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College of Education, Belin-Blank Center for Gifted Education & Talent Development

STEM Excellence & Leadership Final Evaluation Report

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Overview

The *STEM Excellence and Leadership* project (Assouline et al., 2017) was funded by the National Science Foundation from 2017 to 2023 (Award #1713123) with additional support for project extensions from the Jack Kent Cooke Foundation. The primary goal of the project was "to raise the STEM interests, aspirations, and achievements of under-identified, high-ability middle school students in rural schools so that they would be prepared to take advanced coursework in high school and beyond." (p. 110, Assouline et al., 2023). The project was organized around a research-practice partnership (RPP) between The University of Iowa College of Education Belin-Blank Center for Gifted Education and Talent Development (B-BC) and 11 original partner districts. Schools used an above-level talent identification process to recognize a wide range of students with potential for advanced learning in STEM. Through out-of-school opportunities, teams of teachers created place-based opportunities for middle school students to engage in meaningful STEM learning. This report provides an overview of the rationale and design of the STEM Excellence Project, the key findings and takeaways from the research, and future directions for raising the aspirations of rural students for success in STEM fields. The work of creating opportunities is impactful and pathways to excellence in STEM must continue for students from rural and underserved communities.

B-BC provided learning experiences for both teachers and their students that provided enhanced opportunities to raise STEM aspirations while also honoring the expertise of teachers to create localized programs that served their students and leveraged the strengths of their rural communities. The opportunities provided by B-BC included training on Dimensions of Success for high-quality afterschool STEM programming and developing professional learning communities with experts in informal learning and STEM education. Students participated in 96 hours of out-of-school learning opportunities organized around advanced science and mathematics domains. Rural place was taken into account in all aspects of the program to urge districts to capitalize on community assets and expertise.

Outcomes

The project led to incredible learning opportunities for students in the partnership districts ranging from local environmental science projects to near-peer mentoring programs initiated by student participants to exposure to advanced learning opportunities such as the Junior Science and Humanities Symposium. The project also led to impactful research on talent identification and development of rural students with potential for advanced learning in STEM. Research on the identification process showed that teachers benefitted from integrating students' above-level testing results and psychosocial measures to create a more inclusive talent pool of students identified for programming (Assouline et al., 2017).

Research from this project also demonstrated that rural schools can promote students STEM aspirations and advanced achievement through services that are locally adapted to draw on community strengths and resources (Ihrig et al., 2020; Lakin et al., 2021). Program participation led to improved outcomes for students in these rural, underserved communities including enhanced academic self-efficacy and recognition of their STEM potential (Assouline et al, 2020). Importantly, the project showed how the talent development process is situated within many systems and contexts that affect students' developmental trajectory (Assouline et al., 2023). This suggests that talent development programs must be designed with these factors and influences in mind to create impactful opportunities for these students.

Learn more: Visit **https://belinblank.**org/excellence for an updated list of publications, information, and resources.

SECTION ONE: Program Overview

This section provides an overview of the *STEM Excellence and Leadership* project (*STEM Excellence*) and includes key components of the program, the rationale for implementing *STEM Excellence* in rural schools, and rationale for the emphasis on talent development and informal learning environments and teacher support.

Key Components of STEM Excellence

The *STEM Excellence* project (Assouline et al., 2017) was designed to help teachers foster STEM interest and talent among students in rural, under-resourced schools. The program originated in Iowa, where rural students make up a larger part of the K-12 population (34.2%) than we see nationally (18.7%; National Center for Education Statistics, 2017). The program worked to (a) enhance teachers' ability to identify and prepare rural students for high level mathematics and science classes, (b) expand middle school mathematics and science curricula, and (c) boost underserved middle school students' preparation for and achievement in the highest level mathematics and science classes in high school and beyond. The *STEM Excellence* project included five primary components:

1. Broadening the talent pool of students who come from under-resourced communities;
2. Drawing from the broadened talent pool to identify rural middle-school students with high STEM aptitude to participate in the STEM Excellence after-school programming;
3. Providing 96 hours of STEM after-school programming scheduled over 24 weeks, twice a week, for approximately two hours per session;
4. Offering professional development to the after-school facilitators of the program and;
5. Conducting research to understand how informal STEM learning shapes the academic and psychosocial outcomes of rural, high-potential students, as well as to identify key characteristics of successful informal STEM learning environments for rural, high-aptitude students and their teachers.

In seeking to broaden participation in STEM careers, the *STEM excellence* project chose to focus on afterschool programs designed for students in the middle grades. Afterschool (more generally, out-of-school) programs allow teachers greater flexibility to adapt their program to student interests and needs (National Research Council [NRC], 2015; Duschl et al., 2007). Middle school was also chosen because it is a vital period for STEM identity development. Students' interest in science, technology, and mathematics tend to decline (on average) in these grade levels (Ardies et al., 2015; George, 2000), suggesting that interventions to maintain interest are vital in these grades. In addition, these are the grades where students start to make choices in their courses and extracurricular activities that shape their preparation for careers later (Malyn-Smith et al., 2021). Carefully constructed STEM opportunities in middle school and high school have the potential to impact one's future career trajectory and success (Benbow, 2012).

An in-school talent search model (Assouline et al., 2017) was used to identify students for programming. Students who participated in *STEM Excellence* engaged in 96 hours of challenging curriculum in mathematics and science out of school. On average, students met 4 hours per week afterschool with their math and science teachers over a 24-week period throughout the academic year for 48 hours of mathematics instruction and 48 hours of science instruction.

Rurality and STEM: The What and Why of STEM Excellence

The *STEM Excellence* project focused specifically on integrating STEM into rural schools. This focus is part of an equity and excellence framework to provide additional access in rural areas. Teachers in rural school districts often serve multiple roles to meet the needs of students. Serving as a science teacher in a rural district also puts educators in a central role to inspire talented students to pursue careers in science or engineering. Teachers often notice the behaviors of talented students in the classroom—from their quick pace of learning, insightful connections, or out-of-left-field questions. But talented students need more than the standard curriculum to prepare for the rigorous training needed to pursue STEM careers.

Being from rural areas adds an added dimension to consider in conjunction with talent development in STEM fields. Every district has students with great potential in STEM, and rural schools may have greater challenges as well as assets to ensure that students receive the resources they need. The adage "one's strengths is one's weakness" is true here as being from a rural area is a double-edged sword. This project focused on the rural context for multiple reasons related to the strengths of rural communities and the potential for untapped STEM talents in these communities. Here are some of the paradoxes of living in a rural area and supporting STEM talent:

1. **Multiple roles among staff.** Rural teachers are very present in students' lives. Due to the breadth of many rural areas and the smaller staff sizes, rural teachers hold many roles. One's science teacher may also be the band teacher, track coach, community group leader, and neighbor. It is also likely that the same teachers in the general classroom also run the afterschool program and organize informal STEM learning opportunities, such as science fairs and robotics clubs. Therefore, teachers in rural areas play an outsized role in recognizing students' academic potential and helping them cultivate their talent, both through career counseling and connecting them to appropriate professional mentors. They may also recognize that some students need support that goes beyond what can typically be provided. The frequency of engagement with students can support students' talent development as teachers get to know students better in all facets of their lives.

2. **Student access to STEM fields, mentors, and coursework.** Rural students face particular challenges in pursuing STEM talent. First is accessing post-secondary education. In 2015, while 42.3% of adults aged 18-24 were enrolled in any kind of post-secondary program, just 29.3% of adults in rural areas were enrolled (Stambaugh & Wood, 2015). Students in rural areas may face various barriers to accessing college or training programs (Stambaugh & Wood, 2015). Another issue is whether they have role models or mentoring to reinforce knowledge about the possibilities of higher education and support in pursuing education. On the flip side, talented rural students are more likely to have access to limited opportunities, such as representing the school in competitions.

3. **Place-based approaches.** Rural students, in particular, have benefitted from place-based approaches to education. Due to the size of communities, there are generally greater opportunities for students to deeply engage in areas of interest. Some schools have been able to tap into their community assets and show how STEM content is applied within the community agencies. Students may be able to learn from local experts. In this way, students are able to see a broader range of applications to STEM fields than the traditional approaches available to other students. On the other hand, sometimes communities are too small to have the experts in STEM and students must travel long distances to interact with experts in a particular field.

4. **Should I leave or stay?** Many students feel, or have even been told, that they need to leave a rural area in order to have success in a field, especially in STEM. This is particularly true in rural communities that are more remote or have declining populations and financial struggles. Students end up leaving the area to pursue careers and do not return, culminating in what some rural scholars label as "brain drain" (Stambaugh & Wood, 2015).

5. **Critical mass.** As rural schools, by nature of the definition, are smaller in numbers, a critical mass of students with similar passions can be challenging to amass in one setting. The smaller numbers of students can be beneficial for targeted instruction. However, funding costs for qualified personnel are similar whether two or twenty students are participating in a project. Having a few students with expansive needs can deplete district resources and staff quickly. The lack of peers can also leave talented students feeling alone or different if their interests differ greatly from others. Afterschool programs in rural schools are one way to allow for multi-age groupings of students with similar interests and readiness levels for academically advanced STEM projects.

The rural population was the selected group of population for this project as every state in the US has rural places, though rural voices are sometimes overshadowed by more concentrated population area needs; moreover, geographic access, particularly in STEM is not as readily available in rural areas even though rural areas are great spaces for place-based STEM activities.

Talent Identification: Who is the STEM Excellence Target Population?

An in-school talent search model (Assouline, Ihrig, & Mahatmya, 2017) was used to identify students for programming. To recognize talent from a wide range of backgrounds, teachers were encouraged to consider grade-level assessments, above-level assessment scores, as well as psychosocial measures. These data were not used to exclude any student from participating, but instead to see if students had other characteristics beyond academic aptitude that might make them more likely to benefit from the program. In fact, feedback from *STEM excellence* teachers has been that they have observed students grow into leadership skills as well as develop their STEM skills through the program.

The use of multiple measures and out-of-level assessments (Benbow, 2012) - when matched to student needs and strengths - are part of a best-practice repertoire for assessing talents and providing appropriate interventions that support their ongoing talent development. Out-of-level assessments, in particular, allow teachers to determine what students know beyond grade-level material and may provide a more accurate measure of advanced performance and relative strengths and weaknesses that could be addressed through extended learning opportunities. In order for students to be successful in STEM fields, psychosocial factors matter as much or more so than ability (Subotnik et al., 2011). Psychosocial skills such as curiosity, perseverance, motivation, mindset, and self efficacy are important to measure and support as part of a talent development framework as students move from potential toward expertise and even creative productivity in a field. As part of the talent development process and development of expertise, teachers may initially look to build a love of learning, then focused skill, before moving toward mentorship and preparation for expertise and creative productivity (Subotnik et al., 2011). To maximize success in a field, the talent development process has different windows of access for different fields. For STEM fields, expertise begins to develop in adolescence, whereas the humanities fields may occur later in one's career journey (Subotnik et al., 2011).

Within a talent development framework, the focus on STEM academic potential was emphasized over current high achievement as we did not want to unnecessarily frustrate students. Instead, exposure and interest in STEM fields were key foci, allowing students to engage at a more advanced level than they might previously have had opportunities to do so. Thus, an important impact of *STEM Excellence* was to provide opportunities for exploration that might spark additional challenges and advanced academic engagement.

Talent Development: Place-Based Opportunities in Informal Learning

In seeking to broaden participation in STEM careers, the *STEM excellence* project chose to focus on afterschool programs designed for students in the middle grades. Afterschool programs allow teachers greater flexibility to adapt their program to student interests and needs (National Research Council [NRC], 2015; Duschl et al., 2007).

The talent development literature also clearly supports the benefits of ongoing access to advanced or accelerated opportunities, particularly those beyond the school day (Wai et al, 2010, Lee et al, 2009) in support of students' use of leisure time (Csikszentmihalyi, Rathunde, Whalen, 1997; Bloom, 1995). The Study of Mathematically Precocious Youth (SMPY; Benbow, 2012) is a longitudinal study focused on the predictive validity of out-of-level assessments on one's career trajectories. The researchers have followed students who were administered the ACT or SAT at age 12 into adulthood. Their research is focused on STEM fields. Key findings from this ongoing study are drivers in *STEM Excellence*. In particular, the magnitude or dose of the experience matters in terms of an overall career trajectory (Wai et al, 2010). As Benbow (2012) notes: *SMPY researchers have concluded that appropriate educational opportunities do correlate to career achievement and creative production. Future STEM innovators can be identified early and [domain-specific] education interventions increase their chance of success.* (abstract) Wai et al (2010) found that the more intense the STEM dose and exposure in adolescence, whether through STEM clubs, advanced courses, competitions, mentorships, or other advanced opportunities, the more likely individuals were to have a PhD, patent, or critical publication in a STEM field. The findings controlled for and matched ability levels on the SAT and ACT of 12 year old participants.

As part of a talent development framework, motivation is another factor that impacts one's trajectory (Subotnik, Olszewski-Kubilius et al., 2011). Motivation is more likely to happen when individuals have the 6 C's of motivation in place within their curriculum: choice, challenge, control, collaboration, consequences, and constructing meaning (Turner & Paris, 1995). Motivation enhances one's potential for success in a field. Teachers were encouraged to create programs that provided choice, control, opportunities for constructing meaning, and control over how their programs were designed based on community assets. Collaboration opportunities were encouraged within the community and with other STEM Excellence schools.

Districts were encouraged to create programs based on their community assets. Local autonomy was encouraged as educators designed programs that drew on local strengths and built student interests, particularly as it relates to local funds of knowledge (Avery, 2013). To provide guidelines for these informal learning environments to flourish and to promote motivation and talent development in STEM fields, the Dimensions of Success (DoS) framework (see **section two** – teacher professional development). was shared with teachers as a guide to program development. The DoS was essential to the project as it allowed the program to define high quality informal STEM education without constraining the focus or structure of the afterschool programs. The DoS has 12 dimensions organized into four broad categories: Features of the learning environment, activity engagement, STEM knowledge and practices, and youth development in STEM. The associated observation rubric was also central to the evaluation of the afterschool programs.

SECTION TWO: Program Participants and Evaluation

This section provides an overview of the *STEM Excellence* program participants and features of the project implementation and oversight, including internal and external evaluation activities.

District Demographic/Geographic Information and Recruitment Efforts

The study population draws from schools in the state of Iowa, a predominantly rural, Midwestern state. The investigators posted a general announcement describing the goals of the *STEM Excellence and Leadership* program, which specified the focus on rural schools. Then, the investigators used NCES locale codes to identify rural schools with students in Grades 6 to 8 (N = 180 schools). All 180 schools received an announcement inviting them to submit an application to participate in the project. Twelve districts applied and 11 were selected based on their:

a) demonstrated commitment to the program through the application process, which required a signed commitment of program-support from each school's central administration,
b) location (NCES-definition of rurality and distribution throughout the state), and
c) the district's free or reduced-cost lunch (FRL) status. (Because of confidentiality constraints, individual information about FRL was not available.)

A summary of the participating schools from the first year of implementation (AY2016-2017) is provided in **Table 1.**

Table 1. Participating District Demographics (2016-2017)

School Name (Pseudonym)	FRL (%)	Geographic Location	Non White (%)	Total Enrollment (Grades 6-8)
School A	55.28	Rural: Distant (42)	10.30	150
School B	59.41	Rural: Fringe (41)	28.80	802
School C	46.76	Rural: Remote (43)	1.66	135
School D	43.60	Rural: Remote (43)	4.65	282
School E	44.09	Rural: Distant (42)	8.07	73
School F	20.96	Town: Fringe (31)	5.42	376
School G	48.25	Town: Remote (33)	9.55	329
School H	46.08	Town: Remote (33)	23.24	441
School I	39.27	Rural: Fringe (41)	11.98	473
School J	41.69	Rural: Distant (42)	5.36	219

Note. Data retrieved from Iowa Department of Education State Data and NCES Public School Search. FRL% is based on K-12 total enrollment. Non-White% is based on PK-12 total enrollment.

Over the course of program implementation, 3 districts dropped out of the program. Two of the districts that dropped out of the program were the most remote of the participating districts and the smallest in student populations (the 2022 sizes of the prekindergarten - grade 12 students numbered 600 in one district, and 360 in another according to the NCES database). The other district was also remote, but located in a larger town with 1,255 prekindergarten - grade 12 students. In these districts, staffing the programs was also too great a barrier to overcome. In one district, staff had too heavy of an existing workload, in the other two districts, the program was run by a single staff member and when that staff member left the district, the district no longer implemented the program.

Table 2 summarizes the total number of students who enrolled in the STEM Excellence program in each participating school over the course of grant funding. The difference in numbers between total enrolled, total consented, and total outcome data reflect the fact that students could choose to participate in the research activities associated with the program. Program participant was not contingent upon nor jeopardized by not agreeing to research participation.

Table 02. Number of Students Who Enrolled in the STEM Exc. Program, Consented, and Had Valid Outcome Data

School Name (Pseudonym)	Total Enrolled	Total Consented	Total with Outcome Data (Achievement)	Total with Outcome Data (Psychosocial)
School A	56	39	33	16
School B	118	81	66	56
School C	29	15	15	10
School D	74	54	52	16
School E	12	5	5	1
School F	51	43	34	16
School G	72	52	38	4
School H	106	78	63	22
School I	112	67	63	18
School J	45	32	32	17
Total	675	466	401	176

Note. The students included in this table are the ones who enrolled in the first semester of their program as a 6th grader.

Data Collection Strategies and Instrumentation

Table 3 outlines the original data collection plan as well as adjustments for COVID-19. In sum, qualitative and quantitative data were collected through observations, school leadership focus groups/interviews, student surveys, and student test scores. Instrumentation protocols are found in Appendix A.

Table 03. Data Collection and Instrumentation with COVID-19 Adjustments

	Original plan	COVID-19 adjustments	Data
Site visits	• Two visits for each of 10 sites (2017-18, 2018-19, 2019-20) • Dimensions of Success observation rubric	• Recorded site sessions, used for field notes by team; • DoS scored virtually from videos	• DoS ratings, field notes, other observations
School Leadership Interviews and Focus Groups (individual and focus groups)	• Focus groups during summer PD 2018-2021 • Focus groups and interviews in summer of 2022 • Separate interview and protocol using an appreciative inquiry approach led by evaluators 2022	• Conducted virtually 2020-2022	• Led by program team 2019-2021 • Led by evaluators in 2018 and 2022
Student survey data	• Sixth, seventh, and eight grade students took the Student Engagement Survey (included items from the Patterns of Adaptive Learning Survey and other psychosocial measures) at the end of the school year	• Spring talent identification and post assessments were not conducted in 2020.	• Psychosocial measures of academic outcomes, academic attribution, self-efficacy
Student test data from above-level tests (pre/post each year)	• 5th and 6th grade students took an above-level achievement test (I-Excel); 7th and 8th took ACT • Collected grades, Iowa assessment scores, and CogAT scores	• Spring talent identification and post assessments were not conducted in 2020; ACT was unavailable in 2020-21	• 5th grade is pre-test, then 6/7/8 is post-test

The external evaluators participated in focus groups with program coordinators or reviewed the transcripts if unable to attend. Evaluators also had access to all qualitative and quantitative data collected for the purposes of annual reports. Prior to COVID-19, they had the opportunity to attend summer programs or conduct site visits with schools in person. The team also met at least twice annually with the external evaluators about progress and findings. The evaluators provided constructive feedback about the program, which informed the work and this final report.

Program Implementation and Design

The *STEM Excellence* program required that school districts provide 96 hours of STEM after-school programming scheduled over 24 weeks, twice a week, for approximately two hours per session. The DoS framework was essential to the project as it allowed the program to define high quality informal STEM education without constraining the focus or structure of the afterschool programs. Teachers had a great degree of flexibility in the program design at each district.

They were also supported in designing programs that were responsive to the needs and interests of the students in the program. This tailoring of the program to the local STEM talent pool is consistent with the "youth voice" component of the DoS framework. Youth voice means that students are active in shaping their learning. Local control of programs also promoted "relevance" of the STEM learning , where students make connections between their STEM learning and their own experiences and prior knowledge. This also promoted motivation from school leaders and students as there was choice and control over the program content as well as opportunities for collaboration and challenge.

For rural districts, locating potential mentors and connecting students to these resources can pose particular challenges. Schools found different strategies effective for enlisting the support of experts within the school and the local community. Educators worked diligently to provide engaging experiences for students that promoted interest, challenge, and inquiry. The types of experiences varied and took on a variety of forms from phenomenon-based activities, to service-learning or community-based projects, to problem-based learning, to field trips and guest speakers, to science STEM showcases. Teachers were sometimes able to find opportunities for their students that aligned to student interests by being creative in how students may be able to match their interests to local industry and governmental agencies.

Table 4 provides an overview of how districts chose to implement their program. As mentioned before, the DoS framework was essential to the project as it allowed the program to define high quality informal STEM education without constraining the focus or structure of the afterschool programs. Teachers had a great degree of flexibility in the program design at each district and thus districts varied widely, with some combining grade levels and others combining math and science content areas. This led to a wide range of designs, from schools that focused on preparing for formal competition programs, such as Science Olympiad, to weekly engagement activities (without an overarching focus), to a coherent project that was developed locally.

Table 4. Overview of STEM Excellence structure and content at each district

School Name (Pseudonym)	2016-17				2017-19	2019-22
	Grades	Personnel	Schedule	Content structure	Changes	Changes
School A	grade 6 and 7 combined, but M and S separate	Teachers in M and S	Math flex period, science afterschool and Saturdays	Combined STEM	6, 7 with science and math combined	No change
School B	grade 6 and 7 math separately, science combined	Teachers in M and S	afterschool	Some grades have separate math and science sections, other grades have combined STEM sections	Added 8th grade	All grades with combined STEM
School C	grade 6 and 7 combined	Teachers in M and S	afterschool	Separate math and science sections	All grades are combined	Ended participation
School D	grade 6 and 7 separately, M and S separate	Teachers in M and S	Math in flex period, 6th science afterschool, 7th science mornings and Saturday	Separate math and science sections	6, 7 with science and math combined	6, 7, 8 math and science separately
School E	6 and 7 combined	Teachers in 6 M and one for 6 S + 7 S/M	During school day	Combined STEM	No change	Ended participation

School F	grade 6 and 7 separately	Teachers in M and S	Afterschool, some weekends	Combined STEM	Added 8th grade, 7/8 combined	No change
School G	6 and 7 combined	Science teachers only	Monday afterschool	Combined STEM	Just one teacher involved	No change
School H	grade 6 and 7 separately	Teachers in M and S	6th grade before school, 7th grade flex period	Combined STEM	Added 8th grade, 7/8 combined	No change
School I	grade 6 and 7 separately	Teachers in M and S	afterschool	Separate math and science sections	Added 8th grade, all grades separate	All grades with combined STEM
School J	grade 6 and 7 separately	Teachers in M and S	6th grade afterschool, 7th grade science mornings, 7th grade math afterschool	Some grades have separate math and science sections, other grades have combined STEM sections	6th separate, 7th/8th grades combined	Ended participation

Here are some specific examples of how districts used their out-of-school time:

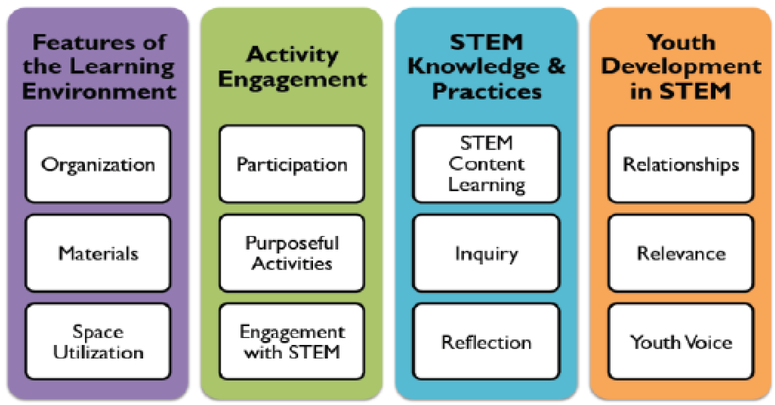
- One of the school sites was given a large parcel of land by the community. The school administration allowed the *STEM Excellence* program to decide how the parcel of land should be used. After much discussion and debate, students within *STEM Excellence* collectively decided that the space should be restored to its natural state as a prairie. Students worked with the local community groups to restore the prairie and planned to create an education boardwalk for younger students to enjoy.
- Students at another *STEM Excellence* site took initiative after a unit on rockets to build their own rockets based on designs they had personally created.
- At another *STEM Excellence* site, students who had graduated with previous cohorts chose to return and mentor incoming *STEM Excellence* site students. This student-developed mentoring initiative was so successful that current *STEM Excellence* site students conceived of and implemented a program in which they mentored the members of the elementary school's Lego League.
- Another program site led phenomenon-based learning activities as exposure. These activities were so popular that additional in-school units were created based on the *STEM Excellence* curriculum and demand.
- Students at two *STEM Excellence* schools worked closely with their teachers to hold exhibitions for their communities that showcased research projects based on the STEM concept and curricular unit that each student viewed as the most compelling thing they learned that year in *STEM Excellence*.

Teacher Professional Development

Program educators participated in an annual, 2-day intensive summer PD including topics such as assessment and working with a rural population of advanced STEM students; modeling effective implementation of STEM curricula; understanding students' thinking, including asking questions, investigating questions, and problem-solving, to better comprehend how active engagement in STEM facilitates the development of accurate representations of fundamental STEM concepts and processes. Following PD, organic, locally initiated efforts drove program design. Local decisions were grounded in the practices modeled during PD, students' level of achievement, interest, motivation, and community resources.

Year 1. Professional development consisted of whole-group and breakout sessions focused on the following topics: 1) the affordances and barriers of each local program, 2) identification of non-traditional giftedness, 3) career development and underserved youth, 3) reinforcing and teaching mathematics concepts through computer science, 4) argument-based strategies for STEM infused science teaching, 5) using the DoS framework to plan and evaluate informal learning (https://www.informalscience.org/news-views/dimensions-success-dos-observation-tool).

The Dimensions of Success



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Year 2. Educators engaged in professional learning to deliver curriculum from the National Council of Teachers of Mathematics (NCTM) Navigation series (NCTM, 2001) and Lawrence Hall of Science (2009) GEMS curriculum sequence. Facilitators engaged in workshops on teaching math through computer science, using argumentation to teach science concepts, and on using DoS to plan effective out-of-school learning experiences.

Year 3. The development sessions were led by two outside consultants: Deb Dunkhase of the Iowa Children's Museum and member of the Governor's STEM Advisory Council, and Dr. Cary Sneider of Portland State University. The sessions were devoted to training facilitators and coordinators to use the DoS observational tool to plan and evaluate their lessons, and on the practical implementation of the Great Explorations in Math and Science curriculum.

Year 4. The professional development took place virtually, over the course of two days during the summer. This year's professional development training featured training from The Search Institute that complemented previous professional development training on DoS, which centered around youth development and agency. Additionally, our professional development events featured training and collaboration on mathematics curriculum, community-based funding and resources, and science lesson plan development.

Program Oversight

Each fall, the research team collected information from each district about their programs' personnel, structure, and schedules as well as collecting consent forms from each site. Observations were also conducted throughout the school year by team staff using the DoS framework as a guide for observation and evaluation. In addition, program evaluators met with researchers twice per year. Evaluators also reviewed documentation, conducted interviews, and participated in school visitations (once per evaluator), and supported final report writing.

COVID-19 Impacts

Due to the impact of COVID-19 on schools, districts encountered a variety of barriers to implementation. One district began programming later in the academic year. One district moved to a fully online program through Brilliant.org where students worked asynchronously and independently. Another district met in-person with their students during the school day but held after-school programs online. There were a wide variety of responses to implementation during the pandemic, however schools were unable to conduct pre and post assessments, and program observations did not take place.

Additionally, the project team restructured the summer 2021 professional development session from the traditional in person, on-campus experience to a virtual format. Throughout the year, professional development opportunities were made available through memberships to the National Council for Teachers of Mathematics (NCTM) and the National Science Teaching Association (NSTA).

SECTION THREE: Results and Impact

This section provides a summary of the qualitative and quantitative results from student surveys and academic data as well as focus groups/interview results after talking with school leaders. The section concludes with ideas for sustainability and continuous improvement. **Part one** provides qualitative results and educator voices about programming and rurality when introducing innovation in STEM. **Part two** outlines quantitative findings related to achievement, broadening the talent pool, and leading innovation in rural schools.

PART ONE: Qualitative Findings

Educator Voices on Innovation, Talent, and STEM in Rural Schools

In summer focus groups held throughout the project, teachers were excited about the project and used the focus group time to share implementation ideas and learn from each other. They valued the time to work together and to learn more about talent search and the DoS framework. They shared positive outcomes they observed based on students' comments and interests. They also described many factors constraining their program design. Competing priorities such as sports and other after school activities were a limitation especially for older students, where some schools only offered the STEM program in fall when there were fewer sports conflicts (for the students as well as teachers who had multiple roles including coaching or other after school clubs). Other programs felt constrained to one-off activities rather than sustained projects because students could drop into the program intermittently. Teachers were attuned to what interested students and (despite quite different programs) felt it was engaging to students and aligned with both the students' and teachers' interests.

At the end of the project, focus groups were held by the external evaluation to learn about the "wins" and lessons learned from the project. Participants were also asked about plans for the program in the future. District leaders and teachers were asked to share their responses to a set of questions provided prior to the meeting. The question protocol is found in Appendix A. Nine individuals from six districts participated. Data were coded using open and axial coding (Corbin and Strauss, 2012). The following themes emerged from the focus groups:

Talent Identification Access

Educators felt that the talent identification process opened doors for students to be identified in STEM. One educator summarized this access succinctly. She said that [STEM Excellence and talent identification] "*allowed us to reach students that may not otherwise have programs at our school directed at their passion areas.*" Other participants also commented on the benefits of testing and access as follows:

- *We got to tap into students we don't really get to tap into.*
- *Really the above level testing was good for me specifically because I don't have any TAG background with identifying students, so it was good to have my own piece of data on top of the existing data, like NWEA.*

- *The above level testing aspect has also opened up more doors. Being able to have kids go to summer programs and open up scholarships - we were able to give full tuition to 2 students to go to summer - it was so cool to give to kids to offer the opportunity. It has opened doors for my students.*

- I *would like to see [name of district] continue the IExcel assessment - that would be helpful. It is a good indicator of strengths and weaknesses and helps us understand who to support and how. We see how students are strong in one area but not another so we are moving them through because they were strong in one area. This is concrete evidence to share and advocate for students. The ISAT doesn't work that way because it is too wide of a range for advanced students.*

Place-Based Approaches and Community Assets and Involvement

District leaders were innovative and resourceful in finding community experts, projects, and community assets to engage students in relevant and place-based activities and to connect students with experts in a given field; they took advantage of the local community opportunities as appropriate Groups were able to take field trips and bring in guest speakers. They focused on place-based options and capitalized on community assets. Here's what participants said about the opportunities provided:

- *Our last lesson that we did this year accumulated everything we did this year. We did a two month archaeology study. I got in touch with the state archeology department to set up a field trip to visit them. They even gave us materials that we might use as part of it. We were more interested in arch/paleontology because in* (named nearby town) *there is a large mammoth find….We were able to travel up to the Mammoth area and talk to the people up there setting up a museum…We were able to connect things in the classroom to things in real life, talk about careers and career options. I notice with kids in our community they have a very small understanding of what kinds of things they could do with their education. It helped open up some options.*

- *I believe that the onset of our pollinator garden initiative came about through discussions of the ecology of Iowa both in the past and present. Being surrounded by agriculture, students saw the need to increase biodiversity in our landscape and thus thought the best way forward was to plant native ecotypes.*

- *Just for me, the community thing keeps coming up. And agriculture, a lot of my kids are just really into the ag stuff. Just playing into that more, as much as we can. I'm not an ag teacher. Guest speakers…there's an idea.*

They also provided innovative approaches to STEM engagement. They incorporated field trips and invited community and school leaders in the initiatives. One school held a Shark Tank session and the superintendent, principal, and community leaders came to judge the inventions. They also met with a conservationist at a local park and discussed survival skills. Another school reported how they paired up with the nature center and did a session on the great outdoors.

Access to Resources

District leaders found it challenging to provide the appropriate resources, transportation, and to find content experts in the STEM fields for which students were interested. Other district leaders explained how STEM Excellence allowed students not otherwise in gifted programs to participate.

One teacher lamented how some students couldn't participate due to transportation: "[we] *struggled with staffing and transportation - as an issue being in a rural area and getting to different places - and they (students) have to leave when the bus leaves."* When talking about access, another teacher discussed the struggle between access to the program and transportation:

> *We mostly just look at their scores and then go from there as far as their strength or interests. This year we didn't have many kids so we did a little bit of recruiting. We ended up with a couple of kids who couldn't get a ride, so they would come when they could.*

Transportation issues, sports, and geographic distance also affected the decisions of an administrator when thinking about changes for implementation:

> *Can we provide an experience to students 15 miles in each direction? I knew that we would lose students when softball season started. We need a central location to meet or after school transportation arrangements. I couldn't give students a hard time if they could attend. We had to be very flexible due to distance and transportation.*

Relevant and Engaging Activities that Fueled Interest, Participation, and Passion

Educators felt that the hands-on activities, interesting phenomenon, career connections, field trips, and interest-based learning kept students engaged and wanting to participate. STEM Excellence opened up doors to future careers that wouldn't have been enjoyed otherwise.

- A participant said that: *Kids came home talking about the different experiences they were having. A lot of times we had an engineering challenge, which included science content, but…they got to create their own solution and bring home their solution. The kids just seemed to be excited to tell the parents and the parents felt it was cool.*

- Another participant noted, when asked about success, that: *Kids year after year want to continue to be in it. This speaks to the activities and challenges they are feeling in a good way. Parents want their kids to be in the program; parents don't understand it is for the high ability kids.*

When asked about rural districts and STEM Excellence, here are what two different leaders articulated:

- *When you go to the bigger districts and you hear about the collaboration you have with huge businesses and funding and opportunities you think "man we really get [cheated]". I used to teach in Chicago and we could go* *to the Shed or Planetarium and the urban kids complained. I am from Iowa and can't believe they are complaining. WE have corn. We would take kids to field trips and quad cities [through STEM Excellence] and see labs and other things - exposure and experiences. Even if online we can continue to do tours and other career explorations, looking at different opportunities that we can partake in. It [STEM Excellence] has opened doors by making connections with the business community. We are a poor district - 60% FRL - and going places. Some of our students have never been to Iowa City - let alone out of the state. That is becoming more and more obvious as the years have gone on. They just don't know what is even out there. [STEM Excellence] has helped that to some degree*

- *…Kids came home talking about the different experiences they were having. A lot of times we had an engineering challenge, which included science content, but…they got to create their own solution and bring home their solution. The kids just seemed to be excited to tell the parents and the parents felt it was cool.*

- *For my GT students it has closed a gap as we did not have anything that was meeting their needs in math and science and get them to think about different problems and just exposing them to different areas of science… you know.. there was one year where kids were really interested in water quality and kids were building mechanisms so they could catch trash coming through the river while allowing fish and wildlife to go through and then all of a sudden we have all these kids who are really interested in looking at that side of environmental sciences. It opens up pathways that well I know we don't have anything else that does that. That has been the best thing.*

In summary, the group leaders believed the STEM Excellence project was a success. They were able to better identify talented students through out of level assessments. Leaders saw visible differences and positive results in their students' interests and engagement, even beyond the years students participated in the project. Districts were creative in their approaches for maximizing local resources and assets as a way to apply STEM learning within the local area. Many district administrators who were not involved in the implementation of the project reported to project leaders an interest in continuing the project due to parent, student, and educator requests to maintain the program or move it into the school day. Struggles with transportation and competing priorities among leaders and students were the primary reported barriers that hindered participation or required districts to scale back the grade levels served or other components of the project. Still, all districts but one had a strong plan for sustainability after the grant ended as a result of the positive impacts realized. Project leaders and educators also desired ongoing collaboration among participating districts to continue beyond the grant period, highlighting the shared community and stories of other districts helped with overall innovation and new ideas.

Competing Priorities and Consistency

The adage "we had a great program but she moved" seems appropriate here. Participants found that in rural schools, in particular, there are competing priorities. Coaching and sports commitments, family obligations, and funding were constraints to programs. It was hard for some educators to find the time to support STEM Excellence due to other obligations and no one else to lead the initiatives. Thus, some districts changed their program structure each year to match the staffing availability. Other districts had to limit which grade levels participated or which months to host STEM Excellence based on instructor availability.

Administrators discussed the struggle of finding and maintaining staff:

- *I asked middle school teachers and other admin who else could help with the program and I don't know if it was everyone in the swing of one person doing it. I would love to have one person to collaborate and plan with. Parents are asking when STEM in 8th grade is going to start and we don't have it for them - it is only 6th and 7th.*

- [I need to] *find more people to help, facilitators, would help grow the program. I thought about how I have 11 7th graders and 6th graders. I just feel like it's more impactful for me to more closely help them and they get more out of it in that small setting. I could throw the 8th grade in, but we all know as the numbers increase the effectiveness goes down a little bit. More facilitators could offer it to more kids.*

Competing priorities for students was also a factor as outlined by administrators and facilitators:

- "*Times for sports are more important [to others]. We were supposed to have STEM Excellence two times per week but we did not have personnel.*"

- *We are big enough to offer a lot of extracurriculars and small enough that kids can do it all; getting kids after school is hard because I find myself competing with basketball practice.*

- *Kids are conflicted between STEM Excellence and cheerleading - for example - we will fit in the STEM Excellence stuff when we can. We have to be flexible and take them when you can get them; bigger districts don't allow you to do everything; it's good and bad - getting them there; and getting them home.*

In focus groups, teachers described many factors constraining their program design. This included some programs who were "more traditional" because retired teachers ran the afterschool program. Other programs felt constrained to one-off activities because students could drop into the program intermittently. Sports and other activities were a limitation especially for older students, where some schools only offered the STEM program in fall when there were fewer sports conflicts (for the students as well as one teacher who was also a coach). Teachers were attuned to what interested students and each (despite quite different programs) felt it was engaging to students and aligned with both the students' and teachers' interests. Finally, districts sometimes modified their programs from spring to fall to accommodate student sports and teachers' roles as coaches.

Sustainability and Collaboration

Many district leaders explained how they were trying to be innovative after the grant to continue STEM Excellence in some way or another. They also hoped for more collaboration among the participating STEM Excellence schools and community partners. Leaders explained student and parent initiatives were an important part of requesting ongoing programming. They explained:

- *I currently have three students who are working on a fundraising campaign. I've uploaded the artifact in the shared upload folder. I believe this speaks to the success of the program as students are so invested that they want it to continue throughout their entire middle school career.*

- *I kept thinking of all the parents who are grateful for this extra opportunity. There is nothing like this at any level for additional STEM learning. The Superintendent said we're going to continue this for sure after the grant ends.*

Even if not all STEM Excellence components are kept, many schools are keeping some aspects of STEM or incorporating more of the activities into the regular school day. Here are some ideas in their own voice:

- *While STEM Excellence as a whole seems to be moving out the door unless we can secure some outside funding for next year, aspects of the program will stick around. I've already talked to my principal about keeping the I-Excel test for 5th and 6th graders. This has been a pivotal component to our GT program's acceleration practices. The above-grade level data we ascertain from the I-Excel test has allowed us to identify numerous students for subject-specific acceleration.*

- [We] *have run a specific schedule since I have been here; STEM had to be before or after school;* now *we can have the activities from STEM Excellence to incorporate into our school day; that was a massive undertaking*; *we flipped school - took pieces apart in our old schedule to have 30-60 minutes every day for our kids to get what they need (intervention, band, choir, extension activities to build on their school day and we made happen). We asked what types of STEM activities might happen during this time? We designed a maker space - getting those items we have used in our STEM [Excellence] program to use for everyone during the school day and having someone in charge of it was also a priority. Our district librarian has taken that on and we are currently building the space*.

- *Without this program started by [name] I guarantee there would be nothing at our school for this; it was great to not have it on the school's budget and to prove the concept; it was the proof of concept that gave our administration the idea to have us continue on our own; I am just really grateful for that.*

Other district leaders noted the impact the program had on students well after they left middle school:

> *This year was the first year we saw a lot of kids in STEM; kids saying "of course I want to do this again" when they are in high school; they do a lot of things and get a lot of opportunities in ag and sports and this is a great opportunity to give them other opportunities in STEM. They may run track for fun but they also need to know that they are good in biology and chemistry and it is a great way to help them develop their skills in high school.*

Still others discussed how they hoped to continue collaborating with the granting institution and other STEM Excellence districts so that they could continue sharing ideas as part of sustainability and ongoing scale up. Here are some of the specific comments:

> *I hope we can maintain a partnership; I loved when we could get together in the summer and network with other schools and find out what they were doing - some schools were doing ongoing projects and doing really cool stuff.*

PART TWO: Quantitative Findings

Impact on Student Psychosocial and Academic Development

A critical goal of the project was conducting research to understand how informal STEM learning shapes the academic and psychosocial outcomes of rural, high-potential students. A series of research articles outlined the findings regarding these outcomes as well as identifying key characteristics of successful informal STEM learning environments for rural, high-aptitude students and their teachers. The findings of previous reports and articles are summarized below with links to the publications in the NSF Public Access Repository for this award.

Research products	Specific outcomes	Broader implications
Assouline, S. G., Ihrig, L. M., & Mahatmya, D. (2017). Closing the excellence gap: Investigation of an expanded talent search model for student selection into an extracurricular STEM program in rural middle schools. *Gifted Child Quarterly, 61*(3), 250-261.	Integrating students' above-level testing results and psychosocial measures helped create a more inclusive talent pool of students identified for programming.	Created an opportunity to discover and develop talent in math and science in an educational setting that was responsive to the community needs to prepare students for advanced STEM educational pathways.
Ihrig, L. M., Assouline, S. G., Mahatmya, D., & Lynch, S. (2022). Developing students' science, technology, engineering, and mathematics talent in rural after-school settings: Rural educators' affordances and barriers. *Journal for the Education of the Gifted, 45*, 381–403	Teachers were given the agency to adapt their programs to leverage rural/local strengths and needs.	Professional development and curriculum support for rural educators created opportunities to develop talent in math and science and connect to rural communities.
Ihrig, L. M., Lane, E., Mahatmya, D., & Assouline, S. G. (2018). STEM excellence and leadership program: Increasing the level of STEM challenge and engagement for high-achieving students in economically disadvantaged rural communities. *Journal for the Education of the Gifted, 41*(1), 24-42.	Students expressed enjoyment, satisfaction, and more curiosity about math and science from participating in the program.	Psychosocial variables such as motivation and self-efficacy (measured through ACT Engage and Patterns of Adaptive Learning) help to sustain talent development.
Assouline, S. G., Mahatmya, D., Ihrig, L., & Lane, E. (2020). High-achieving rural middle-school students' academic self-efficacy and attributions in relationship to gender. *High Ability Studies, 32* (2), 1-27.	Program participation was associated with students' sense of academic self-efficacy, with differences by gender.	Talent domain and development trajectories are supported through the alignment between STEM aptitude and programming.
Lakin, J.M., Stambaugh, T., Ihrig, L.M., Mahatmya, D., and Assouline, S.G.. (2021). Nurturing STEM talent in rural settings. *Phi Delta Kappan, 103*(4), 24-30.	STEM programs focused on local strengths and resources created new advanced learning opportunities for rural youth.	Expanding opportunities for STEM talent development includes connecting with community expertise, leveraging near-peer mentors, and broadening the reach of programs.
Assouline, S. G., Mahatmya, D., Ihrig, L. M., Lynch, S., & Karakis, N. (2023). A theoretically based STEM talent development program that bridges excellence gaps. *Annals of the New York Academy of Sciences. Online First*.	Program integrated facets of the Talent Development Megamodel and aligns with the Bioecological Systems Model.	Programs addressing excellence gaps must attend to diverse aspects of student characteristics related to talent as well as consider the various systems and contexts that affect student development.

SECTION FOUR: Sustainability & Future Considerations

Rural sites are distinct; therefore, to ensure the usability, feasibility, fidelity of implementation, and sustainability programs must draw from place-based evidence and encourage, rather than dismiss, adaptations to implementation (Eppley et al., 2018). We know that out-of-school STEM programming designed from participants' personal interests and/or their community engages underrepresented students in the accumulation of STEM learning opportunities thus positively impacting students' cognitive and psychosocial development (Avery, 2017; Bevan et al., 2018; Congress, 2015; National Research Council, 2015; Noam & Triggs, 2017). As such, we strongly encourage an approach to program implementation that honors and leverages the interests and affordances of the students, district, and rural community.

Consistent with the features of effective informal STEM learning, school partners were supported in tailoring their afterschool programs to the students who chose to participate in the program and with consideration of what they learned about their students from the talent search process. Data from observations of programs led the research team to conclude that Youth Voice was a strong attribute of student experience in the program and that students had opportunities to shape the design, development, and implementation aspects of the program.

The combined research and evaluation activities for the *Excellence* project indicates that the program was successful in broadening the talent pool of participants in each of the participating rural districts from 3% to 13% of students (Assouline et al., 2017) and is perceived positively by educators and students (Ihrig et al., 2018). *Excellence* also increases student STEM achievement; post-test above-level test scores were significantly higher for participants than non-participants in math and science (average effect size across cohorts, d = .07 and d = .09) respectively. We believe that even more students can develop advanced STEM talent if the program is open to all interested students who score in the 85th percentile or higher on their grade level assessment and then the above level assessment is used as a part of the program to provide additional information about areas of strength for students, instead of as a requirement for program entry.

Additionally, programs may want to consider incorporating the new CogAT Spatial Battery for participants - as an additional set of data, not a barrier to entry. Although adoption of spatial reasoning to discover talent is relatively new, this domain of reasoning is important to understanding math and science achievement (Lakin & Wai, 2020).

Currently, *STEM Excellence* offers a dosage of 96-hours of out-of-school STEM programming each year during grades 6–8. Educators' have reported barriers to participation during grades 7 and 8, due to the many out-of-school pulls on students' time. Thus one option may be to implement an adjusted dosage of 96 hours only during grade 6 and assess the gains in students aspirations and achievement from this dose.

Consideration should also be taken when implementing innovation in rural schools. Research and innovation in rural schools involves recognizing rural identity. Place based approaches, relationship building with families and community partners, an understanding of contextual factors, and recognizing and capitalizing on community assets play an important role in the success of innovation in rural districts. Competing priorities for students and educators may serve as a barrier but when families, educators, and students see the value and impact of the innovation sustainability is more likely to occur.

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Appendix A – Evaluation Protocols

Quantitative & Qualitative Data Manuals (available via informalscience.org)

Search "STEM Excellence and Leadership Data Manuals" under Research and Evaluation instruments

Focus Group Protocol (2018, 2019, 2021)

A detailed focus group guide was used in year 1 and 2 during the summer PD events (year 3(2020) PD was canceled). Evaluators led the focus group in 2018 and the project team led the focus groups during the summer PD in all other years indicated.

1. How has the STEM Excellence and Leadership program impacted your teaching in other classes this year? Describe some specific examples.
2. What are you hopes for students who participate in this program? Prompts if needed:
    a. How did participation and expectations differ between the new and continuing students?
    b. What did you notice about new and continuing students?
    c. In what ways do programming efforts need to be adjusted to support increasing students' academic preparation for the highest-level math and science in high school?
    d. In what ways do programming efforts need to be adjusted to support increasing students' aspirations for the highest-level math and science in high school?
3. In what ways did you feel supported when implementing STEM Excellence and Leadership? How so?
    a. What barriers did you encounter when implementing STEM Excellence and Leadership?
    b. What would have helped you to be more successful in implementing the program?
4. What else would you like for us to know about the next year of the program?

Focus Group Protocol (2022)

The external evaluation team organized a final round of focus groups in summer 2022. Due to scheduling, some individual interviews were also scheduled. The semi-structured protocol focused on these questions, inspired by the appreciative inquiry framing. Appreciative Inquiry is an asset-focused approach to evaluation that emphasizes what is working well and what can be built on to address other areas of growth for an organization (Coghlan et al., 2003). While the appreciative inquiry framework is typically used for a full-day or multiple conversations, similar to a strategic planning process, we sought to use this approach within a one-hour focus group setting. The questions were organized around the appreciative inquiry phases of "discover, dream, design, destiny". With additional questions about rurality to ensure that this facet of their programs and experiences was captured.

- What artifact, story, event, comment, or memory from your STEM Excellence experience best speaks to the success of STEM Excellence in your school? Why?
- How does your specific location, team, organization structure, rurality, or other factors play into this success?
- What vision do you have for the future to continue and build on your success during STEM Excellence? What are your hopes for the program? Think about and describe what you want STEM Excellence to look like in 5 years.
- How do the assets in your rural area impact your dreams for success?
- What are at least two ideas you have for moving from where you are now to help realize your vision previously described?
- How does being in a rural school impact how you design or generate your ideas?
- What is at least one specific action step you can take toward realizing your ideas?
- To what extent does being in a rural area impact how you go about achieving your designs and plans?
- Anything else you want us to know?