 6(1)*.

Jassawalla, A. R., & Sashittal, H. C. (2006). Collaboration in cross-functional product innovation teams. In M. Beyerle (Ed.), *Innovation through Collaboration (Advances in Interdisciplinary Studies of Work Teams, Volume 12)*, (pp. 1-25). Emerald Group Publishing Limited.

Marchand, D. A. (2009). Leadership through collaboration and harmony: Perspectives for managers, No 180. Retrieved from http://www.imd.org/research/publications/upload/PFM180_Marchand_Margery_LR.pdf

Melton, P. A. (2002). Collaboration and resource sharing to improve services to Indian youth. American Indian Development Associates Quarterly, 1(1).

Rink, F., & Ellemers, N. (2008). Diversity, newcomers, and team innovation: The importance of a common identity. In E. Mannix & M. Neale (Eds.), *Diversity and Groups (Research on Managing Groups and Teams, Volume 11)*, (pp. 221-243). Emerald Group Publishing Limited.

Southeast Comprehensive Center at SEDL (2012). Engaging diverse learners through the provision of STEM education opportunities.

Stowell, C. (2005). Collaboration – An important leadership development skill. Retrieved from http://ezinearticles.com/?Collaboration---An-Important-Leadership-Development-Skill&id=88620

Walters, W. (2005). Nanoscience Education. Retrieved from http://www.nanoscience.com/education/profiles/Wilbur_W/WW-1.html

Winship, J. M. (2011). The spirit of collaboration. SouthEast Education Network (SEEN). Retrieved Nov. 29, 2013, from http://seenmagazine.us/articles/article-detail/articleid/1302/the-spirit-of-collaboration.aspx.

Zuga, K. F. (1991). The technology education experience and what it can contribute to STS. *Theory Into Practice, 30(4)*, 260 – 266.

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