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Building Partnerships in Mathematics and Science: Challenges, Leadership, and Promises of an Interdisciplinary University-School Partnership

This paper highlights some of the challenges and milestones inherent in building partnerships between institutions of higher education and public-school systems from an interdisciplinary approach. It discusses lessons learned from a Mathematics Science Partnership (MSP)-Start Partnership that was funded by the National Science Foundation from 2008 to 2011. The core partners of the partnership were Morgan State University and the Baltimore City Public Schools. One of the lessons learned was that it took a strong and committed leadership team working together to maintain and sustain this interdisciplinary partnership.

Keywords: partnership, leadership, trans-disciplinary, interdisciplinary, higher education, trust

Introduction

The focus of this paper will be to use concepts and theories of leadership and partnership building, including trans-disciplinary, interdisciplinary, and disciplinary discourse theories to answer the following research question:

> *What conditions facilitate or hinder effective interdisciplinary university and school partnerships?*

To answer this question, we discuss lessons learned from the Baltimore Research and Innovations for New (BRAIN)- STEM Partnerships which was a Morgan State University Mathematics Science Partnership (MSP)-Start Partnership funded by the National Science Foundation (NSF) from 2008 to 2011. The paper will address the various processes of the partnership from initial proposal conception to the module development workshop that was held during the summer of 2010 on to the final integrated modules completed in August of 2011. From project data, we use qualitative as well as quantitative information to analyze and explicate themes that are evident in the process of school/university partnership building and develop these interdisciplinary themes. The plan is to pay particular attention to what we have learned about building effective partnerships, identifying the various challenges to partnership building, and how we have negotiated these challenges to meet the goals of the project.

Morgan State University (Morgan), a mid-sized Historically Black Institution (HBI) in the city of Baltimore, Maryland, has had a long history of creating and sustaining university and school partnerships with the Baltimore City Public Schools as well as other school districts in Maryland. The nature and context of these school and university partnerships have varied over the years. However, these partnerships have often been driven by the need to provide comprehensive programs and services to educators and students in the Baltimore metropolitan area. Specifically, several initiatives have been introduced to improve mathematics and science teaching methodologies and learning in Baltimore and surrounding areas. The initiatives include teacher education and professional development through the School of Education Professional Development Schools, various projects and programs initiated by the Center for Excellence in Mathematics and Science Education (CEMSE), and mathematics and science teacher professional development projects through Morgan's Graduate Programs in Mathematics and Science Education. Through these initiatives, Morgan has developed important relationships with the major school districts in the Baltimore region to provide high-quality mathematics and science education to students and teachers.

In addition to building relationships with school systems, several initiatives have been established to build interdisciplinary partnerships among various schools, departments, and institutes on campus. Specifically, through the School of Computer, Mathematical, and Natural Sciences (SCMNS), there have been systemic efforts to encourage faculty to work on cross-disciplinary research and to create inter-departmental collaborations to advance research in mathematics and sciences and prepare Morgan students for careers that require an interdisciplinary understanding in mathematics and science. Through these programs, faculty members in mathematics and the sciences have formed inter-university partnerships as well as partnerships with faculty at other universities and government agencies. These collaborations have resulted in published interdisciplinary research, a Master of Science in Bioinformatics Program, Ph.D. programs in Bio-Environmental Science, and Industrial and Computational Mathematics, establishing an alliance with the Morgan Estuarine Research Center, and development of a multi-instructor/cross-departmental undergraduate course with concepts from computational biology.

Given Morgan's mission to educate and serve urban students, Morgan faculty examined ways to expand the impact of its already established partnerships. The plan is to combine a learning experience in mathematics and science education and interdisciplinary mathematics to improve educational outcomes for students in mathematics and science, especially minority students. The MSP (Math and Science Partnership) program of the National Science Foundation provided an opportunity to explore new dimensions of our currently existing partnerships by providing a context to create and sustain an interdisciplinary multi-institutional university/school partnership designed to improve student achievement in mathematics and science. As a result, Morgan State University established the BRAIN-STEM Partnerships, an MSP-Start Partnership.

The Math and Science Partnership program at NSF responds to a growing national concern — the educational performance of U.S. students in mathematics and science. Through MSP, NSF awards competitive, merit-based grants to teams composed of institutions of higher education, local K-12 school systems, and their supporting partners. These partnerships develop and implement pioneering ways of advancing mathematics and science education for students. They bring innovation, inspiration, support, and resources to educators and students in local schools, colleges, and universities. MSP also serves students and educators by emphasizing strong partnerships that tackle local needs and build grassroots support to:

- Enhance schools' capacity to provide challenging curricula for all students and encourage more students to succeed in advanced courses in mathematics and the sciences;
- Increase the number, quality, and diversity of mathematics and science teachers, especially in underserved areas;
- Engage and support scientists, mathematicians, and engineers at local universities and local industries to work with K-12 educators and students;
- Contribute to a greater understanding of how students effectively learn mathematics and science and how teacher preparation and professional development can be improved; and
- Promote institutional and organizational change in education systems — from kindergarten through graduate school — to sustain the partnerships' practices and policies.

MSP-Start Partnerships are for awardees new to the MSP program, especially from minority-serving institutions, community colleges, and primarily undergraduate institutions, to support the necessary data analysis, project design, evaluation and team building activities needed to develop a full MSP Targeted or Institute Partnership (NSF, 2010).

BRAIN-STEM is an MSP Start Partnership. The focus of the BRAIN-STEM is to connect faculty in the mathematics, biology, mathematics, and science education departments, and the CEMSE at MSU with key administrators and teachers in the Baltimore City Public Schools. The goals of the partnership are: 1) to conduct a needs analysis by collecting and analyzing student achievement and teacher characteristic data in K-12 mathematics and science, 2) to design a project that addresses the content and pedagogical needs of City Schools life sciences and mathematics teachers through the use of integrated problem-based learning (PBL), 3) to build sustainable partnerships with other institutions of higher education and school districts and engage all partners in the design and piloting of integrated mathematics and biology teaching modules, and 4) to design a plan for developing a full MSP Targeted Partnership based on the evaluation of the outcomes of the BRAIN-STEM project. One of the key goals of the BRAIN-STEM partnership is to develop and sustain partnerships among school systems, higher education institutions, and other organizations for the enhancement of teaching and learning in algebra and biology in high school. As an MSP-Start project, we engaged ourselves in various activities designed to build sustainable interdisciplinary partnerships including, workshops, focus group discussions, module development activities, partnership building meetings, and professional development.

Conceptual Framework

To address the complex needs of schools' budgetary constraints and demands for greater performance and accountability, several educational policies have been enacted to improve K-12 education. To meet the sometimes daunting goals of these educational policies and initiatives, there has been a growing need for K-12 schools, institutes of higher education (IHEs), community-based organizations and non- profit organizations to collaborate and build partnerships to address the issues we currently face in the educational landscape. Specifically, the NSF MSP program developed under the Title II No Child Left Behind act of 2001 was one the mechanisms through which K-12 institutions and IHEs have been encouraged to develop partnerships that will create better learning environments (Waschak & Kingley, 2006). Through a highly competitive application process, applicants must demonstrate that a substantive partnership between K-12 schools and IHEs will be formed and that those involved in this partnership will engage in activities that will improve mathematics and science education. Besides, applicants must develop and implement an extensive evaluation plan to understand the extent to which the partnership has met its goals. One of the major consequences of programs such as MSP is that it requires researchers and policymakers to develop a basic knowledge of the term partnership, understand and operationalize the "work" of partnerships and create theoretical frameworks and models of partnership formation, implementation and evaluation that can be used to understand various aspects of educational partnerships, specifically the impact of the partnerships on stated outcomes (Kingley & Waschak, 2005).

As an MSP-Start project whose primary goal is to develop and sustain a viable partnership, the BRAIN-STEM team reviewed literature that informed the partnership formation implementation and evaluation. We assessed and analyzed academic, industrial, and scientific literature about partnership building to create common conceptions of partnerships, understand how to effectively form, sustain and evaluate partnerships, understand the characteristics of effective partnerships, and develop conceptual models that were used to understand different challenges and of interdisciplinary K-12 partnerships. In particular, we used Winkler and Fretchtling's (2006) framework on evaluating new versus mature partnerships to understand the extent to which the BRAIN-STEM project meets the definition of an effective MSP-Start partnership. This body of literature formed the conceptual frame through which we used to plan BRAIN-STEM activities and to understand the conditions that facilitate or hinder effective partnerships framed with an interdisciplinary approach.

Definition of Partnership

Many definitions of partnership have been used in a variety of disciplines including organizational studies, public management, behavioral studies, and educational issues across fields of inquiry (Kingsley & Waschack, 2005; Waschak & Kingley, 2006; Treisman & Klijin, 2002). For example, scholars in organizational studies in which the primary goals are to explain the reasons for partnership building and understand the conditions that foster or hinder cooperation and coordination tend to define partnership as the relationship between entities that require exchange, knowledge needs, and expertise, and a need for collaboration in order to secure strategic positions within a field or organization (Oliver, 1990). Public management scholars Treisman and Klijn (2002) summarize three features of partnership a) the interdependence of actors in order to achieve desired goals, b) the resources needed to achieve goals are distributed among actors, and c) the system and processes developed under the partnership are complex since they are dependent upon negotiations of participating actors.

Partnerships in education, including university/school partnerships, are highly informed by various conceptions of partnership; however, definitions of educational partnerships are more closely aligned with those found in the public rather than the private sector (Kingsley & Waschack, 2005). Boyer (1981) asserts that partnership is the condition of moving beyond organizational collaboration to a point where common problems are agreed upon, mutual rewards are understood, there is leadership, and there is a project focus. Embedded in this definition is a focus on common problem solving, mutual goals, and an understanding that all participants benefit from the partnership and shared leadership. Common to many of the definitions of partnership found in the literature (Clark, 1988; Bennett and Krebs 1994; Boyer, 1981; Goodland, 1988, 1991; Firestone & Fisler, 2002; Provan & Milward, 2001; Harding, 1990) is an emphasis on mutual goals and benefits, ongoing collaboration through well-defined activities, shared responsibilities and leadership, relationships and systems, working as a team, or mechanisms through which the partners interact to accomplish goals (Maxwell, 2007; Rath & Conchie, 2008). For MSP projects, there is an additional requirement that partnerships drive institutional change and sustainability (NSF, 2008; Holley, 2009). Also, institutions of higher education are often asked to produce innovative, collaborative, and interdisciplinary scientific knowledge bases. Responding to the challenge of the disciplinary concentrations and the study of students, faculty members, and researchers, scientific partnerships offer new knowledge bases and "is no longer the *de facto* norm for colleges and universities" (Holley, 2009, p. 331). A key feature and innovation of the BRAIN-STEM MSP Start are that the institutional change and sustainability is based on the development of an interdisciplinary partnership. Typically, interdisciplinary partnerships consist of collaborative partners from various organizations and institutions, and multiple STEM and education fields. The work of an interdisciplinary partnership is to focus on a common problem, topic or theme that cuts across various disciplines (Holley, 2009). In building the partnership, the focus was to ensure that students, teachers, administrators, faculty members, and other stakeholders communicate and interact from an interdisciplinary perspective. Hence, when forming the BRAIN-STEM partnership, the project team continually monitored the extent to which these elements were present or absent and made adjustments when needed. For the sake of this paper, we are defining interdisciplinary school-university partnerships as partnerships between two or more disciplinary departments within a university and school district.

Partnership Formation

The literature also suggests that partnerships between individuals, groups, and organizations are formed for a variety of reasons and to meet particular needs. Much of this literature suggests partnerships are built around relationships or networks of individuals who come together to meet a strategic need or mutual goal that could not be met if the entities operated individually (Burt 1992; Whetten, 1981; Goodland, 1988; Grannovetter, 1992). Kingsley & Waschack (2005) synthesizes literature from a variety of disciplines to develop a model that reflects the partnership formation process. In their work, they hypothesized that "partnership formation is the product of embedded relationships among individuals and organizations coupled with an overarching strategic need" (p. 6). They postulate that the greater the overlap of these two conditions, embedded and strategic need, the more likely the partnership formation will impact the partnership operations. Specifically, they argue that mutual goals are more likely to be met when partnerships are built on embedded relationships (Goodland, 1994; Sanders & Epstein, 2000).

In addition to embedded relationships, partnerships are formed based on a strategic need, which is anything outside of the organization that will enhance its ability to accomplish goals (Kingsley & Waschak, 2005; Waschak & Kingsley, 2006). Although the existence of a strategic need is important to partnership formation and subsequently choosing members of the partnership, it is less important than the existing environment and socially embedded relationships inherent in the partnership. Additionally, when partners see that there is not only personal fulfilment from their participation in the project but also the professional significance and career enhancement, there is a greater likelihood that there will be a continued commitment to the partnership along with achievements (Waschak & Kingsley, 2006).

Many of the initial BRAIN-STEM core partnerships were developed through existing relationships that had been formed to address various aspects of interdisciplinary research or K-12 mathematics and science initiatives. As the BRAIN-STEM core team recruited additional partners, there was a specific intention to ensure that new partners were informed about and understood the mission and goals of the project. It was also imperative that new partners understood that the project had the potential to address and express the need of individuals as researchers and scholars and organizations as professional teams. Consequently, as the partnership grew, there was an ongoing effort to foster positive working relationships, trust, and professional engagement of all participants and partners.

Implementation of BRAIN-STEM Partnership

As an MSP-Start project, one of the key goals of the BRAIN-STEM project was to develop and sustain partnerships among school systems, higher education institutions (HEIs), and other organizations for the enhancement for the teaching and learning of algebra and biology in high school. To achieve this goal, it was important that the project team plans, implement and evaluate activities that had the most potential ~~of~~ for solidifying the project team and create an understanding of the viability and importance of integrated mathematics and science curricula and instruction at the high school level.

Hence, as activities were planned, one of the main goals was to maximize relationship building, ensure that the partners mutually benefited from the project, and make sure that the goals of the project logically correlated with the activities planned. The project team consulted bodies of literature that highlighted models and frameworks for partnership implementation that could assist in achieving these goals. Specifically, as we implemented BRAIN-STEM activities, we drew on the work of Clark (1988) and his conceptualization of work independence. In his work, Clark argues that one key factor that influences the strategy, operations, inter-organization, and outcomes of partnerships is the degree of interdependence of its participating members in executing the work and activity of the partnership. According to Clark's framework and philosophy of partnership interdependence, this executing of work includes three levels; they are pooled, sequential, and reciprocal work. On the other hand, his framework of interdependence entails three levels of implanting project activities that reflect varying degrees of interdependence among partners. They are pooled work, sequential work, and reciprocal work. Pooled work is the lowest level of interdependence and requires members to carry out the work of the project independent of each other. Second, sequential work requires the work of partnership to be dependent on the producing effort of another working member or partner and may require input from other partner members later. Last, reciprocal work requires the effort of work and activity to be shared equally and collaboratively among members/partners. This effort will ensure successful productivity toward a positive outcome (Clark, 1988). For this present project, planning activities that required reciprocal work among partners was important to BRAIN-STEM as activities were proposed, planned, diagrammed, and executed. However, high-quality reciprocal work was not always achieved. Nevertheless, core leadership ultimately ensured success.

Characteristics of Effective Partnerships

Winkler and Frechtling (2005) identified five characteristics of effective educational partnerships that involve multiple entities working together that 1) share a joint vision, 2) each benefit from the partnership, 3) have and meet clearly understood obligations, 4) are engaged in the current and future direction of the partnership as well as decision making, and 5) have shared accountability and ownership in the partnership. These five characteristics of effective partnerships served as a framework to evaluate both mature and new partnerships. They define mature partnerships as those that have existed at least five years, while new partnerships are those that have existed for less than five years. They assert that although the five characteristics of partnership do not change when evaluating new and mature partnerships, the criteria for the successful operation of these characteristics do. Hence, the indicators of effectiveness will be different when they are at different developmental stages.

In Winkler and Frechtling's (2005) conceptual framework, they illuminate contrasts and similarities between new and mature partnerships based on each of the five characteristics of effective partnership and identify evaluation indicators for both new and mature partnerships. First, new educational partnerships must decide on a set of goals that encompass both K-12 and postsecondary issues. Further, these partnerships must ensure readiness and the development process of a shared agenda. It is critical that new partners mobilize and direct their energies toward goals that they deem compatible. Also, new partnerships should develop a joint vision based on common cross-partner goals (Jones, 1998). Secondly, new K-12 university partnerships must be able to balance the benefits among K-12 and postsecondary partners and be sensitive to and perceptive of the possibility of unequal benefits. It is important that new partners understand that mutual benefits may take time and are encouraged to be patient until benefits ensue. The third characteristic of effective partnerships is that of clearly understood obligations, roles, and responsibilities. In new partnerships, it is important that partners sign contracts or memorandums of understanding that identify expectations and obligations of each partner. However, it is not unusual that those creating new partnerships may be less knowledgeable and in articulating partnership obligations might sometimes fall victim to passive acceptance of faulty partnership visions and missions as opposed to more informed and professional commitments.

Also, for example, new partnership members must learn how to negotiate and resolve conflicts and problems between teams. The partnership entity may require certain support to effectively resolve conflict. Furthermore, new partnerships must be mindful of how they encourage intellectual engagement and shared decision making. Specifically, new partnerships must make every effort to build trust among partners (Maxwell, 2007; Rath & Conchie, 2008), assess engagement of all parties, select a strong, committed, and balanced leadership team (Rath & Conchie, 2008), and determine how the school districts' decisions are impacting the developing partnership.

Finally, new partnerships must ensure that there are shared accountability and ownership of all aspects of the partnership. Partners must develop mechanisms through which they all have a serious stake in project outcomes. At the pragmatic level of all partners understanding project results, this means that partners share in collecting, analyzing and sharing data. It is important to encourage all partners to think critically and deeply analyze and collected research data. They subsequently pool their resources for the benefit of the partnership and the dispensing of the information and results to constituents.

Some components for developing new and effective interdisciplinary partnerships, as suggested by Holley (2009) consist of having: 1) senior administrative support, 2) collaborative leadership, 3) a flexible vision, 4) faculty and staff development, and 5) visible action. The goals and objectives of the BRAIN-STEM MSP Start project required that we address each of these components at the initiation of the project, during project implementation, and at the project's completion. To ensure success, it was imperative that we partnered with qualified STEM and higher education faculty from various disciplines. They worked in tandem and collaboratively with teachers, school administrators, and other non-academic partners. The characteristics of effective new partnerships identified in Holley (2009) and Winkler and Frechtling (2005) were used to evaluate the effectiveness of our interdisciplinary university-school partnership. We used these experts' theoretical frames and the subsequent indicators to evaluate the extent to which BRAIN-STEM meets the operationally-defined components of effective new partnerships.

Overview of BRAIN-STEM Partnership Activities

As an MSP-Start project, it was critical that we engage in team-building activities. Some of these activities were built on previous project activities which led to research and a better understanding of partnerships. We became more skilled from research and by reading the literature on effective partnership building. These activities included: 1) Core Partnership Meetings and Workshops, 2) Expanded Partnership Meetings and Workshops, 3) Module Writing Activities, 4) Collaborative Grant Writing, 5) Mathematics and Science Education Conferences, 6) Annual Mathematics-Science-Engineering Fair (Parent Meeting), and 7) Parent, Student and Teacher Focus Group Discussions. This section will provide an overview of the activities that we engaged in to build the partnership.

1. Core Partnership Meetings and Workshops

Core partnership meetings and workshops were initially held to begin the process of partnership building between universities and public schools. The initial core included three universities: Morgan State University, The Johns Hopkins University (JHU), Rutgers University, and the Baltimore City Public Schools (City Schools). The lead partners were Morgan State University and Baltimore City Public City Schools. There was also one partnership high school from City Schools. The meetings involved each partner discussing "what roles could they have in the development of the partnership." The discussions focused on the kinds of activities that they were engaged in with their organizations and how these activities could support BRAIN-STEM. Each core partner gave presentations that highlighted their successes. The Baltimore City Public Schools, an initial school district partner, addressed their individual needs that included: student academic success in STEM, the need to increase student achievement on standardized tests, professional development for STEM teachers, and technology needs, in general. Discussions were made on how to get assessment data from schools and who were the key stakeholders within the system to get the information needed for the targeted proposal.

2. Expanded Partnership Meetings and Workshops

Meetings and workshops to discuss expanded partnerships included decisions to team with outside partner groups that have specific expertise in various areas to enhance BRAIN-STEM project goals. Their contributions aided in ensuring that objectives and project goals were met with success. Those contributing as expanded partners included the Baltimore County Public Schools, Coppin State University, and the United Negro College Fund Special Programs. We also added two new partnership high schools and additional STEM faculty. Much like the core partnership meetings, these meetings allowed each partner to discuss their involvement in the targeted proposal and how they could productively contribute. This activity also encouraged team building between partners readying all for the collaborative grant writing activities and other BRAIN-STEM endeavours.

3. Module Writing Activities

Module writing activities involved mathematics and science teachers working together in a collaborative way across mathematics and science disciplines to develop instructional strategies that could improve the teaching and learning of mathematics and science. The module writing activities consisted of mathematics and science teachers from targeted schools working together in groups to develop modules (defined as a group of lessons focused on a particular theme related to relevant research topics in mathematics and science). Teachers were given a template developed by the leadership team as a guide for developing modules that were linked to state standards and could be used in their classroom instruction.

There were several lessons learned by the partnership in developing module writing activities and working with teachers. Most of the lessons learned came from the implementation phase of the modules. First, mathematics and science teachers needed additional professional development training in content areas that they did not teach (either mathematics or science). Second, teachers who did not author modules needed training on how to best utilize these modules. Third, strategic planning of the implementation modules was important to link the activities to the curriculum. Fourth, it is critical for STEM faculty to be involved in all phases of the module-writing activities. Fifth, the STEM faculty needs professional development for working with school teachers and administrators. Finally, school administrators needed module implementation training and the value of interdisciplinary approaches to the teaching and learning of mathematics and science to support the overall project. The mathematics and science teachers were the authors and implementers of the modules, and thus, played a significant role in the partnership building process. The cohort of teachers writing modules contributed positively to the partnership-building process by discussing the obstacles associated with module development and implementation as well as how these modules were linked to the curriculum.

4. Collaborative Grant Writing

One of the major contributions to the partnership-building activities involved grant writing with our key partners. Several preliminary grant writing meetings were set up to assist the partnership in organizing and writing the targeted grant proposal. These meetings were held to allow each partner to stake-out the role that they could play in the targeted proposal. Timelines were set up to guide the partners through the process. Key to these meetings was the development of common goals and objectives that each partner could agree on and then to develop appropriate activities that focused on how they perceived addressing their specific needs. Also, the key to these meeting was consistent and frequent communication between the partners. Several steps were involved in developing collaborative grant writing partnership activities to meet the deadline for the targeted proposal:

Step I: <u>Developing a Proposal Template</u> - Each partner was required to complete a common proposal template that could be merged into the targeted proposal. This template included general goals for their specific project, the targeted audience, objectives, project descriptions and activities, a budget with narrative, resources provided by the partner, criteria for evaluating success, and criteria for selecting consultants.

Step II: <u>Review of the Proposal Template</u> - A proposal writing team was set up to edit the proposal, look for consistency in goals and objectives for each template, analyze each budget, construct the overall budget, collect letters of support, and statements of work. This step involved the writing team making revisions and communicating with each other daily through electronic media and face-to-face meetings.

Step III: Electronic Submission of the Proposal – After final edits and cuts to the original document the final step involved the electronic submission of the proposal. Since this was a federally funded proposal this process included support from the University's Office of Sponsored Program (OSP). This office submitted the proposal electronically by the deadline date and time.

The collaborative grant writing activity helped to build the partnership in several ways that included the following: 1) identified strengths and weaknesses in terms of their expertise; 2) developed a feeling of trust between each partner; 3) shared of ideas between partners; and 5) developed a feeling of ownership between partners for the overall project.

5. Mathematics and Science Education Conferences

The BRAIN-STEM project team participated in mathematics and science education conferences sponsored by one of its core university partners, the Center for Excellence in Mathematics and Science Education. These conferences provided professional development activities that supported the instructional needs of local teachers. BRAIN-STEM teachers were involved in making presentations concerning their module development activities associated with the project. Additionally, the conference provided an opportunity for teachers to discuss strategies for completing their modules and also implementation strategies in their schools. Teachers were able to discuss various issues related to module development and implementation along with their progress. The partnership-building activities with CEMSE provided a venue for working with targeted schools, administrators, teachers, students, and parents through conferences and special technical assistant workshops that were focused on the professional development of K-12 teachers as well as the academic enrichment of K-12 students in mathematics and science.

Also, members of the BRAIN-STEM team participated in the MSP Learning Network Conference (LNC). The MSP LNC is the annual conference for all NSF MSP projects. In 2010, the BRAIN-STEM team presented a conference abstract entitled "Partnership Building: Integrating Math & Life Sciences in Baltimore City High Schools". This paper was presented during one of the paper sessions at the conference. The abstract was a preliminary report on the BRAIN-STEM project. Some of the topics presented were 1) Integrated Mathematics and Science as a Curriculum Innovation: A Needs Analysis, 2) Teachers as Curriculum Developers: A Case Study of a University-School Partnership for the Development of Integrated Mathematics and Biology Modules, and 3) Building Partnerships in Mathematics and Science: Challenges and Promises. The team received valuable partnership building information at the conference and shared key lessons learned from working with city schools' teachers on integrating mathematics and science.

6. Annual Mathematics-Science-Engineering Fair Parent Meeting

Each year the CEMSE provides an Annual Mathematics-Science-Engineering Fair for K-12 students to increase the research skills of K-12 students and to expose them to science fair competition. During the competition, parents are engaged in a parent workshop that was focused on some aspect of STEM (science, technology, engineering, mathematics). During this activity as a part of developing a connection to parents, BRAIN-STEM facilitators engaged parents in a discussion of the feasibility of integrating mathematics and science in the classroom. The results of this discussion demonstrated that parents felt that this was a natural fit into the curriculum and understood the value of integrating mathematics and science to show connections between the two disciplines. This was valuable information for the partnership-building process to have clear cut evidence that this interdisciplinary approach to the teaching and learning of mathematics and science was important to parents.

7. Parent, Student and Teacher Focus Group Discussions

As a part of our work, we conducted several focus groups discussion with key stakeholders, particularly parents, students, and teacher. These focus groups were conducted to understand of parent, student and teachers' perspectives on the feasibility and value of integrating mathematics and biology at high school. Two-parent focus group discussions were conducted which included a total of 28 parents. Four focus groups were conducted with high school mathematics and biology teachers which included a total of 40 teachers participating in these focus groups. We conducted one focus group discussion with students in three pilot high schools. The information generated from these focus group discussions were central to us understanding how to improve our outreach activities and strengthen our partnerships in ways that would increase parent, student and teacher support of the implementing integrated mathematics and science curricula into high schools.

Methods

Data Collection

To answer the research question, data from the BRAIN-STEM partnership activities were collected and analyzed to expound upon and explain themes and answers to the questions. Certain information and data were collected from partnership meetings and minutes, interviews with core partners and stakeholders, personal reflections of partnership members, and from partnership-building activities, such as observation field notes. Also, we created a survey relevant to the questions and collected data. Partners, teachers, and administrators were then required to take the survey. These surveys were developed using the framework on effective partnership building, including literature on the implementation and sustainability of new partnerships. The literature also includes factors that facilitate and hinder effective partnerships. Qualitative information from one school administrator, six-core partners, and nine teachers was collected and analyzed to answer the research question.

Data Analysis

As mentioned earlier, various forms of data were collected to answer the research question guiding this study. We used qualitative as well as quantitative methods to analyze and explicate themes using the conceptual framework shaping this study. Each source of data was coded using a start list of codes derived from our conceptual framework. After coding the data, we used inductive analytic strategies to understand the relationships between codes. These relationships were used to develop preliminary themes that reflected what we have learned about building effective partnerships, identifying the various challenges to partnership building, and how we have negotiated these challenges to meet the goals of the project. These themes were then given to a select group of core partners and teachers for their comments and feedback. After this was complete, we integrated the core partner and teacher comments into our data analysis. Throughout our analysis, we looked for disconfirming evidence for our preliminary themes to ensure that the emergent themes represented accurately reflected the data collected. From this ongoing analysis, the following themes emerged.

Findings

In the sections that follow, we highlight the themes that emerged from our data collection and analysis. The themes that emerged from the data reflect what the partners believed were the major factors and conditions that facilitated and hindered effective interdisciplinary partnerships. The themes that emerged from the data analysis were categorized as follows: partners' perceptions of need, building commitment and capacity and ownership of the partnership. Under each subheading, the major themes that emerged are discussed. In the final section, a discussion of the findings is presented, particularly the challenges and promises of interdisciplinary partnerships. The discussion is ended with the lessons we learned from our MSP-Start project.

Partners' Perception of Need

The literature suggests that effective partnerships are built and sustained based on the perceptions of need by the partners. Hence, as the BRAIN-STEM core partners created activities designed to expand the partnership, there was a concerted effort to ensure that goals, objectives, and activities of BRAIN-STEM reflected the needs of invited partners so that would be more likely to join the partnership and sustain their participation in the partnership over time. Data revealed that school partners, particularly Baltimore City Public School partners, saw a need for interdisciplinary curricula in biology and mathematics because they had a system-wide commitment to improving students' performance in these areas. Yet given the limited resources of the school system, they were unable to implement systemic initiatives, particularly professional development activities that would increase student achievement in these areas. Core partners from Baltimore City Public Schools were very interested in the idea of the BRAIN-STEM project and dedicated several city-wide administrators to work with the BRAIN-STEM project. One of these core partners commented in an early meeting of the project held on February 16, 2010:

> *The BRAIN-STEM project is just what we needed, and we will make sure that our teachers know about your project. It will be my business to have as many teachers as possible to come to the [module building] workshops. What do we have to do next?… I am excited to be on board with this! I think this is a great way to get our science and mathematics teachers talking to each other.* (Sandy, City School administrator, science)

Figures 1-3, in support of their strong desire to partner in the project, demonstrate a critical condition in student academic achievement in Baltimore city along with a state-city-county and a racial comparison.

The High School Assessment (HSA) graduation of 2010 has been analyzed to have an informative knowledge on the performance of students in mathematics and sciences, particular algebra and biology. Figure 1 presents the data on data algebra and biology for the grades 9- 12. The success rate of students is consistently higher in algebra than biology. The difference is found to be much wider in lower grades *(See Figure 1).*

The performance in algebra is compared among state, Baltimore County and Baltimore City. Asians, closely followed by whites, appear to have the highest success rate as compared to other racial groups in Maryland state as a whole as well as in Baltimore County, while African Americans have the lowest in all three regions with exception of Hispanics in Baltimore city. The performance of Baltimore County appears to be higher than the state as a whole across all racial groups.

A somewhat similar pattern is also observed in the context of Biology; however, the performance of both Baltimore County and Baltimore city are lower than the state as a whole. The difference is much larger between the city and the state *(See Figures 2 & 3).*

This school-system administrator, in particular of Baltimore City, saw this project as a way to improve the academic achievement of their high school students in mathematics and biology, which were key areas that were assessed by the state. Because they saw this project as a way to help gain professional development training for their teachers, they were inclined to continue with the partnership even after the turnover of key administers in the system. Further, with the adoption of the Common Core Standards, City School partners believed that an interdisciplinary approach to mathematics and science teaching could be a viable framework for addressing the demands of the new standards.

There was a need by the school partners to develop a strong university partnership with Morgan State University and other partners to help them with other initiatives. As one of the school system partners discussed at one of our partnership meetings:

> *We have been trying to reach out to you guys [Morgan State University] in a systematic way and us not quite sure how this could be done; through this project, we now know some of the key players [in math and science], and we can work with you all on other projects. We can use the help.* (Donald, school system administrator, mathematics).

Although Baltimore City Public Schools saw the BRAIN-STEM project as a way to increase student achievement, provide professional development experiences for their teachers and forge new alliances that could support other initiatives, Baltimore County Public Schools did not quite see their role in Brian-STEM in the same way as "City" given their unique needs. When first approached about joining the BRAIN-STEM project, initially there was some interest in the project. However, key administrators declined to become a part of the project due to commitments with other projects and their involvement in other university-school partnerships. Although they initially felt the project was a good idea, and they already were engaged in STEM-related efforts to integrate mathematics and science interdisciplinary curricula, they did not see the BRAIN-STEM project as a way to fill a need they had nor were they willing to furnish resources and personnel to ensure the success of the partnership project. However, when they realized that this project could support their efforts to build interdisciplinary curricula materials for their virtual learning environment, they decided to join the project with the expressed intention to use these projects to help with this systemic effort. As one of their senior-level administers admitted:

> *We have several partnerships with Johns Hopkins and UMBC that are connected to our virtual learning environments. It would be good to incorporate your work to help us create interdisciplinary modules…. This is what we need: Support with for our technology high school.* (Jerry, City School administrator, STEM programs)

Also, as the BRAIN-STEM team developed the targeted proposal, Baltimore County Public School partners saw the project as a way to secure funds for their ongoing work in the STEM. This need was also shared by Baltimore City Partners. During the time of the partnership, both school systems were revising and adapting their STEM initiatives that would be used to shape STEM education in their perspective school districts. Hence, they saw the focus on interdisciplinary curricula as a viable framework that could be used to shape their system-wide STEM initiatives. Hence, the need to develop a vision for STEM education was a key need that they saw their participation in the project could fill. As a result, this perceived need was a key motivator for the school partners' ongoing participation in this partnership.

Finally, the analysis revealed that the university partners perceived that the BRAIN-STEM partnership could fill their need for securing funding, conduct research, provide professional development and build relationships with key personnel from the school system. Although this was not a major goal of the MSP start project, the university partners could see this partnership as a way to expand their current research interests. As one of the partners revealed in his response to the survey:

> *I am interested in vocational education, and I think an interdisciplinary approach to vocational education can help students learn trades. This is what I am interested in researching on, and I wanted to be a part of this because I could see how it fits in with what I want to do*. [Harold, university partner, mathematics department]

The statement reveals that many of the core partners joined and continued to participate in the BRAIN-STEM partnership because they saw how interdisciplinary mathematics and science curricula development and implementation could benefit their organization's needs. Although these needs varied for each of the partners, the fact that each of the partners saw this project as an opportunity to build on their existing initiatives, particularly their STEM initiatives was a significant and useful observation. The project team made ongoing efforts to ensure that the needs of the partners were met. This was important in facilitating an effective partnership.

It also revealed some challenges to building effective partnerships based on partners' perception of need. As new school leaders and key personnel were replaced, there were sometimes challenges in convincing new leadership that this project was important. As new leadership focused on certain priorities, there was a need for continuous communication explaining to these new leaders that this partnership was important to their innovative visions and goals. This was not much of a challenge given that throughout the leadership change, STEM education was a major concern for each school system, and they understood that interdisciplinary mathematics and science curricula, and instruction and professional development were critical components to an essential and workable STEM educational framework.

Building Capacity and Informed Commitment

Research suggests new partnerships must create common goals and create joint visions based on cross-partner goals. One BRAIN-STEM partner views the partnership as a vehicle to address needs. One concern was the need to expand partnerships' professional capacity (as mentioned above). One way to build partnership capacity is to seek like minds that are willing to partner with BRAIN-STEM and who are informed and committed. This is necessary as sometimes a common pitfall of new partnerships is that they may fall victim to passive acceptance of partnership visions with no real commitment and therefore fail to articulate mutual benefits to all partners. Partnership qualitative data did not surprisingly reveal that the institutions, organizations, and individuals that made up the partnership had various resources and experiences and were able to work collaborative and successfully because of these overlapping but positive differences. Additionally, the success of the partnership was connected to BRAIN-STEM's ability to use each institution', organizations' and individuals' experiences and resources in the development, design, and implementation of high-quality partnership activities.

Although there were numerous partnership activities, the module writing and grant writing activities were the activities that were critical to building the partnership and strengthening the commitment among the partners. For example, during these activities, partners could use their areas of expertise and experiences and in due course create the direction of the partnership. For instance, when asked what activities were most beneficial to your participation in the partnership, all participating teachers surveyed said their involvement in writing interdisciplinary mathematics and science modules was most beneficial. One teacher commented in the survey:

> *Our school has a medical vocation based curriculum, which means that our students are required to apply their basic science and mathematics skills to real-world careers. We felt strongly that we needed to increase our interdisciplinary planning as well as improve our own schools' education and teaching practice. Though helping write [interdisciplinary] modules, I was able to do that and this kept me involved in the [BRAIN-STEM] project.* (Terry, a high school biology teacher, City Schools)

When asked what had her commit to the project, a school administrator revealed that:

> *Our teachers were invited to write modules that expressed collaboration between the algebra and biology teachers. I wanted to be involved more with the project and so I asked could our school be involved with the piloting of the modules. As a high school administrator, I was able to provide a lens on how to create an environment for a partnership of this nature and to develop strategies on how to implement* [integrated curricula] *like insuring that the master schedule provided an opportunity for collaboration between algebra and biology teachers and making sure we had the equipment needed to implement the project.* (Lashawn, high school administrator)

Several teachers' comments revealed that their initial interest in the partnership was driven by their desire to participate in writing modules and eventually implementing them in their classrooms. As a result of their participation, several teachers commented that their participation in this activity contributed to them becoming better teachers and also motivated them to commit to the partnership. Additionally, they said that their involvement motivated them to encourage their colleagues to participate. One teacher noted:

> *I have become a better instructor since participating with BRAIN-STEM. My students have benefited from encountering material that is more engaging and relevant to their lives than I was used to doing. [Being a part of the module writing] helped to think differently about teaching math and looking for ways to integrate science in my math class. I asked others in my building to come to the [module writing] workshops so that we can have others who can do what I am doing… I plan to stay with the project and keep learning. (Cynthia, high school mathematics teacher)*

Similar sentiments were expressed by university partners. Several of the university partners surveyed said that the module writing workshops were useful to them and helped to keep them continuously engaged in the project. Several of the core partners stressed that it was difficult to attend all of the general partnership meetings; however, they felt that module writing workshops were beneficial because it afforded them a more intellectual understanding of how integrated curricula materials were created. They also expressed their satisfaction because their expertise was useful in helping formulate ideas and design for the modules. One core partner stated:

> *I was excited about getting teachers to expand their subjects to develop a deeper understanding of the content through interdisciplinary teaching. I was able to interact with teachers* [during the workshops] *to help them think more deeply about the content and do something different.* (John, university core partner, science professor)

In addition to module writing activities, again, partners believed that being involved in writing the MSP targeted partnership proposal helped them stay committed to the project and take more ownership in the project. Through their involvement in writing this grant, they could see how their individual and university's expertise could be utilized in the project. Besides funding, partners were also able to distinguish other ways in which they and their university or institution could benefit from being a part of the project. This was particularly true for our non-profit organization partner which had areas of expertise that was essential to designing the targeted project.

Unfortunately, we found several challenges in our ability to build the commitment and capacity for the partnership. Although we had the interest and several partnership meetings, attendance at these meetings were sometimes sporadic. Partners were often involved in other academic projects which made it difficult for them to attend all meetings. On the other hand, when the partners were addressing a specific issue and they saw a clearer picture as to why their presence was critical toward project and activity success, meetings designed to address these special issues related to module development or writing the MSP-targeted proposal were better received. General meetings to update partners on the project or to review activity processes was not met with the same enthusiasm. One partner commented in the survey:

> *I could not make all of the meetings because I have a lot on my plate. I like working with the teachers and the workshops but often I did not have time to come to all the meetings. I would tell Dr. Nkwanta* (the PI of the project)*, that if he needed something for me to do, just let me know. I am committed but I don't have a lot of free time because I have a lot going on right now.* (William, university core partner, science professor)

The statements revealed that BRAIN-STEM partners were committed to the project and had a desire for the project to succeed. They saw that the project's vision and mission were consistent with their individual and institutional goals and needs. However, consistency was sometimes challenging, as the major activities between the module writing activities and the proposal writing workshops became cloudy. Since these projects required the development of a product, partners felt that their particular expertise was, correctly or not, more critical to producing a viable product that would be overall useful. For the school partners, they saw particular value in helping with the development of the modules since they desired to use these in their schools. Besides, they saw this as a way to help their teachers become more effective teachers in mathematics and science, which was one of their primary needs. Conversely, the University partners felt that their participation in the grant proposal writing process would allow them to utilize their special expertise and ensure that their university's interests were reflected in the proposal and project.

Partner Ownership

Through several of the partnership-building activities, partners were able to create ownership of the partnership. It was the leadership teams' expressed intention that all of the partners have clear roles. Relationship building is essential in this area. That is, it was important that each partner felt useful and that he or she was critical to the success of the partnership (Maxwell, 2007; Rath & Conchie, 2008). However, as observed, the statements revealed that several partners were unclear of their roles and therefore were not as inclined to see the BRAIN-STEM partnership as their own. For example, when Baltimore County Public Schools were initially contacted to join the partnership, they declined to participate not only because they did not initially see the need, but they also felt that since they were not a part of the initial conceptualization of the project, they could not participate in the partnership in the same way as the Baltimore City Public Schools. Due to administrative changes, Baltimore County is reconsidering and meeting to better understand and re-establish their role and ownership of the partnership. However, after a change in systemic leadership, particularly the appointment of a new STEM director, they saw a clearer picture as to how the partnership could be useful and was, therefore, better able to express interest and take ownership of the project. Once they could see the benefit of their participation, they were not only willing to participate but also willing to help the partnership expand its vision and take the lead on integrating mathematics and science in virtual learning environments. As one STEM administrator commented:

> *The needs of Baltimore County Schools and Baltimore City Schools are vastly different. What Baltimore County needs from the project appears to be much different than what Baltimore County was looking for. However, we were able to share our ideas on the Virtual Learning Environments at Chesapeake High School, Baltimore County's STEM academy and discuss how the principles and expertise of the BRAIN-STEM project could be used to assist in teaching professional development and the creation of integrative, virtual learning activities. This is where I think we can contribute to the project (Jerry, City School administrator, STEM programs)*

One of the major challenges to fostering ownership of the project among the various university and school partners was a lack of time concerning the competing demands of the partners' jobs and the project activities. Several partners commented that the time it took to participate in the project meetings and other activities were some of the main reasons as to why they were not able to be more involved in the project. As mentioned, when asked what were some of the major challenges that they experienced during participation in the BRAIN-STEM partnership, school and university partners alike commented that time commitment was a big issue:

> *It was hard to find enough time to work with the project especially since my I worked with teachers from other schools. I know I could have done more with the project; it was just hard juggling all of the demands of being a teacher and working with the project* (Valerie, high school science teacher)
>
> *Carving out common meeting times is a great challenge to buying into the project. Given that we have so much to do, it was hard to stay on top of all of the meetings and activities.* (Donald, school system administrator, mathematics)
>
> *I needed more time so that I could work on activities individually* (Susan, high school mathematics teacher)

In addition to time constraints, the expressed statements indicated that one of the key barriers to individuals' and organizations' developing ownership was defining critical roles and responsibilities for partners during those times when they were not engaged in module or proposal writing. As one core partner commented:

> *I was not always clear about what my role was in the partnership and this was a major challenge for me. Since I was not involved in the professional development aspect of the project, I did not know how I fit in. We [me and my organization] are on board with the project since we have a lot of interest in STEM projects. I just wasn't always able to see what I could take the lead on…* [Jonathan, mathematics professor, university core partner]

One core partner recommended that we develop an action plan whereas the partners specify and commit to developing the next steps of the partnership even in the case of not receiving additional funding. He believed that this was critical to keeping partners committed to the project and their ongoing investment in the success of the partnership.

Views and Thoughts of Parents and Students in Integrated Approach of Teaching

Thus far we have learned views thoughts of partners of school administrators and teachers. This section provides some thoughts and views of parents and students towards an integrative approach to teaching math and biology.

Parent survey provides a glimpse of parents' knowledge on the Math and Science integration in schools. Morgan State University has a Science Fair Project. Every summer, a group of students from Elementary to Freshman College is selected to participate in the project. While they are in the program, the parents also visit the campus. Thirty-nine of these parents were available and fill out a small survey. The following are the results of this survey. Over two-thirds of participating parents were female, and three quarters were Africa-American. Asians were 16 percent and Caucasians were only 8 percent. About half of them had a High school Diploma, and forty-six percent had Bachelors or higher degree.

Table 1 presents the knowledge and beliefs of parents in Math and Science integration in their child's school. Ninety-two percent of parents believe that Math and Science should be taught in the integrative approach. Only forty-five percent knew that Math and Science are already being taught integratively in school. About three-fourths reported having familiarity with the school's Math and Science curriculum, as two-thirds of these parents are products of the Baltimore City Public School System. All the parents have plans for college for their child. Every parent reported that they found the Science Fair Project of Morgan State University to be beneficial for their child *(See Table 1).*

The Student Belief Survey on their learning in classrooms was conducted on students of grades 9-12 while they were attending the Science Fair Project of Morgan State University. Forty-one students participated in the survey. Of the forty-one students, 22 were in eleventh, 12 in twelfth, four in tenth grade and three did not mention their grade. They were given a structured questionnaire to the response. The questionnaire had seven items. Each item had two choices. The students were asked to circle one in which they believe in along with a short explanation *(See Table 2).*

Item 1 relates to the approach to learning complex problems. About three-fourth of students considered the answer A, which states that a student should be taught necessary skills before presenting a complex problem to them (Table 2). The explanations for considering A indicates that the students need to be prepared by teaching necessary materials before they are given complex problems. However, one-fourth of the students provided a contradictory view. Their explanation was a complex problem provides a challenge to students. When students enjoy taking a challenge, they learn the materials better.

Item 2 relates to students' belief in the method of learning mathematical concepts in classrooms. Fifty-eight percent considered B as their choice, which states, "I learn mathematical concepts best my teacher telling me the meaning of the concept". Both choices are concept-choices. A relates more to personal experiences while B implies the role of the teacher in explaining the concept.

In support of their choices, each of these provided explanations. From the explanations for considering A, two things play an important role in their consideration. These are: hands-on activities and relating math problems to a real-life situation. These will enhance the retention and application of math. On the other hand, those who considered B believe that if a teacher explains the concepts, it will help better understanding the problem and finding a solution to that.

Item 3 relates to how a student understands math better. Sixty-eight percent think that they understand math by listening and imitating the teacher. While the rest believe that discussing the problem and teaching others enhance the understanding. Those who considered A believes that listening and imitating manifest as hands-on training. However, the explanations for selecting B is that by discussing and teaching others, one can broaden the knowledge of math.

Item 4 relates to the issue of whether math should be taught separately or in the context of everyday life. Sixty percent favor the idea that math should be taught in the context of everyday life and then separate it later, while the rest think math should be taught first separately and then applied to practical problems. As observed earlier, students are more inclined and feel comfortable in learning math in the context of everyday life.

Item 5 addresses the issue of the relationship of math skills. Seventy-one percent reported that the retention of skills will be enhanced by repeating the problems and reviewing them by the teachers. Others view that the retention will be better if the skills are learned with other students in the real-life context as explained that some student learns better with peers.

Item 6 relates to the role of motivation in learning math. Almost all agreed that students with stronger motivation can learn higher levels of math if they are motivated to work and apply themselves. In this explanation, they believe that everyone can learn; only those who want to further their knowledge will get better in school. Motivation is the key to learning any subject matter.

Item 7 asked about the best method of solving a math problem. In math, a problem can be solved more than one way. Eight seven percent believe that the best method of solving a problem is what makes the best sense to the student as long as the answer is correct. Different people understand things differently, so there is no one way to teach a student to solve a problem.

Discussion and Conclusion

Interdisciplinary Partnerships: Challenges and Promises

Literature suggests that the roles of the partners are greatly impacted by their area of expertise. Partnership members and organizations should be strategically aligned with their roles, responsibilities, and areas of expertise roles to more successfully build and sustain the said partnership. Understanding and applying this leadership and partnership strategy, we found that in the interdisciplinary university/school partnership, university faculty, teachers, system-level administrators, and nonprofit partners collaborated productively to develop and implement module writing activities and develop the targeted proposal. Through these activities, project partners had an opportunity to leverage resources, coordinate work, and increase collaboration to complete these activities. Hence, it is critical that in early aspects of partnership building, it is imperative that key partners are engaged in activities that allow them to contribute their expertise in meaningful and concrete ways. Since there were clear intentions and benefits of the project activities, partners saw intellectual and academic reasons to engage in the project activities, and could, therefore, fully appreciate and share in the creation of the final product.

Some of the main promises and challenges of sustainability and creating successful interdisciplinary partnerships are relevant to the differences one would find in the various communities of practice of each discipline of study (Wenger, 1998). Academicians will also find these challenges and promises between scientists and educators of these various disciplines. BRAIN-STEM has found that to successfully build interdisciplinary and collaborative partnerships, there must be a concerted effort to build "mutual discourse" at every phase of the partnership-building activities. We found that to foster commitment and ownership of the partnership, it was important that the partners spoke the "same language" to effectively communicate with each other.

Lessons Learned in Interdisciplinary Partnership Building

There have been many lessons we have learned that could be of value and have positive implications for the MSP learning network. First, to other MSP-Start projects, do not expect major instructional changes during your project. The focus of the MSP-Start project must be building trust, mutual respect, and commitment from each of the partner organizations and specifically, the teachers. These experienced sentiments support the partnership and leadership work and literature of Clark (1988); Oliver (1990); Kingley & Waschak (2005); Maxwell (2007); and Rath & Conchie (2008). We have learned through literature and the experience of this partnership that although it is important to build relationships with central administrators and personnel from the school system, universities, and other organizations, it is also the relationships that the partnership builds with teachers that are an essential element to the sustainability of the partnership. Since teachers will play a key role in implementing the interdisciplinary curricula materials, we found that their perception of the need for integrated mathematics and science materials, their input in the designing and implementing of the materials, expertise, and commitment will shape the extent to which the partnership will be sustained. This is particularly important given the transient nature of many of the school-based administrators and systemic instructional leaders. Second, effective interdisciplinary partnerships must address the need to cross disciplinary boundaries that may impede understanding between partnership members who are not in the same discipline (Holley, 2009). For example, how scientists and educational researchers view "research" can be very different. In some cases, these different understandings of what constitutes research and the value of educational and scientific research can cause challenges. To address these challenges, in the early phases of partnership building, there must be frequent meetings between all stakeholders. One of the major intentions of these meetings must be to identify areas that may cause conflict or differences and develop a shared understanding of content and processes that are critical to the partnerships' goals and activities. Thirdly, we have found that sustaining university and school system partnerships is based on the extent to which the school system sees the partnership responding to their needs, particularly their needs regarding accountability and student achievement. Goodland (1991) and Ledoux and McHenry (2008) stress the need for teacher-professor, college-school and administrative cooperation in such partnerships. Although we found administrators and teachers very receptive to the idea of integrating mathematics and science in the classroom, this interest was not sufficient to partnership sustainability. How they see the partnership responding to their needs was critical to their willingness to continually engage in partnership building activities.

We have also learned that there needs to be trusted and developed working relations between STEM and higher education faculty and teachers. The faculty will work with the teachers on expanding their content areas in mathematics and science. Conversely, the teachers must be open and receptive to learning new material to expand their understanding of their respective content areas. Further, teachers gained trust with the higher education faculty when they felt their skills and expertise was valued and respected in the same way as university faculty. In our project, we drew heavily on teachers' knowledge and expertise of the curricula to help develop interdisciplinary modules. Several module ideas were changed based on the feedback from the teachers. This willingness to change the focus, scope, and content of interdisciplinary modules based on teachers' feedback was critical to building the trust of the teachers and ensuring their going participation in the partnership activities.

In addition to valuing teachers' skills and expertise in meaningful ways, evaluating and assessing as partners or a team are imperative. We also learned that to build the level of trust needed to engage teachers in an interdisciplinary university/school project requires ongoing time, commitment and incentives that should be interwoven into the partnership activities (Panaritis, 1995). Partnership incentives could include access to university programs, faculty mentoring, in-school support and resources, professional development, financial support, and letters of recognition for their work with the partnership.

Unlike university-level partners, teachers were sometimes challenged by time constraints and resource demands, particularly about changing curricula and school system priorities. Hence, they were sometimes distrustful of the project as they feared their efforts and time may be wasted in light of possible foreseen and unforeseen changes in school system policies, curricula, and school priorities. This issue was particularly problematic given the complexity of the interdisciplinary work that was being undertaken by the project participants, work which required teachers and faculty across disciplines to coordinate schedules, engage in activities that required teachers to expand their understanding of content and to design interdisciplinary learning experiences. In light of this, it was important as the focus of the school system shifted. We were clear about how the work of the partnership was modified to address these new goals and priorities. This readjustment of priorities in response to these changing needs of the school system helped sustain the partnership and created mutual trust between all university and school partners.

We also observed that partners may not be able to sustain commitment. For example, the JHU Education Department discontinued its relationship with the partnership after a crucial JHU BRAIN-STEM member participant moved to another university. The faculty member from JHU Education department was instrumental in the BRAIN-STEM partnership activities; however, what we learned is that it is critical to always consider broad and varied university support from each division of the university. This thought process along with applied action strengthens leadership as well as the partnership. Consequently, the JHU STEM faculty remained committed to the partnership because there were several faculty members from the STEM division who were invested in the partnership. Hence, as some JHU STEM faculty disengaged in the partnership, several others continued the work of the partnership; this, in turn, lessened the impact of activities and the partnership when some faculty members had to vacant the project and/or university.

To conclude, it takes a strong and committed core leadership team to maintain and continue the partnership. The core leadership team remained intact and connected throughout the project and remains committed to working together as a professional team. They are the nucleus of promoting trans-disciplinary and interdisciplinary partnerships. Key to strong and committed leadership teams are visionaries and leaders who understand the processes involved in moving projects from the idea stage to actual implementation. In some respect, this comes from this committed leadership team also understanding and trusting the academic skills, research abilities and contributions that each team member can offer. This project demonstrated that partnerships that have a strong, committed and centered leadership can sustain and overcome unexpected and unrealized obstacles that may occur during project and research activities. With strong and solid leadership, other activities can be initiated and delegated due to previous leadership and academic experiences in developing collaborative and effective higher education partnerships.

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Table 1. Parent's knowledge in math and sciences education in their child's school.

	Questions	Percent Responded 'Yes' (n =39)
1	Do you believe math and science should be taught integratively in schools?	92
2	Are you aware of math and science being taught integratively in your child's school?	45
3	Are you familiar with the math and science curriculum in your child's school?	74
4	Are you a product of the Baltimore City Public School System?	63
	Do you have plans for your child to go to College?	100
6	Do you think Sciences Fair Projects are beneficial to your child's education?	100

Table 2: Students beliefs in methods of learning

Item	Response choices	Percent Preferred (n =39)
1	**A.** You as a student should first be taught a set of skills in mathematics before being presented a complex problem	72.5 (29)
	B. First presenting a complex problem to me as a student motivates me to want to learn the skills necessary to solve the problem.	27.5 (11)
	(Z =2.84, p <.05)	
2	**A.** I learn mathematical concepts best by being prompted with questions to reflect on my own experience and activity.	42.5 (17)
	B. I learn mathematical concepts best by the teacher telling me the meaning of the concept.	57.5 (23)
	(Z =-0.94, p >.10)	
3	**A.** I understand more math by listening and imitating the teacher	67.5 (27)
	B. I understand more math by discussing and teaching others math.	32.5 (13)

	($Z = 2.21$, $p < .05$)	
4	**A.** Math should first be taught as a separate subject and then applied to practical problems.	40.0 (16)
	B. Math should first be presented to students in the context of everyday life and then the math separated or abstracted from it.	60.0 (24)
	($Z = -1.26$, $p > .10$)	
5	**A.** I only retain math concepts and procedural skills when they are constantly repeated and reviewed by the teacher.	70.7 (29)
	B. I best retain math concepts and procedural skills through learning experiences with other students where math is placed in a meaningful context.	29.3 (17)
	($Z = 2.61$, $p < .05$)	
6	**A.** All students can learn higher levels of mathematics if they are motivated to work and apply themselves	97.4 (38)
	B. Only the brighter students can learn higher levels of mathematics and that students of lesser ability should learn math that is more practical, such as applied math	2.6 (1)
	. ($Z = 5.99$, $p < .01$)	
7	**A.** There is usually one or a best method of solving a math problem and that the role of the teacher is to clearly demonstrate such a method to students.	13.2 (5)
	B. There is often more than one way to solve a math problem and that the one or best method depends on what makes the best sense to the student as long as the answer is still correct	86.8 (33)
	. ($Z = -4.65$, $p < .01$)	

Figure 1. Passing Rate of High School Assessment Test in Baltimore City Public School, 2010.

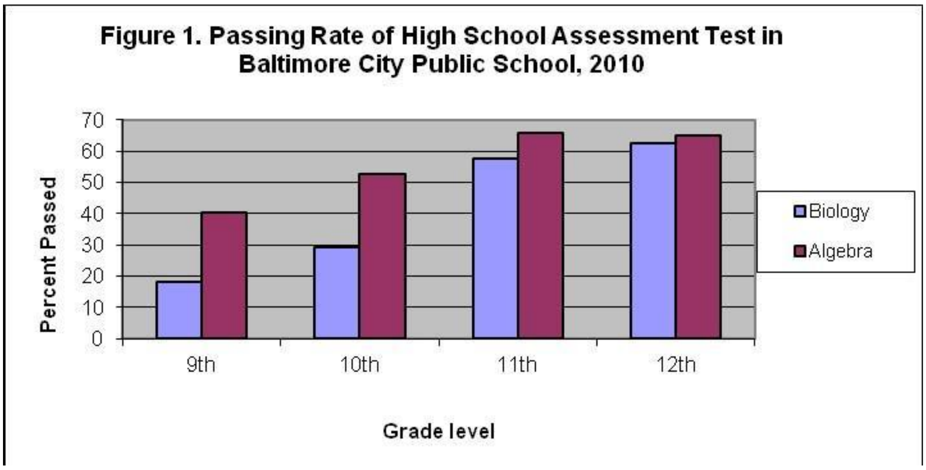

Figure 2. Passing Rate of High School Achievement Test in Biology and Algebra by Race in Baltimore City, 2010.

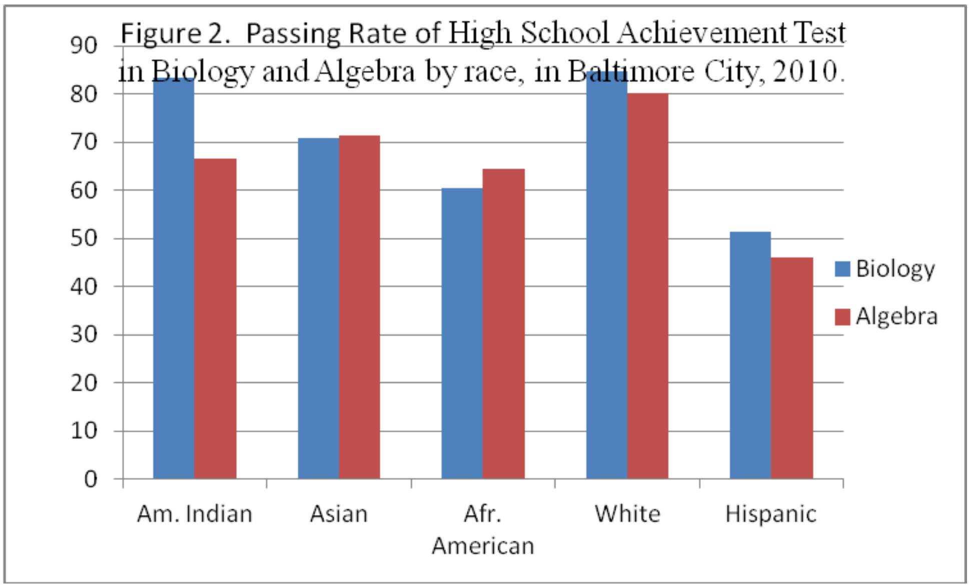

Figure 3. Passing Rates of High School Assessment Test in Algebra of Twelfth Grade for Maryland, Baltimore County and Baltimore City, 2010.

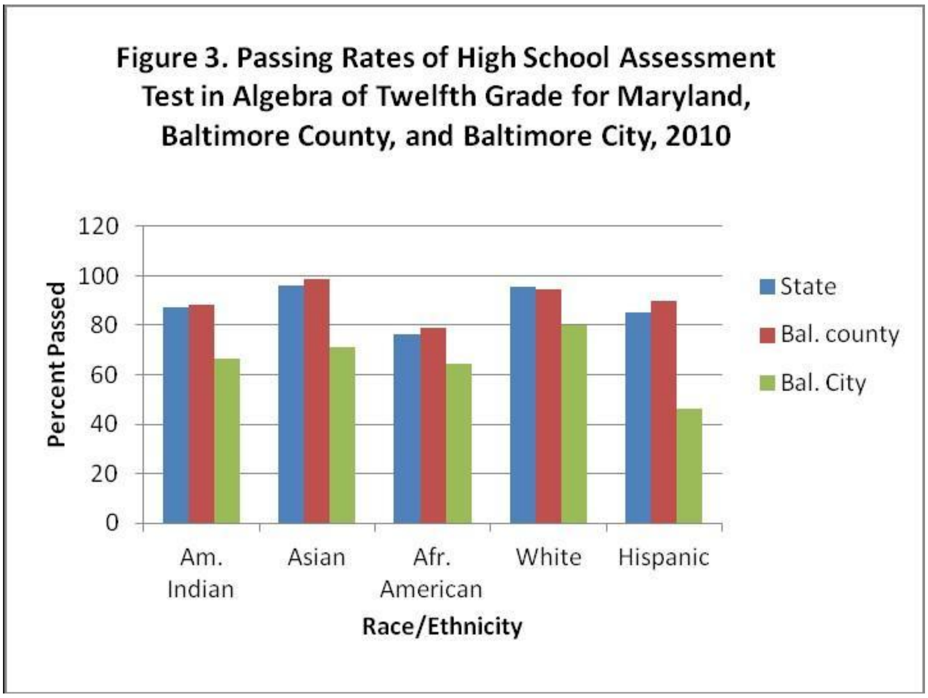

Figure 4. Passing Rate of High School Assessment Test in Biology of Maryland, Baltimore County and Baltimore City, 2010.