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Determining the Efficacy of a K-12 and Higher Education Partnership (Evaluation)

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Abstract

Engineering students and professionals in the United States do not reflect the country's demographics. Women and minority students remain largely underrepresented. To help diversify the STEM pipeline, it is essential students are exposed to and engaged in STEM active learning experiences in K-12. This is especially effective when post-secondary institutions partner with K-12 schools. Establishing the partnership can be challenging as the institutions must have congruous objectives, determine who is responsible for what, and define success similarly. To address this set of issues, a program partnership rubric was designed. The rubric was then used to plan and evaluate four piloted STEM program collaborations between the University of Massachusetts Lowell (UML) and the Advanced Math and Science Academy (AMSA) charter school.

The four programs included an AMSA-exclusive STEM open house at UML, as well as three engineering summer camps, one for middle school students, and two for high school students. UML's overarching objective was to increase the number of underrepresented students from AMSA who showed interest in and applied to STEM fields at UML. AMSA wanted to provide access to hands-on STEM activities and/or representative role models for AMSA students from traditionally underrepresented populations. The programs succeeded in varying degrees at meeting stated objectives. The open house led to the most scalable model that UML has now adopted with several school districts. The other programs will continue if grant funds continue to be sourced. The success of these programs in meeting their objectives demonstrates how vital it is to jointly consider three factors: Results (learner outcomes), Reproducibility (adequacy of resources), and Representation (diverse and inclusive staffing and student participation). The program partnership rubric was developed to help partnerships plan and evaluate their programs based on these three factors. How the rubric was used to plan these pilot programs and determine how and/or whether to run them again is explained.

Introduction

In the United States, students in engineering programs and professionals in the engineering workforce do not accurately represent the general population. For example, despite making up 50 percent of the population, women represented only 24 percent of engineering bachelor's degrees conferred in 2021 [1]. Furthermore, although 12.1 percent of the US population is Black only 4.7 percent of engineering bachelor's degrees conferred were to Black students. Research suggests that earlier exposure in K-12 programs to STEM active learning experiences encourages greater participation in STEM amongst women and Underrepresented Minority (URM) students [2], [3]. As such, it is vital that K-12 districts introduce students to and interest students in STEM fields and careers.

An effective strategy is to build school-university partnerships where students can engage in activities that allow for greater understanding and interest not just in the field, but in the university context [4]. In an effort to expand and diversify the STEM pipeline, K-12 educators, professors, and researchers have increasingly been working together to offer out-of-school-time (OST) opportunities for students to explore STEM careers with promising results [5]. It can be challenging for K-12 schools to initially develop relationships with higher education institutions though. Furthermore, determining efficacy of OST programs can be difficult, as most metrics developed focus on learning objectives and learner attitudes, and make it difficult to navigate how to pair these results with logistical and programming concerns [6].

Historically, universities and K-12 schools have collaborated successfully in teacher education efforts and different rubrics and protocols exist for these efforts [7]. Universities and school districts have also partnered to collaboratively come up with programs to meet specific needs, such as developing programs that allow for dual enrollment for high school students in both their district as well as a partnering post-secondary institution [8], [9]. However, the requirements of these types of accredited programs means the tools developed do not offer much guidance to less formalized co-ventures. Increasingly, higher education institutions and schools have been partnering to offer STEM learning opportunities [10], [11], meaning the need for tools that help structure and assess such programs is also increasing. It is especially important that planning and evaluation tools include ways to tangibly consider and assess how inclusive a program is [12]. Tools and rubrics have been developed specifically for STEM faculty to self-assess their individual and departmental efforts in being more diverse, equitable, and inclusive [13], but no specific guidance exists to help in building partnerships to develop programs. This lack of guidance on planning and evaluating program partnerships led to the development of a rubric to guide and assess four pilot programs in the collaboration between the University of Massachusetts Lowell (UML) and the Advanced Math and Science Academy (AMSA) charter school in Marlborough, Massachusetts.

Partnership Background

UML is ranked in the top ten percent of universities nationwide for conferring engineering bachelor's degrees to URM students [1]. In an effort to increase their success, UML wanted to recruit more URM students and women who would be highly qualified candidates in engineering and STEM fields. AMSA is ranked second across all public high schools in the state of Massachusetts, with a high enrollment of students who come from underrepresented backgrounds in engineering: a 50 percent female enrollment, a 32 percent minority enrollment, and 24 percent High Needs enrollment (High Needs includes students who have a disability, are English language learners, and/or who are economically disadvantaged). UML wanted to partner with AMSA to increase underrepresented student applications to UML in STEM fields. UML also wanted to partner on initiatives that introduce younger (grades 6-8) underrepresented students to STEM active learning opportunities, as their teachers and students would be more likely to be better prepared to integrate such learning opportunities as a STEM-focused institution. AMSA was eager to participate as UML had access to more specialized equipment and their programming had greater capacity to handle more of their students during OST timeframes.

AMSA had a grant writer who was also a doctoral candidate conducting research on what supports improved academic engagement and outcomes. In her role, she was well-positioned to collaborate with university faculty and to write grants to fund these initiatives. UML has a Biomedical Engineering faculty member who had written for a grant to fund a collaboration before. These two individuals met and were able to collaborate, bringing in staff and faculty members from both institutions to create four programs. The four programs included one AMSA-exclusive STEM open house, as well as three summer camps: one oriented to middle school students; another introducing high school students to the engineering design process through prototyping prosthetics; and the last was a math acceleration academy where high school students applied advanced mathematics to engineering problems.

Program	Population	Purpose
STEM Open House	Grades 9 & 10	Attract UR AMSA students to STEM fields at UML through an AMSA-exclusive event
Introduction to Engineering Summer Camp	Grades 6-8	Give UR students hands-on experience in and exposure to different fields of engineering
Engineering Design Summer Camp	Grades 9-11	Attract UR AMSA students to STEM fields at UML by exploring the engineering design process through 3D printing prosthetics
Engineering Acceleration Academy	Grade 10	Encourage UR AMSA students to consider pursuing engineering at UML while developing their math ability and confidence

Table 1. An Overview of the Four UML-AMSA Pilot Programs

Determining Efficacy

AMSA and UML came into this partnership with similar but distinct aims. Both institutions wanted to encourage traditionally underrepresented students to pursue and persist in STEM, engineering specifically. UML hoped these students would do so at their institution.

AMSA wanted students to consider UML as well because UML offers financial aid packages that would benefit and incentivize their economically disadvantaged populations. As such, the four programs had some overarching objectives, but they all had their own specific initiatives, planning processes, student outreach, funding, and so on. For example, most of the programs were funded through a combination of grant-funding sourced by AMSA, and UML donations of facilities, materials, as well as faculty and staff's time. This meant that the AMSA coordinator had to keep track of fulfilling the parameters of the grant funding each initiative, and the UML coordinator had to manage university logistics, interests, and needs.

It became clear very quickly that a structure was needed for planning and evaluating the programs. The two original contacts (grant-writer and engineering faculty member) were designated coordinators of the programs and came together to determine a rubric that would guide and assess the different initiatives. A pre-existing tool could not be found that simultaneously measured student outcomes and program sustainability in terms of logistical infrastructure and capacity [6]. A third measure was also essential to this partnership, the ability to attract and support a diverse student population. Ultimately, it was decided that three factors were integral to this partnership and each program therein: Results, Reproducibility, and Representation. Results refer to clearly articulating program objectives and having an accurate way to measure success. Reproducibility assesses whether the institutions have adequate means to run the program currently and in the future. Representation refers to their ability to engage and support diverse learners. To measure each category, each category was broken up into three subcategories. The rubric is attached in Appendix A.

Results

Program results required determining program objectives clearly, and outlining which institution was responsible for which parts of programming. Additionally, a metric instrument had to be identified to measure these objectives, and a way to seek and assess stakeholder feedback needed to be determined.

Reproducibility

Reproducibility first determined the adequacy of current program supports, and also assessed whether sufficient resources were available in the future to run the program again. This category assessed three subcategories, beginning with employee capacity. Are there enough employees to plan and run the program? Are employee roles clearly defined? The next subcategory is logistical infrastructure. Are the facilities adequate for the programming? Does the timing of the programming work for staff and participants? Finally, financial supports were considered. What are the costs of the program? Which institution pays what cost? Are adequate funds available?

Representation

Lastly, evaluating the quality of program representation efforts required questioning the planning process and program itself across three subcategories. First, i) inclusive staffing, are staff members representative of the target audience of students? Are diverse perspectives welcomed in the planning of the program, as well as how it is run, and how success is defined? Regarding ii) inclusive student participation, are students invited and recruited in a way that encourages diversity? Are students selected in a way that matches their interests and abilities? Finally, are iii) adequate accessibility and appropriate accommodations sourced? Program coordinators should seek to discover what accommodations are required and what accessibility concerns students and staff have. These accommodations should be sourced, and then appropriate stakeholder feedback sought.

Rubric Outcomes

The rubric developed allows users to determine if each subcategory and correlating component is "developing," "meeting," or "exceeding" goals, in order to make the overall determination of whether the program "needs further development," can "continue as is," or "could be expanded." Both AMSA and UML had to consider the components of the rubric independently and then analyze findings together to plan the program and then determine program efficacy. This allowed the two institutions to determine the Return on Investment (ROI) for each program. Essentially, what is the cost per student? Do learner outcomes merit the expense?

These four programs were free to students through grant-funding, but as the grant-writer was grant-funded only through the 2021-2022 school year, both institutions understood new funding avenues would likely need to be sourced afterwards, greatly impacting how many programs would be determined "needs further development." In addition, the UML coordinator was taking on greater responsibility in their role at UML, and so both coordinators would need to be replaced to continue the programs. As such, although most of the programs met or exceeded their intended learner outcomes as well as their intended participation of UR students, most programs are deemed "In Need of Further Development" until funding and new leadership can be established. This outcome is common in school interventions, as often programs are contingent upon grant funding, and the success of an intervention hinges on one or two program "champions" [6]. This is why a rubric is essential to understand what elements determine the success and sustainability of a program.

Program Efficacy

This next section briefly describes each program and how it performs using the program partnership rubric.

AMSA-Exclusive STEM Open House

As the main objective of this partnership for UML was to increase enrollment rates from AMSA, a natural collaboration was to determine how to get more students onto the UML campus. The two coordinators met to determine a model for an AMSA-exclusive STEM open house at UML. AMSA sourced grant-funding for transportation and identified interested students. The university organized the event and provided lunch for students. The event was planned to coincide with a half-day at AMSA for teachers' professional learning so as not to interfere with students' classes as they were bused in after their school day ended.

The AMSA-exclusive STEM open house involved 40 eleventh and twelfth grade students, 85% from underrepresented populations. Overall, it cost $53.50 per student. 13 of the students who attended the event applied to the university, contributing to a 75 percent increase in STEM applications from AMSA to UML compared to the year before. This was deemed the most successful program of the collaboration. UML even used the model to expand to ten other school districts.

Program Title	*STEM Open House*
Results	**Exceeding:** 75% increase in AMSA applications to STEM programs at UML
Reproducibility	**Developing:** $53.50 per student, grant and donation funded
Representation	**Meeting:** 40 Students, 85% UR
Program Determination	Could be Expanded

Table 2. A Summary of the Listed Program's Determination Process Using the "Continuing Program Partnership Rubric"

Introduction to Engineering Summer Camp (Grades 6-8)

Over the summer, over six Fridays, middle school students from grades 6-8 were invited to participate in a collaboration between AMSA and the Research Academics & Mentoring Pathways (RAMP) program at UML. This collaboration was developed to offer underrepresented students in-group university and student mentors and role models while engaging in hands-on research that introduced them to the different fields of engineering. The invitation to participate went out to all parents in grades 6-8 via email and explained that this was a pilot study to seek further funding from the National Science Foundation (NSF), so preference would be given to students who identify as being from one of the underrepresented populations determined by the NSF. This meant ideally participants would identify as being from specified racial/ethnic origins, gender orientations (women), sexual orientations, economic backgrounds, identified as a first-generation college student, or had an identified disability. The middle school collaboration included 18 students, 83% from underrepresented populations.

This program was mostly grant-funded (with some funding for university student staffing provided by corporate partnerships) and included transportation (provided by AMSA) to and from the academic institutions as well as lunch (provided by UML). It cost approximately $400 per pupil. The greatest difficulty of the program was that the aim was to have students engage in hands-on activities in each field of engineering for which UML has a department. The College of Engineering at UML consists of six departments: Biomedical Engineering, Chemical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Mechanical Engineering, and Plastics Engineering. There was a university student group conducting research in each field; however, to have middle school students exposed to a different field of engineering each week meant they had very little introduction to the actual research skills necessary to be able to engage in experiments. This meant AMSA's students' time was more observational in nature, rather than hands-on. Still, 71% of AMSA students indicated in their exit survey that the experience made them more likely to consider becoming an engineer, and to consider attending UML. However, using the program partnership rubric this program is "in need of further development" prior to running again. New funding and coordinators must be sourced.

Program Title	***Introduction to Engineering Summer Camp***
Results	**Meeting:** Students report 71% more likely to pursue engineering
Reproducibility	**Developing:** $400 per student, grant and donation funded
Representation	**Meeting:** 18 students, 83% UR
Program Determination	Needs Further Development to Determine Future Funding & Future Coordinators

Table 3. A Summary of the *Introduction to Engineering Summer Camp* Program's Determination Process Using the "Continuing Program Partnership Rubric"

Engineering Design Summer Camp (Grades 9-11)

UML and AMSA partnered to offer an immersive two-week summer camp introducing AMSA students from underrepresented backgrounds to the engineering design process. Science teachers were asked to identify students from underrepresented populations in engineering who had an interest in STEM fields and would benefit most from hands-on experience and student-led inquiry. The goal was to increase self-efficacy in vulnerable populations. Teachers identified a possible participant pool of 50 students. 24 students decided to participate, 88% from underrepresented populations. In the first week, students met on AMSA's campus to develop team-work capacity and plan what prosthetic prototype they would like to 3D print to respond to an issue or problem they identified within the field of prosthetics. In the second week, they went to the university's campus and 3D printed their design. They also created posters and developed their final presentation for friends and family.

The program was grant-funded and provided busing to and from AMSA's campus from students' homes for student populations that identified this need, as well as to and from both institutions the second week for all participants. The overall cost of the program broke down to $708 per pupil. The S-STEM survey [14] was used as a pre- and post-intervention measure, as well as an additional exit survey. The S-STEM survey indicated no statistically significant changes in interest in or attitudes towards STEM. Program coordinators felt this was probably not the correct program metric instrument considering the population involved and the brevity of the program. The additional exit survey in comparison to the entrance survey saw no difference in students planning to apply to UML. However, 75% of exit survey respondents indicated that the program improved their understanding of Computer-Aided Design (CAD) and ability to apply those principles. Using the program partnership rubric, this program falls into "in need of further development" because either the program was unsuccessful according to program objectives or a better metric needs to be identified to measure success. Additionally, grant funds had expired, and new funds needed to be sourced.

Program Title	***Engineering Design Summer Camp***
Results	**Developing:** 75% improved CAD; No change in UML interest or STEM interest, new metric for success needed
Reproducibility	**Developing:** $708 per pupil, grant and donation funded
Representation	**Exceeding:** 24 students, 88% UR
Program Determination	Needs Further Development to Determine Future Funding, Appropriate Metrics, & Future Coordinators

Table 4. A Summary of the *Engineering Design Summer Camp* Program's Determination Process Using the "Continuing Program Partnership Rubric"

Engineering Acceleration Academy (Grade 10)

A grant-funding opportunity was identified to create a program where students would be asked to apply mathematical principles to different fields of engineering. This would allow for needed math preparation coupled with a practical introduction to engineering. However, the funding opportunity was prescriptive in nature and severely limited the timing and structure of program, as well as the objectives. A minimum number of hours of math instruction had to be offered, in classes no larger than 12 students. To follow these parameters, a 9 am – 3 pm, one-week summer program on UML's campus was designed where professors from different engineering fields presented a brief introduction to the field and had students work through a problem that covered the required mathematical principles. The program coordinators ran into two problems; students who needed remediation were not interested in the program, and professors were ill-equipped to incorporate the appropriate level of math instruction for the targeted population. This led to a student population with higher math capabilities than originally targeted, performing math problems at a much higher level than previously imagined.

Ultimately, the Engineering Acceleration Academy collaboration included 10 students, with only 40% from underrepresented populations. The program cost $1,300 per student, with transportation and lunch provided. All costs were covered by the grant sourced by AMSA. The exit survey indicated 100% of students reported they were more likely to consider attending UML, and 80% reported an increase in considering engineering as a profession. This program ultimately was determined to be "in need of further development" primarily because it did not meet the original objectives of reaching students underrepresented in engineering, leading to a poor showing in both the results and the representation categories. Finally, the funding for the program was through a specific grant, and coordinators felt the parameters of that funding opportunity were too limiting.

Program Title	***Engineering Acceleration Academy***
Results	**<u>Exceeding:</u>** 100% more likely to attend UML, 80% more likely to pursue engineering, 100% better understand math applications to engineering
Reproducibility	**<u>Developing:</u>** $1,300 per student, grant
Representation	**<u>Developing:</u>** 10 students, 40% UR
Program Determination	Needs Further Development to Determine Future Funding, Recruitment Strategies, & Future Coordinators

Table 5. A Summary of the *Engineering Acceleration Academy* Program's Determination Process Using the "Continuing Program Partnership Rubric"

Limitations

The rubric allowed program coordinators to plan programs in a way that clearly outlined program objectives, responsibilities, and expectations. This allowed UML and AMSA to identify ahead of time where their interests and abilities converged and/or diverged and anticipate any issues. However, the intention of the rubric was to create a tool that could be adapted to various program initiatives, as the open house and different engineering camps have vastly different structures and content. This tool was not designed to be prescriptive. It is meant to function as an outline for program partnerships to proceed in deciding how to plan and evaluate their joint initiatives. As such, programs should also have additional planning and assessment materials as indicated in the rubric. Finally, this rubric should be validated in research studies to test whether it accurately predicts a program's success.

Conclusion

The UML-AMSA partnership resulted in four pilot programs that were largely successful in meeting their stated objectives. In three of the four programs the majority of the students who participated were from underrepresented populations in engineering. In three of the four programs involvement in the program led to an increased interest in becoming an engineer and in applying to UML. The development and the use of the program partnership rubric identified the three areas that both institutions needed to consider in order to have a successful program: Results, Reproducibility, and Representation. Even if this exact tool is not used in the future, school-university partnerships would benefit from considering how to plan for and assess these areas. Schools and universities serve different student populations which impacts how each institution plans for and understands student needs. It is vital that when the two collaborate, they find a way to understand and consider the other's perspective. This rubric helped the two different institutions plan for successful programs and identify what program elements needed further development to allow for future program success. Further research is necessary to validate the rubric created, but the tool demonstrates a useful way to plan for and measure the success of school-university partnerships.

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Appendix A
Continuing Program Partnership Rubric

Public school staff and university staff independently use this rubric to assess the program and then compare results together.

Results			
	Developing	**Meeting**	**Exceeding**
Program Objectives	Program objectives for each institution are unclear and/or were unmet	Program objectives for each institution are clear and were adequately met	Program objectives for each institution are clear and were surpassed
Program Metrics	A metric to measure program success was either not used or did not appropriately measure program objectives. And/or metric demonstrates program failed to meet objectives	A metric to measure program success was used and demonstrated program objectives were fulfilled	A metric to measure program success was used and demonstrated program surpassed objectives
Stakeholder Response	Either stakeholder feedback was not sought, or it was mostly negative	Multiple stakeholders were consulted, and feedback was mostly positive	Multiple stakeholders were consulted, and feedback was overwhelmingly positive
Reproducibility			
	Developing	**Meeting**	**Exceeding**
Employee Capacity	Available staffing and staffing resources were not adequate for program and/or sufficient staffing is not available to run program again	Available staffing and staffing resources were adequate and similar staffing is available to run program again	Available staffing and staffing resources were more than adequate and similar staffing is available to run program again
Logistical Infrastructure	Available resources (facilities, transportation, materials, etc.) were not adequate for program and/or	Available resources (facilities, transportation, materials, etc.) were adequate for program and are available to run program again	Available resources (facilities, transportation, materials, etc.) were more than adequate for program and are available to run program again

	are not available to run program again		
Financial Supports	Available funding was not adequate for program and/or is not available to run program again	Available funding was adequate for program and is available to run program again	Available funding was more than adequate for program and is available to run program again
Representation			
	Developing	**Meeting**	**Exceeding**
Inclusive Staffing	Staff involved in planning and running program does not represent participant demographics	Staff involved in planning and running program adequately represents participant demographics	Staff involved in planning and running program represents student populations who would benefit most from further representation
Inclusive Student Participation	Students selected to participate do not represent the students who could benefit the most from the program (do not demonstrate an academic, social, or financial need to attend)	Students' abilities and backgrounds are well-suited to benefit from program objectives	Students were invited to participate based upon an explicit set of criteria designed to maximize program benefits
Adequate Accessibility and Appropriate Accommodations	Staff and student needs for accommodations were not considered, or accommodations were inadequate to meet needs	Staff and student needs for accommodations (including physical, academic, etc.) were sought and addressed	Staff and student needs for accommodations (including physical, academic, etc.) were sought and addressed in a way where accessibility did not isolate learners or highlight difference
*****Program Determination Overall:**	**Needs Further Development**	**Can Continue as Is**	**Could be Expanded**

- We recommend no more than one “developing” designation to receive a “Continue as Is” determination.
- We further recommend a final report that explains the findings and outlines future plans.