Elements that Support and Hinder the Development and Implementation of a School-wide/District-wide STEM Integration Program (Evaluation)

Dr. Mia Dubosarsky, Worcester Polytechnic Institute

Dr. Mia Dubosarsky has been a science and STEM educator for more than 20 years. Her experience includes founding and managing a science enrichment enterprise, developing informal science curriculum for young children, supporting Native American teachers in the development of culturally responsive science and math lessons, developing and teaching graduate level courses on assessment in science education, and working with thousands of educators across the country on developing meaningful, standard-based STEM experiences for their students. Mia currently serves as the Director of Professional Development at WPI's STEM Education Center and as PI of an IES funded grant, Seeds of STEM. In these roles she oversees the development and facilitation of STEM themed professional development programs for PreK-12 teachers and administrators and the development and testing of STEM curriculum for preschool classrooms.

Dr. Dubosarsky has an undergraduate degree in Biology from Israel's Institute of Technology and a Doctorate in Curriculum & Instruction (science education) from the University of Minnesota.

Dr. Jeanne H. Hubelbank, Worcester Polytechnic Institute

Jeanne Hubelbank is a program evaluation and assessment consultant in education. She earned a B.A. in French/elementary education at Cedar Crest College, M.Ed. in educational research at Boston University, and Ph.D. in educational research, measurement, and evaluation at Boston College. She is a member of ASEE, the American Evaluation Association and the American Educational Research Association. Her current research interests are in evaluation use and capacity, especially in regards to STEM education.

Elements that Support and Hinder the Development and Implementation of a School-wide /District-wide STEM Integration Program

Mia Dubosarsky & Jeanne Hubelbank

Introduction

High-quality STEM education is crucial for the future success of American students. Researchers recognize the critical role that school and district leaders play in implementation of educational reforms as well as the lack of best-practice STEM education expertise held by school and district leaders. The program, *STEM Integration for Education Leaders (STEMi)*, was developed by the STEM Education Center at Worcester Polytechnic Institute (WPI) to guide school and district leaders in the process of developing a strategic plan for STEM integration. The paper presents the framework, content, and evaluation findings from five years of the program with implications for education leaders, researchers, and policy makers.

Literature review

A recent report published by the U.S. Department of Education [1] emphasizes the constant growing need for STEM skilled employees in the US and the fact that the economy at large, and not just the traditional STEM occupations, will benefit from a STEM-literate workforce. The report builds on multiple national publications from the past decades [2-5], which identified STEM knowledge and skills as highly desired by employers yet pointed at gaps in access and achievement among US communities and students. The 2016 report illustrates a vision for closing these gaps by establishing six components of high quality STEM education: communities of practice, learning experiences that provide play and risk, integrated, real-world, problem-based educational experiences, flexible and inclusive learning spaces, innovative and accessible assessments, and the promotion of diversity and equity in STEM.

The vision proposes a new model of learning, a recognition that students construct knowledge and skills in different locations (in and out of school) in different ways (play and focused learning), from different people (teachers, parents, experts), using different modalities. These ideas may not align with the traditional way of schooling hence implementation of the vision identified by the report may require a systemic change by schools and districts. Systemic change (or cultural shift) relies on a strong research and evidence base, leadership, and adequate resources for capacity building, as well as a 'change team' that develops and implements a strategic plan for the new shared vision [6]. Adelman & Taylor identify the steps toward successful implementation of systemic change, which include the articulation of clear vision and rational for the change, identifying the resources, infrastructure, strategies, and tasks that must be taken and ongoing review of the process. This major investment takes time and commitment from multiple stakeholders and requires determination from the leadership. Multiple research studies pointed at the vital role that school and district leadership play in creating the conditions and culture that supports successful implementation of STEM vision [3], [4], [7], [8].

On the other hand, research reveals some barriers in successful implementation of high quality STEM education. The first is lack of shared vision and understanding of STEM education [9], [10]. Second, education leaders who lack the background in STEM best practices find it difficult to promote rich STEM experiences in their school [5], [11]. A third barrier for implementation of STEM vision and policies is the lack of teacher STEM professional development, especially in the elementary grades [3], [11], [12].

In summary, the need for STEM-skilled society is higher than ever, however, moving forward to implement the vision for STEM education as identified by the U.S. Department of Education is a process that requires clear vision by the education leadership in schools and districts, and the power, commitment, professional development, partnerships, and investment of resources in order to achieve a systemic change and shift in school culture.

Project description

Recognizing the difficulties in shifting the culture towards integrated STEM instruction, the STEM Education Center at Worcester Polytechnic Institute (WPI) developed a program with the intention of supporting education leaders in the process of STEM strategic planning.

STEM Integration for Education Leaders (STEMi) is a unique program that brings together teams of school and district leaders who work for one year to develop a long-term strategic plan for integrating quality STEM[1] education into their schools and districts. This research-based program meets high quality standards for professional development and is aligned with the research-based vision for STEM education [1]. During the year-long program, teams from schools and districts work collaboratively to develop a school-wide or district-wide plan that enhances students' and teachers' STEM outcomes. Developing a common definition of STEM integration and understanding the Engineering Design Process, and its fundamental connection to quality STEM education, are key to the teams' work. Teams are presented with the program's definition of STEM education [13], and are encouraged to adapt the definition in such a way that represents the team's shared values and beliefs regarding STEM education. The program's adopted definition:

> STEM education is *"an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering and mathematics in contexts that make connections between school, community, work, and the global enterprise, enabling the development of STEM literacy and with it the ability to compete in the new economy."* [13]

After creating their shared definition of STEM education, the teams follow the design process as they review models of successful STEM integration, research STEM guiding frameworks and rubrics, define the vision and pillars for their STEM programs, develop a set of expected STEM outcomes for their students and teachers, evaluate existing STEM programs and identify needs, explore STEM curricula, develop models for collaboration with local businesses and higher education institutions, explore funding opportunities, and develop an implementation plan.

[1] While most teams developed plans for STEM education, some teams chose to focus on STEAM education (including A for the Arts), and 3 faith-based schools focused on STREAM (adding A for the Arts and R for Religious values). When we refer to STEM in the paper, we include the STEAM and STREAM formats.

During the course of the year the teams share their developing plans with each other, provide feedback on the plans, and revise them accordingly. A new component to the program is mentorship, where past teams serve as mentors to the new teams. Now in its sixth year, the program has engaged twenty-two school and district teams, both public and private, in the process of strategic planning and implementation of quality STEM program.

The year-long program embodies a structured, yet flexible, approach that emphasizes that creation of STEM integration is a process that occurs over time. The logic model for the program (Fig. 1) displays the components of the structured approach. A detailed timeline of program's activities is found in Appendix A, and agenda for the summer institute is found in Appendix B.

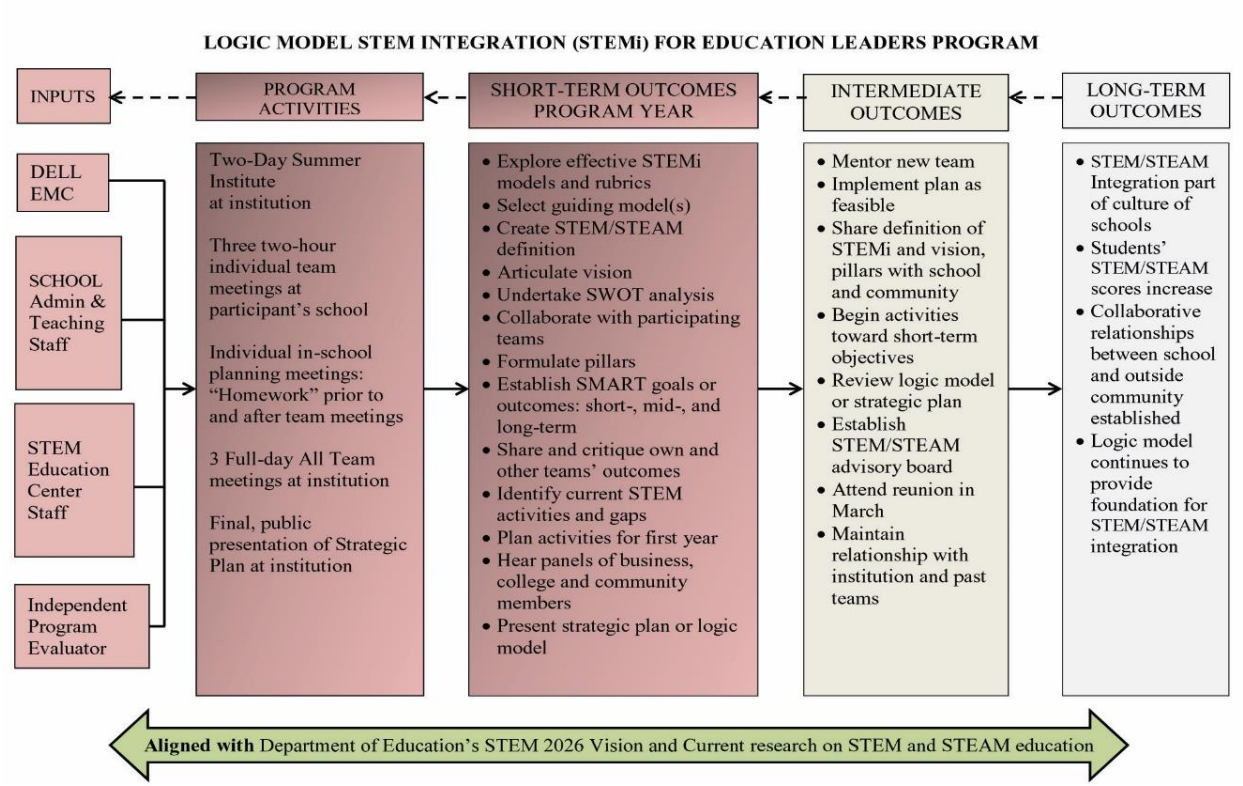


Figure 1. Logic model of program outcomes, with related activities and inputs

Participant population

Over the six years of the program, 22 teams and 160 educational staff participated in the program (Table 1), which is application based and fee based. Commitment from school/district administrations is a requirement, as well as a team that represents all levels of the school/district. The program staff ensures the balance between administrators and teachers, as well as the representation of all grade bands of the school/district, and all members of the selected teams are asked to sign a contract specifying the program's expectations and commitments.

Table 1. Number and position of participants by year of program

	Year						
Position	One 3 teams	Two 4 teams	Three 4 teams	Four 4 teams	Five 4 teams	Six 3 teams	Total 22 teams
Administrators	11	13	12	8	8	5	57 (35.6%)
Teacher/Admin	2	3	1	3	1	-	10 (6.3%)
Teachers	6	6	11	14	19	12	68 (42.5%)
Specialists	1	4	7	8	-	5	25 (15.6%)
Total	20	26	31	33	28	22	160 (100%)

*Shaded column represents 2017-2018 teams

The participating schools' and school districts' grades ranged from prekindergarten through high school. Both public and private schools enrolled, including regional school districts, school districts, individual public schools, two Montessori schools, a school for deaf children, two Catholic schools, and two Muslim schools. The geographic areas included eight city schools, eight suburban schools and six semi-rural schools.

Because the first year of the program began without an evaluator and the last year was underway at the time of this paper, this paper presents evaluation findings for years two through five (2014 – 2017). The next sections outline evaluation purposes, questions, design, and assessment to provide background and context for our findings on what contributes to implementation of an integrated STEM plan in PreK-12 settings.

Program Evaluation

Evaluation purposes

The primary purpose is to provide feedback on the program's implementation. The evaluation emphasizes assessment of program components that support and/or hinder participants' development of a school/district-wide STEM integration program. The evaluation provides the program with continuous data to help the developers make informed decisions based on systematic, representative information. A second purpose of the evaluation is to ascertain the effects and outcomes of the program; both at the end of the program and a year following participation. The evaluation also addresses factors outside of the program's purview that support and/or hinder implementation of STEM integration in the participants' settings.

Evaluation methods

Serving dual purposes of implementation and outcomes as described above, the evaluation follows the Joint Committee's Standards for Program Evaluation [14] and the American Evaluation Association's Guidelines for Evaluation. The utilization and developmental evaluation focuses of prominent evaluator, Michael Q. Patton [15], serve as a foundation for all aspects of the evaluation.

A mixture of qualitative and quantitative approaches supplies data for decision making and assessment of goal attainment. Data gathered from print/online surveys, focus groups, interviews, documents, and participant observation inform the program. Analysis of the data

includes the use of descriptive statistics, comparison of mean differences, and analysis of variance. Content analysis of written and spoken comments, documents, observation notes are triangulated with quantitative data. After each all-day team meeting, the Summer Institute, the end-of-program session, and the two follow-up evaluations, the evaluator provided a report, with recommendations.

In the next session, we summarize the measures used and the results from them. First, we discuss the implementation or formative aspects of the evaluation, followed by the outcomes or summative aspects. Evaluation and survey questions are provided in Appendix C (implementation) and Appendix D (outcomes).

Evaluation results

Program implementation: overall results

The implementation evaluation was designed to assess effectiveness of program activities, document implementation of program activities, and obtain data to help plan for future sessions and years. The data for the implementation evaluation were collected through the following measures:

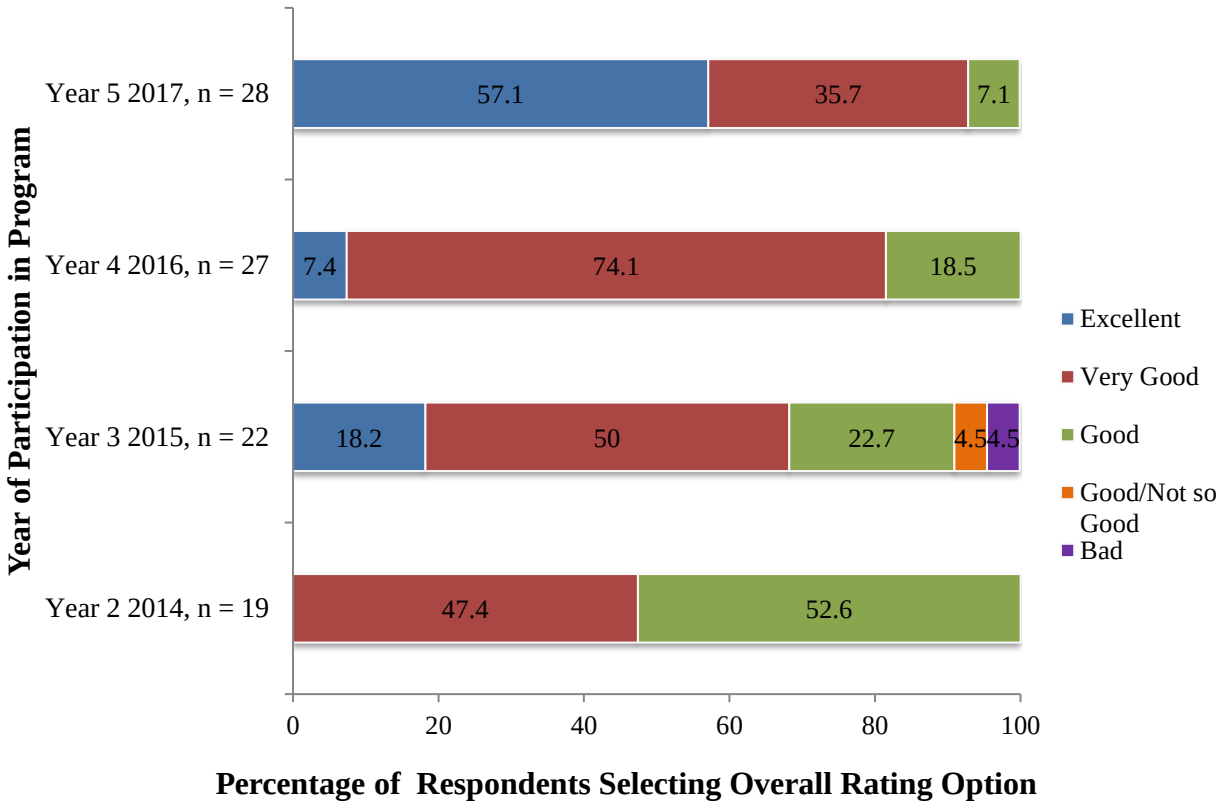
1. End-of-Summer Institute survey
2. End-of-program survey
3. All team meetings (workshops) minute evaluations
4. Participant observation
5. Informal comments (e.g., reunion, alumni visits with new teams, presentations)

Although 160 people participated in the STEMi program, the potential number for the evaluation is 118. The 22 people who are part of the current year, year six, are not included. During the first year of the program, different evaluation approaches were used, precluding inclusion in this report. Participants and respondents for each year reported in this paper are displayed in Table 2 below.

Table 2. Program participants and survey responders

Year of Program	Number of Participants	Respondents #	Respondents %
Year 2 – 2014	26	20	76.9%
Year 3 – 2015	31	25	80.6%
Year 4 – 2016	33	27	81.8%
Year 5 – 2017	28	28	100.0%
Total Years 2 – 5	118	110	93.2%

Overall ratings of the program were generally positive and increased with each year of the program, as seen in Figure 2.



Ratings: 1 = excellent, 2 = very good, 3 = good, 4 = not so good, 5 = bad, 6 = terrible

Figure 2. End-of-program overall ratings

There was a statistically significant mean difference in ratings between the years of the program ($F_{1,3} = 10.22$, $p<.01$.) Post hoc analyses showed statistically significant differences between year five and years two through four. Mean ratings by participants in the fifth year were between excellent and very good, while mean ratings for the second year were between very good and good.

Although most respondents did not write a comment related to ratings, the person who selected "bad" in year three, a teacher, noted wanting to make connections with faculty at the program's institution and to receive lessons to use in the classrooms, which are not a focus of the program.

There was no statistically significant mean difference between administrators' and teaching staff's overall ratings.

Program implementation: activities/components results

On the end of the program survey, participants rated specific activities and components of the program. Most respondents noted that specific program components were helpful. In the graphic in Appendix E 'strongly agree' and 'agree' ratings are combined as helpful and

‘disagree’ is delineated as not helpful. Only one person chose ‘strongly disagree’ for one component, opportunity to find out about STEM events. STEMi staff expertise and support received the highest ratings, followed by tasks or homework that teams were expected to complete between all team meetings.

Although almost all respondents rated the amount of time allocated for presentations by panels (89.9%) and by their and other teams (85.0%) as “just right,” about a third (31.0%) of respondents indicated that there was not enough time allocated to work with their teams.

We triangulated ratings with reviews of comments about the program. The comments provided insight into what worked or did not work. For instance, participants stated that the structure of the program “keeps them on task” and that having the program staff “in the room” with them keeps them focused. Rubrics and STEM frameworks helped guide them, they said, when creating outcomes and objectives.

To address the findings of the formative evaluation, the program’s staff engages in constant improvement of the STEMi program. Some of the changes made during the year include the clarification of terms, the requirement to develop a team definition of STEM education, providing teams with STEM frameworks such as [16], [17], and [18], and establishing the mentorship program.

Outcomes evaluation results

The purposes of the outcome evaluation include assessment of the effects of participation in the program, determination of the extent of implementation of a strategic plan (follow-up), attainment of program objectives, and assessment of program components and strategies. Outcomes were assessed at two points: at the end of the program and, for two teams, a year after program completion. Evaluation questions related to end-of-program and follow-up evaluations, found in Appendix D, include content related to program effectiveness and extent of changes in STEM integration knowledge.

End of program

At the end of the program, participants rated the extent to which their knowledge of STEM resources and of STEM integration at their schools and at other schools increased. Participants also described what happened or did not happen as a result of being in the program.

As reported earlier, the STEMi program was highly rated by its participants. They reported that program components helped them create a plan. On year-end surveys they wrote about how they developed a plan, articulated a vision for STEM integration, and gained confidence. In addition, they mentioned having a better understanding of STEM and enhanced communication and collaboration between teachers and administrators.

Almost all respondents agreed or strongly agreed that the program increased their knowledge of STEM integration at their school (94.8%) and other schools (96.0%). Most respondents (82.4%) agreed or strongly agreed that they learned more about more STEM resource availability as a result of the program (Appendix F).

We also assessed the extent of agreement that the STEMi program increased respondents' knowledge in the three areas. Similar to implementation ratings, knowledge ratings improved over time, with the greatest mean differences between year 5 and earlier years ($F_{1,3} = 5.36$, $p<.01$) for knowledge in schools. There was no statistically significant difference between team years for knowledge of STEM resources.

Follow-up of years two and three

One year after year two and year three's participation ended, the evaluator conducted a follow-up evaluation. The design of the follow-up component was post-only, targeted sample.

Participants included selected members of teams that enrolled during year two and year three. While the interview criteria included recruiting team members who actively participated in the program and selecting an administrator and a teacher from each team, we found following the criteria was not always practical. Staff turnover and scheduling conflicts hampered interviews with teachers. In the end, twenty-two participants who were members of the eight teams were interviewed. This included 15 administrators (68.2%), one administrator/teacher (4.5%), two specialists (9.1%), and four teachers (18.2%)

An open-ended interview served as the main data collection method. Teams members described STEM integration at their school during the time since their participation in the program ended. Another information source was team members' ratings of the current extent of STEM integration at their school or district. Documentation from the team's school or district websites supplemented interview data. Interviews were conducted onsite and recorded, with permission to record and to quote anonymously obtained. The evaluator listened to the recordings to verify and expand notes. Listening to recordings also allowed for transcription of relevant quotes. Standard content analysis practices were used to develop themes and patterns. The amount of STEM integration was guided by rubrics the STEM Education Center provides to participating teams.

Ratings of implementation a year after program end were "a lot," "moderate," "a little," and "not at all." Teams preferred to rate separate grade bands, such as K-8, rather than the whole district or school. After providing a rating, team members were asked to talk about what happened since they left the program and what successes and challenges they encountered.

The follow-up evaluation showed differences in the extent of STEM integration one year after the program; a little, moderately, and a lot. Amount of integration varied across grade bands, with the greatest amount of implementation in the elementary grades.

One year after the completion of the program, the teams continued to rate the program as helpful and valuable. They discussed how the logic model/strategic plan helped them to implement STEM in their school or district. Some teams noted that they followed it exactly, while others said they used it as "a guide" or "a foundation."

In the next section, we discuss the implications of our evaluation results for program development and implementation.

Discussion: Elements that support and hinder plan development and implementation

Comments from our surveys, interviews, and other data sources allowed us to uncover factors that support implementation of integrated STEM plans. First, we discuss program components. Next, we present factors that facilitate and hinder implementation in educational settings.

(a) Elements that support strategic plan development (program components)

Analysis revealed five program components that helped participating teams develop their STEM strategic plans:

1. **Development of logic model**. Program participants indicated that developing the strategic plan and logic model was the most useful component of the program. Defined as 'product driven', the program guided the teams to define a common vision for STEM integration and articulate the pillars of their program. Program staff applied the 'backwards design' by having participants determine the outcomes of their STEM plans prior to the action steps or resources needed.

2. **Structure**. The second component that contributed to the success of the program was its structure. The length of the program (a full academic year) allows for multiple PDs and opportunities for the teams to meet outside of the school. The structure of the program included accountability: the teams were expected to attend all meetings, complete 'homework' tasks, and present their progress to the other teams. This expectation forced the teams to meet in between PDs and move on according to the timeline. Participants commented on the flexible-structure in the development of the strategic plan: the requirements from all teams were similar, yet each team was encouraged to align the logic model with their specific community needs.

3. **Teams**. The third component contributing to the success of the program was the team format. One of the application requirements was that applying teams include a mix of administrators, teachers, and teaching support staff, representing the entire school or district. Teams reported that the program strengthened in-school/in-district relationships among participating members, and provided the opportunity for direct interactions among people who may work in different buildings or teach different subjects. We noticed that the team format allowed for new collaborations to develop and some ideas about integrated projects to bud during team work time. In addition to the power of all-school or all-district teams, participants found value in presenting to and learning from other teams in the current year of the program, as well as learning from past teams who came back to mentor or present their progress to the new teams.

4. **Best-practice/research-based program design**. The fourth element contributing to the success of the program is the reliance on research-based documents and frameworks. The program was developed based on peer reviewed publications and national reports (for example, [1], [2], [5], [9], [10], [19], [20]). Following recommendations from the literature, the program was designed to guide participating teams in researching the common elements of successful STEM schools, developing a shared definition of STEM education,

unpacking the core ideas and practices of the NGSS, addressing the gender and ethnicity gap in STEM professions, and using established frameworks for high-quality STEM schools to develop their own strategic plans. In addition, the STEMi program engages in ongoing formative evaluation to ensure the improvement of the program and update it based on the most current literature.

5. **Connections and partnerships**. The fifth and last element reported by participants as helpful in developing their strategic plans is the partnerships and collaborations established by the program. Participants commented on the helpfulness of the knowledgeable facilitators, connection with the STEM Education Center and its various outreach opportunities, and connections with past participants of the program. Lastly, the program established two panel discussions that received high praise from participants: the first is panel of STEM industry small business leaders, who share with the teams their needs and expectations from incoming workers. The second panel brings faculty from universities and community colleges who share with the teams the gaps and achievements of incoming students. Both panels allow the teams to align their goals and outcomes with college and careers needs. Team members also connect and consult with the presenters to establish partnerships of their own.

(b) Elements that support STEM plan implementation within a school or district

A program such as ours can steer a school or district towards developing STEM integration. But what happens once the program ends and participants return to their schools? Based on evaluation findings from five years of the program, we present conditions and factors that appear to support STEM integration in a school or school district. Our findings were seen consistently across public and private schools.

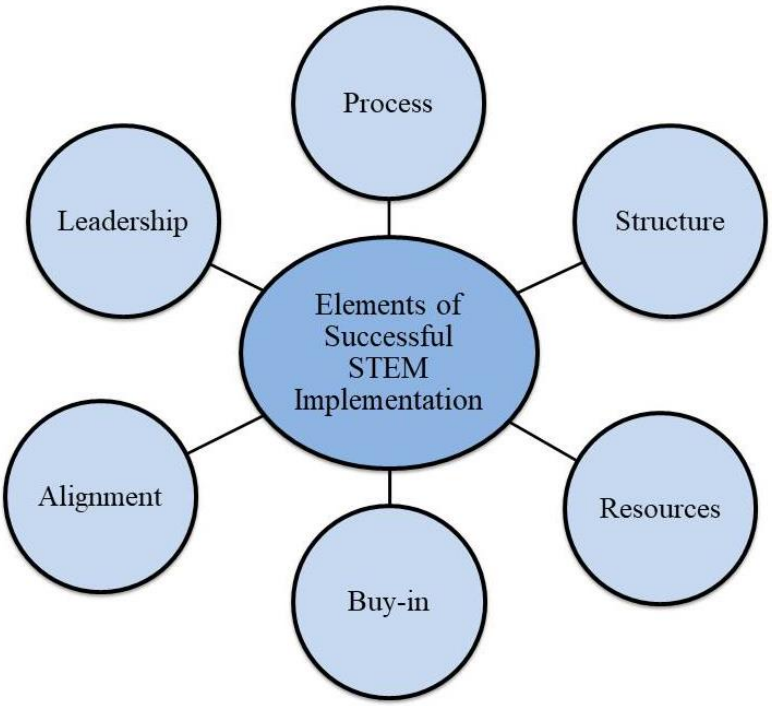


Figure 3. Elements of successful STEM implementation

1. **It's a process!** Throughout the program we stressed that implementation of integrated STEM is a process, not a one-time event. Participants' comments suggest that they followed the recommendation. During follow-up interviews and when returning to share with current teams, past participants emphasized that schools should not expect everything to start at once. "Start small" and "expect changes," they recommended. This outlook mirrors the engineering design process on which much of the STEMi program was based and is intrinsic to STEM integration. Past participants also described the need for a plan that is on-going and long term, with inherent flexibility to create a plan and to design curriculum. Underlying further elements of a successful STEM integration is the idea that implementation and plans are feasible and realistic.

2. **Leadership is key**. A key feature of successful STEM integration is leadership; having one or more key people who both exhibit enthusiasm and have authority to implement a plan. When key people share a common knowledge of pedagogy and concepts of STEM integration, it is more likely to occur in the setting. While administration support is essential, so is support from teacher leaders. Ideally, teams suggest, there should be a leadership team comprised of administrators, teaching support staff, and teachers. However, an administrator or a teacher can spark enthusiasm. One principal reported how, by recognizing teachers who were exhibiting STEM integration in their classrooms, he started acceptance by the whole school.

3. **Structure: plan and schedule**. Although one should be flexible when creating a plan, a logic model or strategic plan is needed. All follow-up interview teams stated that they use the logic model or strategic plan developed during the program, but to varying degrees. All teams reported that it functions as a foundation or guide. While, for some teams, it serves as a "baseline" for others it is a more structured plan. However, even teams that follow what they developed during the program report that they "made a few tweaks" to it.

   Articulation of common goals and outcomes not only helps to create plans, but also to market STEM integration to administration, school committee, and the community. In order to implement STEM integration, planning time needs to be scheduled in advance. Consistent and representative attendance at meetings is important, and based on feedback from past participants, we encourage the teams to schedule meetings for the on-coming year before they leave the program. Participants noted that having specific tasks to accomplish helped them to focus and plan. Rubrics and frameworks from successful STEM programs also provided structure.

4. **Resources**. Resources are multi-faceted. They include money, budgeting, grants, materials, and curricula. Teams mentioned that while a line-item for STEM integration in the budget is helpful, it does not have to be a large amount. Although having a STEM integration coordinator or other staff support can be very helpful, it is not imperative. STEM may be integrated by enhancing current activities, collaborating with other staff, finding local sources for materials and funds, and tapping the community.

   Teams lauded the value of an Advisory Committee of parents, teachers, and members of local businesses and non-profit organizations. Having the committee create goals,

objectives, and specific activities enhances their viability. One activity which teams reported as helpful is having an Advisory Committee create a database of parent and community resources. Continued connection with the University and with other STEM team members is helpful.

Teams tap into the University's professional development and faculty link after completing their program. After participating in the program, team members reported that they feel empowered to contact other institutions in their area. More than one team talked about how participating in a program at an institution with a good reputation enhanced the credibility of their work.

Time is an important resource related to finances and curricular requirements. Time is a resource that is typically limited at schools. Making time for collaboration and planning is vital, teams say. Under structure we talked about the importance of making time to meet, plan, and offer professional development.

5. **Buy-in, enthusiasm**. In order for STEM integration to be successful, teams relate, not only key people, but other educational staff should share a common understanding and enthusiasm. This may start slowly, they say. A teacher in one classroom who shares his/her success with integrating STEM may influence others, especially if there is structured time to do so. When teachers realize that STEM integration is not necessarily new, but something that builds on and enhances their current teaching, they often find the approach more acceptable.

   Most teams had a culture of STEM integration or a STEM mindset as one of their over-riding goals. To attain this goal, they articulated the need for a shared understanding of the definition of STEM integration and its pedagogy. The goals, outcomes, objectives, and activities that the program participants created in their logic models were shared with and adapted by the staff.

6. **Alignment is "crucial"**. Buy-in and enthusiasm cannot occur, they stated, unless the plan is aligned to state curricula standards, to school's or school district's strategic plans, and school curricula. Vertical and horizontal alignment is required. One school whose STEM integration plan matched with its strategic plan was able to implement STEM integration well into its curricula.

   Massachusetts revised its science standards to incorporate the Next Generation Standards. It gave teams the opportunity to align their plans with the new standards. The current emphasis on cross disciplinary learning facilitated the alignment.

(c) Elements that hinder STEM implementation

When factors such as those described above are not in place, implementation of STEM integration suffers. At schools where implementation was limited or emerging, we uncovered examples of situations that impede their progress. For instance, 3 key people retired and 2 people left from one school the year after the program ended. We discovered that only one teacher was able to teach a few lessons with a STEM integration focus. The new principal stated

that she had "other, more pressing priorities." In another school, the director moved away from the state and no one continued to implement STEM. Although at the interview the new director claimed to be an advocate for STEM, she did not encourage it during her first year.

Even though there was no turn-over, administrative support which was required for program participation did not continue in two other school districts. One school with limited support from the administration had some success implementing STEM. A key person, the principal of a preK–3 school, facilitated STEM integration in his school. Without central office help, he started small by supporting and applauding teachers who demonstrated STEM integration in their teaching. The teachers were encouraged to share their work at staff meetings. A scheduled professional development session became STEM focused. The principal secured a grant to hire a STEM coordinator who is a former teacher in the school. After two to three years, the school became a STEM integrated school. Parents are enthusiastic about the approach, the principal said. He thinks that parents may demand STEM integration at the next 4 – 6 grade school and he is working with the principal and teachers at that school.

Finances and lack of resources were reported as the limiting factors by other school districts with limited implementation. A few teachers are implementing STEM, but it is not district or school wide. Further follow-up, however, may uncover more implementation.

Conclusion

This paper presented the *STEM Integration for Education Leaders* program, developed and facilitated by the STEM Education Center at WPI for six years. The program was developed due to the need identified by research to guide and support education leaders in the process of planning for STEM integration. The program was designed based on the literature of systemic change in schools and evaluated formatively during the years. The findings align with and add to the body of literature regarding the implementation of STEM integration.

Over the years we had teams that were more successful than others in developing and implementing their plans, we surveyed the teams in order to learn how to better support future teams on the program. We found that guiding teams in creating a logic model for their plan and applying the backwards design (outcomes first) resulted in complete plans. The structure of the program, with multiple PD days and school visits, was found to help teams to progress on their plans. The team format, allowing multiple people from a school or district to collaborate (and struggle) together, while meeting teams from other schools and districts, supported the development of the plans. Similarly, the opportunities to partner and collaborate with STEM business leaders and university professors contributed to development of outcomes that are aligned with the needs and recommendations of college and industry. Lastly, using rubrics and frameworks that are research based, aligning outcomes to states and national standards, resulted in high quality plans that could be justified to stakeholders.

Once the teams created their plans, each school or district took a different route in implementation. We found that leadership is indeed a key to successful implementation. Without a leader who shares the vision of the plan – the implementation is likely to stay on paper. Since the plan is long-term, some schools took an extra year to pilot the action steps identified in the plan. All teams realized that it is a process, and they should 'bite as much as they can chew'.

Obtaining commitment from all stakeholders, and especially teachers, was also found to support successful implementation. Finally, alignment of the strategic plan with the whole school mission, such as alignment with standards, curriculum, and the school strategic plan was found to support the STEM implementation.

The main implication for schools, districts, and researchers who support education systems, is the understanding that establishing a sustainable STEM program is a process. Like any systemic change it is a long-term process that requires the engagement and support of all stakeholders, starting with the definition of what STEM education means for their communities, progressing with the development of pillars, outcomes, and action steps, supported by investment of resources to build the capacity for the change. Following six years of the program, we are still looking to answer the following questions:

1. What is the extent of involvement and commitment from the administration required for a sustainable STEM integration?
2. How does the team-developed definition for STEM integration manifest itself at the classroom level and by teachers who were not part of the program?
3. How can we better help schools articulate long-term outcomes in addition to short-term benchmarks and action steps?

To answer these questions and share lessons learned, the team at WPI has recently established a collaboration with a team from Northern Arizona University to develop a detailed guide for other entities interested in following the process to establish high quality STEM, STEAM, or STREAM program.

Acknowledgment
The program was funded in part by EMC and Dell-EMC. The authors are grateful for the support which enabled the follow up evaluation and provided some seed money for the team's STEM plans. We would also like to thank Dr. Katherine Chen for her thoughtful comments about the paper.

References

[1] C. Tanenbaum, "STEM 2026: a vision for innovation in STEM education," US Department of Education, Washington, DC, 2016.

[2] National Reserach Council, Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics, National Academies Press, 2011.

[3] National Research Council, Monitoring progress toward successful K-12 STEM Education: A nation advancing? Committee on the Evaluation Framework for Successful K-12 STEM Education, Washington, DC: National Academies Press, 2013.

[4] National Science Board (US), "A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system," National Science Foundation, 2007.

[5] President's Council of Advisors on Science and Technology, "Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future," Washington, DC, 2010.

[6] H. S. Adelman and L. Taylor, "Systemic Change for School Improvement," *Journal of Educational and Psychological Consultation,* vol. 17, no. 1, pp. 55-77, 2007.

[7] P. Cobb and K. Jackson, "Towards an Empirically Grounded Theory of Action for Improving the Quality of Mathematics Teaching at Scale," *Mathematics Teacher Education and Development,* vol. 13, no. 1, pp. 6-33, 2011.

[8] K. Leithwood, K. S. Louis, S. Anderson and K. Wahlstrom, "How Leadership Influences Student Learning," The Wallace Foundation, New York, 2004.

[9] R. W. Bybee, "Advancing STEM Education: A 2020 Vision," *Technology and Engineering Teacher,* vol. 70, no. 1, pp. 30-35, 2010.

[10] R. W. Bybee, The case for STEM Education: Challenges and opportunities, NSTA press, 2013.

[11] J. A. Ejiwale, "Barriers to successful implementation of STEM education," *Journal of Education and Learning (EduLearn),* vol. 7, no. 2, pp. 63-74, 2013.

[12] M. Honey, G. Pearson and H. Schweingruber, STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research, Washington, DC: National Academies Press, 2014.

[13] N. Tsupros, R. Kohler and H. Judith, "STEM Education: A Project to Identify the Missing Components.," Center for STEM Education and Leonard Gelfand Center for Service Learning and Outreach, Carnegie Mellon University, Pittsburgh, 2009.

[14] D. B. Yarbrough, L. M. Shulha, R. K. Hopson and F. A. Caruthers, "The Program Evaluation Standards: A Guide for Evaluators and Evaluation Users Third Edition," Sage Publishing, Los Angeles, 2011.

[15] M. Q. Patton, Essentials of utilization-focused evaluation, Sage Publications, 2012.

[16] T. Benn, "NYC STEM Framework," [Online]. Available: http://schools.nyc.gov/NR/rdonlyres/DE2FC1DE-5FB8-474F-BD27-D75FF70EF610/0/STEMframework_WEB1.pdf. [Accessed 18 March 2018].

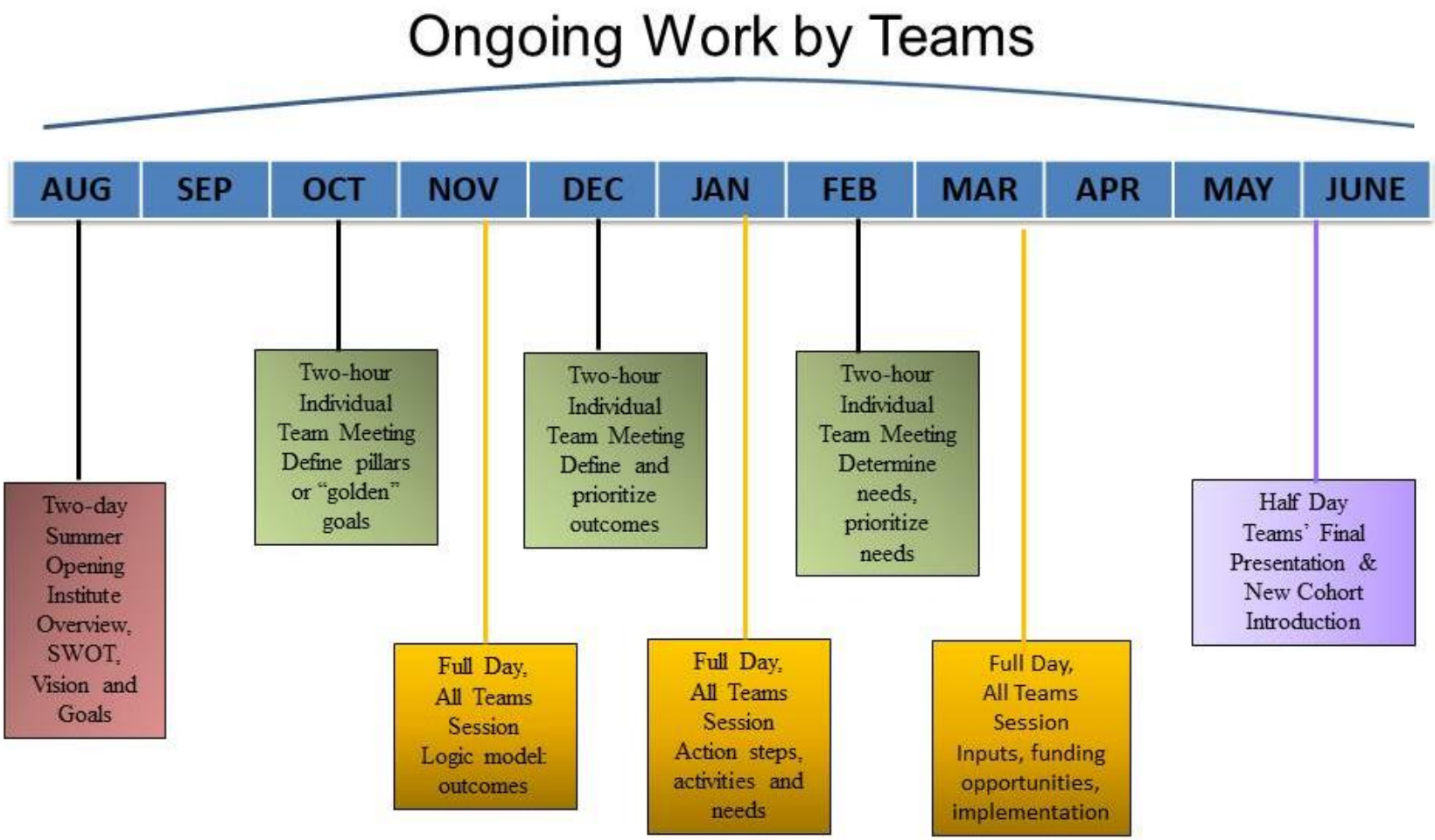
[17] Friday Institute for Educational Innovation, *Middle School STEM Implementation Rubric,* Raleigh, NC: Author, 2013.

[18] M. LaForce, E. Noble, H. King, S. Holt and J. Century, *The 8 elements of inclusive STEM high schools.,* Chicago, IL: Outlier Research & Evaluation, CEMSE| The University of Chicago., 2014.

[19] National Research Council, A framework for K-12 science education: Practices, crosscutting concepts, and core ideas, National Academies Press, 2012.

[20] M. Pinnell, J. Rowly, S. Preiss, S. Franco, R. Blust and R. Beach, "Bridging the gap between engineering design and PK-12 curriculum development through the use the STEM education quality framework," *Journal of STEM Education: Innovations and Research,* vol. 14, no. 4, p. 28, 2013.

Appendix A: Program's timeline



Appendix B: Program's Opening Institute Agenda

STEM INTEGRATION for EDUCATION LEADERS

Opening Institute Agenda*

Day I

8:30 - 9:30	Opening & Introduction
9:30 - 10:50	Defining STEM Education Components of quality STEM learning The Engineering Design Process
10:50 – 11:00	Break
11:00 - 12:30	What does successful STEM education look like?
12:30 – 1:15	Lunch (on your own)
1:15-3:15	SWOT analysis – strengths, weaknesses, opportunities and threats in relation to STEM education
3:15-3:30	Program's website teams' photos closing

Day II

8:30-10:20	The NGSS and STEM education
10:30-12:00	Panel Discussion: Business-School/District Collaboration Models
12:00-1:00	Working lunch with panelists
1:00-2:50	STEM vision and goals
3:00-3:30	Preview of next meeting + homework assignment Schedule future meetings Evaluation Closing

*Please note: the agenda is tentative and subject to change based on daily formative evaluation

Appendix C: Evaluation questions and items

STEMi program evaluation questions and items

All team meetings minute survey questions

1. Give us a grade, an overall rating (5 to 1, where 5 is excellent and 1 is poor)
2. Please describe what was helpful in today's session.
3. Please describe what we can do to improve the next session.
4. Additional comments (space, panel, structure of the day, etc.)

End-of-Summer Institute sessions survey questions (2015 – 2017)

1. Please select your overall rating of this Summer Institute
2. Excellent, very good, good, not so good, bad, terrible
3. How well did the Summer Institute provide you with the a) information and b) strategies to start the process of STEM integration in your district/school?
4. Extremely, very, moderately, slightly, not at all
5. Describe the components, activities, parts of the Summer Institute that were a) effective and/or b) not effective in helping your team move toward creating a STEM Integration plan.
6. Please describe what we could do to improve the Summer Program for the next group of District Leaders and what we should keep.

End-of-program evaluation survey questions

- School/District and Position (no other identification)
- Check list of sessions respondent attended
- Overall rating of program: excellent, very good, good, not so good, bad, terrible
- Likelihood would recommend program: very likely, likely, somewhat likely, not likely
- Likert scale of agreement extent agree/disagree that knowledge increased
  - STEM/STEAM integration in other schools/districts, in your school district, resource(s) availability
  - NGSS: Next Generation Science Standards
  - Components of high quality STEM/STEAM education
- Likert scale of agreement program resources helpful in creating STEM/STEAM plan
  - Expertise of program staff
  - Support of program staff
  - Opportunity to know about different STEM/STEAM events at or related to program's institution
  - Bimonthly meetings at program's institution
  - Bimonthly meetings with program director and evaluator at year's school
  - Tasks to work on at schools (homework)
  - Information about funding resources
  - Networking with other schools/districts

    - Selected STEM rubrics/frameworks to guide planning
- Helpfulness of working sessions a) at institution, b) at participant's school, c) with team: very much, moderately, slightly, not at all, n.a.
- Likert scale of agreement extent agree/disagree helpfulness of Summer Institute Activities (each activity listed separately … with "did not attend" option)
- Likert scale of agreement extent agree/disagree helpfulness of each all teams' meetings at program's institution (each session and its activity listed separately … with "did not attend" option)
- Rating of amount of time allocated for components of meetings at program's institution: too long, just right, not enough.
    - Presentations by schools/districts, presentations, panels, working with team on tasks
- Open-ended: describe the effect, if any, the STEMi program had on you and/or your school district. Tell us what happened, didn't happen, as a result of being in the program.
- Open-ended: aspects of program to keep and change. With request for specific examples.
- Space for anything else they would like to add.

End-of-program "focus group" … number of participants 20 to 30, precluding use of traditional focus group format, formed small groups of team members instead

- Write on flip-chart easel paper what participants should know about the STEM integration program, specific things that would help new years as they start out and program and progress through the year
- Write on flip-chart easel paper or letter-sized paper key helpful and unhelpful components (less emphasis than first activity)

Participant observation

- Taping of presentations
- Extensive note taking
- Pictures during all team meetings

Appendix D: Follow up (outcome) evaluation questions and items

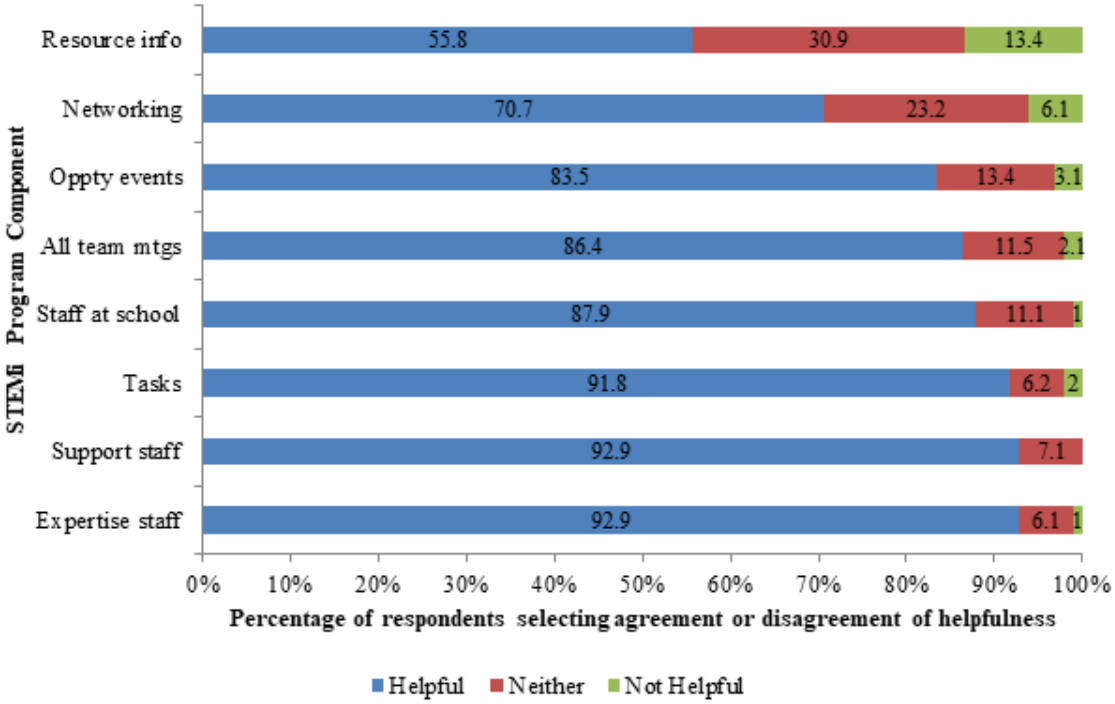
Evaluation questions related to implementation

1. What factors facilitated or impeded participants' ability to develop a strategic plan for STEM integration?
2. How do participants rate the program overall and its specific components?
3. What are participants' reactions to program activities?
4. What conditions (e.g., confusion, interactions) were observed during program meetings?

Evaluation questions related to outcomes

1. What facilitated or hindered development and implementation of STEM/STEAM integration … both institutional and non-institutional factors?
2. How effective was participation in STEMi in supporting the districts/schools' implementation of a strategic plan for integrated STEM?
3. *Follow-up:* As a result of participation, to what extent was long-term, district-wide quality STEM integration planned, developed, and implemented?
4. *Follow-up:* Compared to when the districts/schools entered the program, where are they now in providing STEM integration? To what extent have participants made progress toward integration?

Appendix E: Ratings of helpfulness of specific components of the program



Percentages are based on responses. Missing values ranged from 1 to 4.

Appendix F: Outcome Evaluation Results