# Exploring STEM Engagement in Girls in Rural Communities

## Results from GEMS Clubs

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Creating enriching and encouraging programs to engage girls in STEM is critical because girls and women bring unique experiences, perspectives, and ideas to scientific work. Besides benefiting the women themselves, having more women in STEM occupations will enable society to benefit from women's expertise by maximizing innovation, creativity, and competitiveness (National Academies of Sciences, Engineering, and Medicine, 2016).

More and more jobs involve STEM, yet women are still underrepresented in many STEM fields, particularly engineering and computer science (National Science Foundation, 2019). Rural students in particular have historically faced numerous obstacles to entering STEM fields, including low educational aspirations, lack of STEM role models, and lack of access to advanced STEM curriculum (Versypt & Ford Versypt, 2013).

GEMS (Girls Excelling in Math and Science), founded in 1994, strives to ensure that each participant sees herself "as a change agent or a problem-solver, a possible technology entrepreneur, engineer or a scientist, and a person who makes a difference" (GEMS, 2019). GEMS aims to reach girls who might otherwise not have broad exposure to formal STEM opportunities and role models, such as girls from rural areas and other underserved communities. Through

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its website, GEMS offers online support, including activity ideas, teaching tips, and other resources, to anyone interested in starting a GEMS club or in doing STEM activities at home. GEMS currently operates in more than 150 locations around the world.

As a research partner to GEMS, the National Institute on Out-of-School Time (NIOST) conducted an investigation of girls' experiences at GEMS clubs in rural Pennsylvania between September 2019 and February 2020, with funding from the McElhattan Foundation. Our observation data suggest that GEMS activities successfully fostered cognitive, behavioral, and emotional engagement with STEM in participating girls.

## Learning Activation in STEM: A Theoretical Framework

To observe girls' engagement in STEM in GEM clubs, NIOST staff used the observation instrument designed by Activation Lab (2018), a national research project that aims to determine how best to spark children's interest and abilities in ways that lead to persistent engagement in STEM learning.

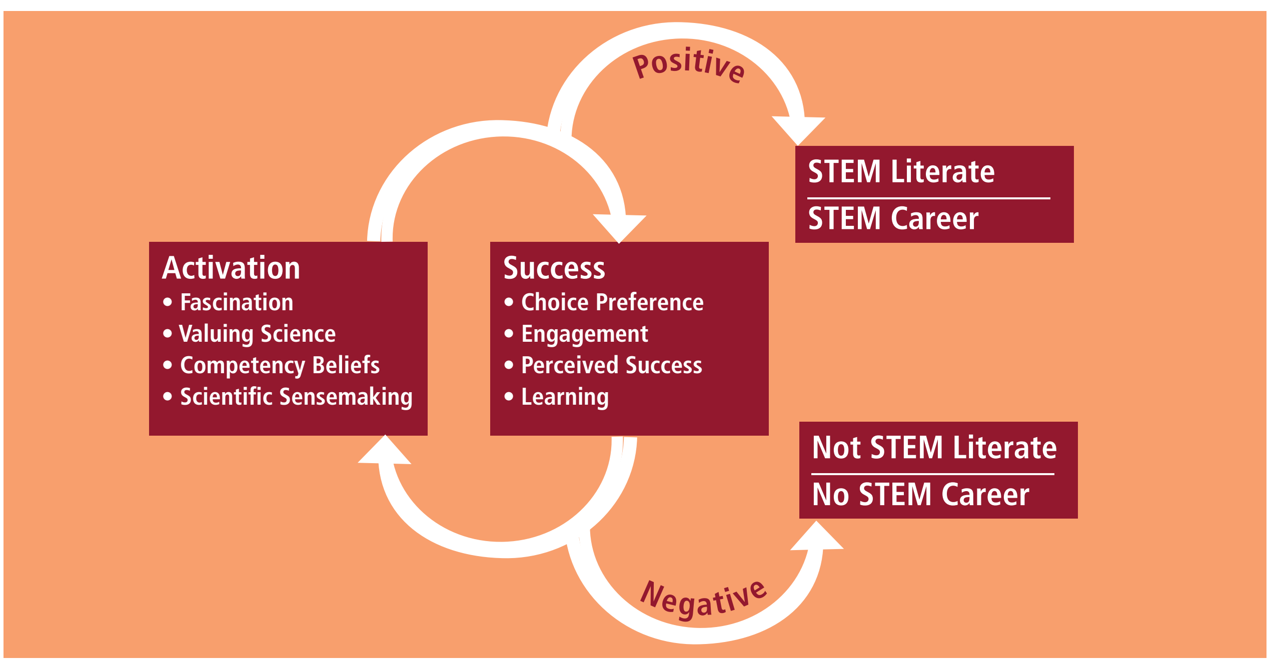
Learning activation in science is defined as "a set of dispositions, practices, and knowledge that commonly enable success in proximal science learning experiences and are in turn influenced by these successes" (Dorph et al., 2016, p. 1). *Proximal* experiences are those that occur next in time. According to Dorph, Schunn, and Crowley (2017), science learning activation is conceptualized as a "developmental feedback loop" (Figure 1) in which "activated science learners have the resources to be successful when they engage with science" (p. 19). Success leads to more activation, which leads to more engagement with science, which leads to more success, and so on. When young people experience success in STEM, they are more likely to engage in extracurricular STEM activities, study STEM subjects in school, and consider STEM careers. By contrast, negative science experiences, especially at a young age, can reduce activation and discourage young people from pursuing STEM literacy or career pathways (Dorph et al., 2017).

This theoretical framework identifies four dimensions of science activation for individual learners (Dorph et al., 2016):

1. Fascination with natural and physical phenomena
2. Valuing science for self and society
3. Competency beliefs in science
4. Scientific sensemaking

Under this framework, success in young people's STEM learning experiences is characterized by the

***Figure 1. The Science Learning Activation Framework***




Source: Dorph et al., 2017. Reprinted with permission.

following elements (Dorph et al., 2016; Dorph et al., 2017).

- Choice: Choosing to participate in a STEM activity when the opportunity is presented
- Engagement: Experiencing positive cognitive, behavioral, and emotional engagement during the learning experience
- Perceived success: Feeling positive about one's experience and ability to learn
- Learning: Meeting the content learning goals of the experience

Our research focused on the choice and engagement elements of success. Past research has demonstrated predictive associations in both directions between the dimensions of science activation and the elements of success in proximal learning experiences. In a study of children's experiences in school science lessons and in visits to a science museum, Dorph, Cannady, and Schunn (2016) found that that choice preferences were predicted by fascination, values, and sensemaking. Engagement levels were predicted by competency beliefs, fascination, and values. Moreover, successes predicted further growth in activation: growth in fascination, values, and competency beliefs themselves were predicted by choice preferences and engagement levels (Dorph et al., 2016).

## Research Questions

Our investigation explored participants' engagement with STEM activities in their GEMS clubs as an indication of the success of the activities. The premise is that, because young people "vote with their feet," they need to feel successful as they engage with STEM activities, or they are likely to drop out. To feel truly successful, participants need to engage with the STEM activities on all three levels: cognitive, behavioral, and emotional. If they are more engaged, they experience more success; conversely, if they are less engaged, they experience less success.

Three research questions related to STEM engagement guided our GEMS club observations:

1. What types of science behaviors did girls engage in most frequently?
2. How actively involved were girls in the STEM activities?
3. What was the affect [emotional state] of girls while doing the STEM activities?

## Program Context

GEMS is an informal network of clubs around the world whose leaders can choose from a wide variety of program activities and designs available for free online (GEMS, 2019). The accessibility and flexibility make GEMS a good fit for underserved neighborhoods, including rural areas like the one we studied. The two GEMS clubs we observed were situated in school buildings in two different small towns outside Pittsburgh; both served girls in grades 3–5. Each club was led by two women who were teachers in the host school. They differed in their STEM backgrounds and their expressed level of comfort with leading STEM activities.

Girls self-selected to participate: Flyers were posted in the school, and girls (or parents on their behalf) signed up if they were interested. Interviews with GEMS participants and alumnae conducted in fall 2019 (Hall & Wheeler, 2020) revealed that girls most often joined GEMS because the description of the club intrigued them, they had friends planning to join, they knew and liked the facilitators, or they had previous interest and/or experience in STEM.

## Methods

Table 1 summarizes the observations NIOST researchers made at the two GEMS clubs in November 2019 and February 2020. Club 1 was on a semester system, while Club 2 offered a yearlong session. The second set of observations thus was conducted during different stages of the program at the two GEMS clubs. The T1 observation in November occurred near the beginning of the program in both clubs. However, the T2 observation in February was near the beginning of the new semester's program at Club 1 but in the middle of the yearlong program at Club 2.

We collected data using the Engagement Observation Protocol of the Activation Lab Evaluation Toolkit (Activation Lab, 2018), which includes open-ended field notes and ratings on Likert scales of various elements of engagement. Two NIOST staff members conducted observations, one at Club 1 and the other at Club 2. During each visit, a randomly selected girl was observed for 10 consecutive minutes; then a second girl was randomly selected, and then a third, and so on for as long as time allowed. The numbers of girls in each observation are listed in Table 1. In all, we conducted 18 observations totaling 180 minutes.

Data recorded during each 10-minute observation included:

*Table 1. GEMS Club Observations*

| Club and Observation (T) | Month | Participants Observed | Activity |
|---|---|---|---|
| Club 1-T1 | November 2019 | 3 girls in Grade 3 | Lego project on windmills |
| Club 1-T2 | February 2020 | 5 girls in Grades 3–5 | Lego project on beehives |
| Club 2-T1 | November 2019 | 4 girls in Grade 3 | Movable models of hands |
| Club 2-T2 | February 2020 | 6 girls in Grade 3 | Kaleidoscopes |

1. A description of what the participant was doing
2. Notes on whether the participant interacted with others and, if so, with whom and for how long
3. Science behaviors exhibited
4. The cognitive focus of the science engagement
5. Participation level
6. Apparent emotional state
7. An overall rating of the participant's engagement

## Observing STEM Behaviors and Engagement

Based on the Activation Lab observation protocol, we report results in three categories: science behaviors, including cognitive focus; active behavioral engagement; and emotional engagement.

### *Science Behaviors and Cognitive Focus*

The observation protocol tracks 16 types of scientific behaviors, from "ask" and "answer" to "experiment" and "problem-solve." For each observation, each behavior is recorded as present if it is observed at least once during the 10-minute observation, whether that behavior occurs once or multiple times and whether it lasts five seconds or five minutes. In all, observers recorded a total of 112 science behaviors during the 18 observations.

Results indicate that the girls engaged in a wide variety of scientific behaviors (Figure 2). The behaviors seen most often across all observations were listening, using, asking, experimenting, answering, discussing, and observing. The least common behaviors were describing and volunteering.

The types of science behaviors appeared to depend, at least in part, on the activities. At Club 1-T1, for example, when girls were involved in a windmill Lego project, the scientific behaviors seen most often were experimenting, exploring, reading, and using. At the same club at T2, also a Lego project, the most common scientific behavior was asking. At Club 2-T1, which involved following complicated instructions to create models of moving hands, the most commonly observed scientific behavior was listening. At T2 at this club, when girls were actively involved in building kaleidoscopes, the common behaviors were using and connecting.

Observational data also included records on the focus of cognitive engagement exhibited by the girls (Table 2). Results indicated that girls were most often engaged in thinking about procedures, ideas, artifacts, and facts; they were least often involved in metacognition or in thinking about phenomena or challenges and problems.

### *Active Behavioral Engagement*

All but one of the 10-minute observations involved one or more instances of "active" behavioral engagement, defined by the protocol as involving initiative; examples are raising a hand or answering a question. In addition, 12 of the 18 observations (67 percent) involved one or more instances of "passive positive" behavior in which girls showed that they were ready to learn and participate, such as listening or being attentive or alert. Only three observations included one or more incidences of "passive negative" behavior, such as not taking initiative, giving up, being unprepared, or being distracted. No observations involved "disruptive" behavior.

Using those same four categories of engagement, we then analyzed which category was dominant, that is, it was observed more than 50 percent of the time in the focal child. Figure 3 shows the results. Active behavioral engagement was the most common dominant level of participation, seen in 12 of the 18 girls. Passive positive engagement was observed in four participants. In none of the 18 observations was passive negative or disruptive behavior dominant. Two observations were

*Figure 2. Frequency of Science Behaviors*

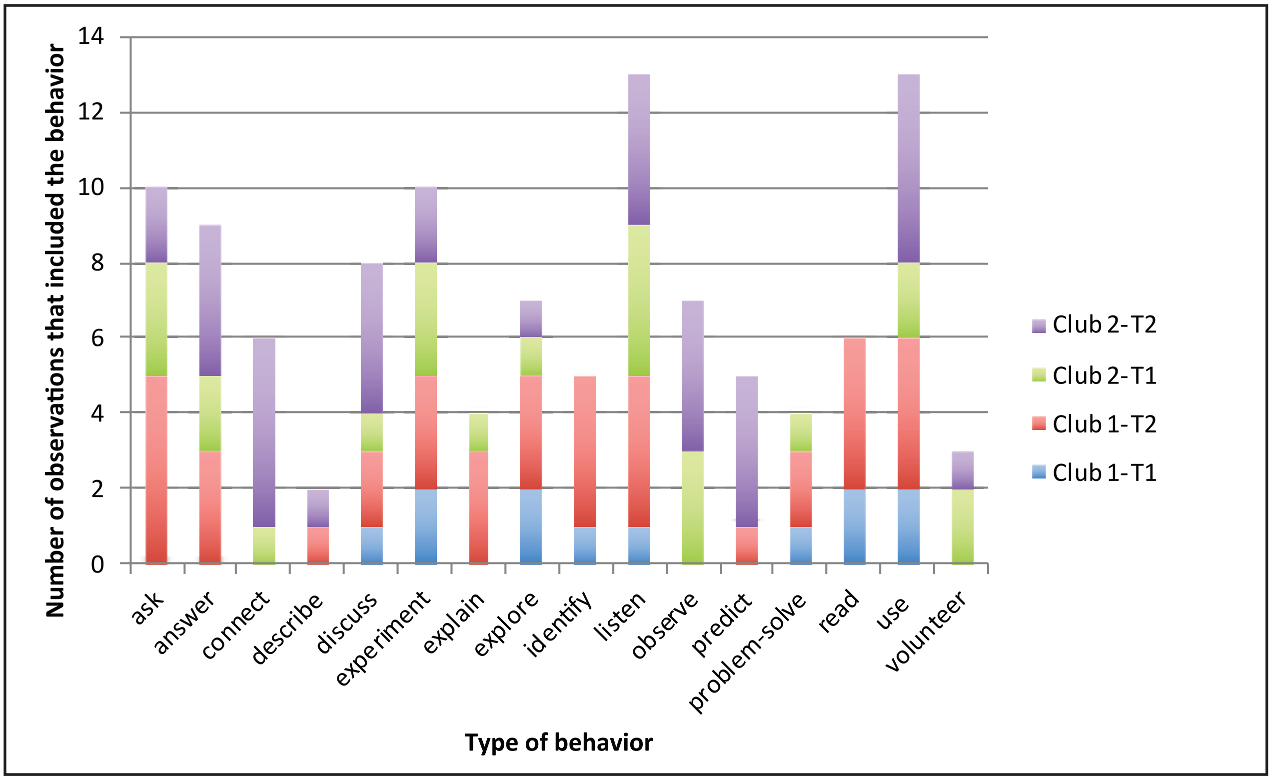


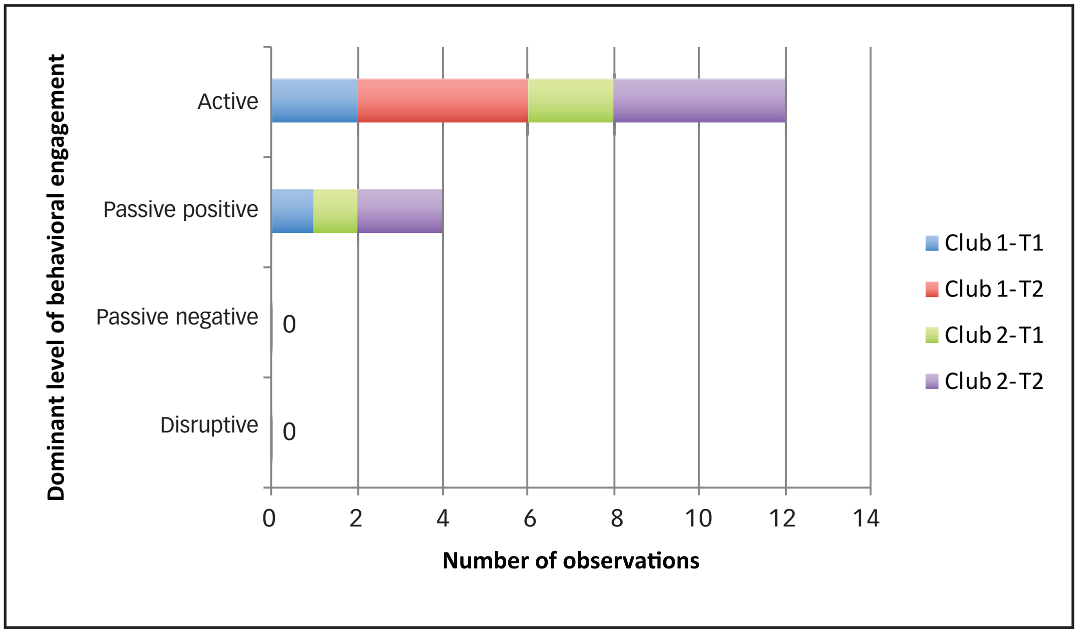

*Table 2. Focus of Cognition*

| Type of Cognitive Engagement | Observations That Included This Type | |
|---|---|---|
| | Number | Percentage |
| Procedures | 14 | 78% |
| Ideas | 10 | 56% |
| Artifacts | 9 | 50% |
| Facts | 8 | 44% |
| Challenges/problems | 6 | 33% |
| Phenomena | 5 | 28% |
| Metacognition | 1 | 6% |

not dominated primarily by any one type of participation. Corroborating evidence of active involvement comes from the fact that 16 of the 18 girls (89 percent) were rated "high" or "very high" in overall engagement.

GEMS activities are designed to be interactive and collaborative. Activities were very social: 17 of the 18 observations involved at least one interaction with an adult facilitator, and 17 involved at least one interaction with a peer. "Extensive, ongoing interactions" with peers were found in 11 observations, whereas only three observations involved extensive, ongoing interactions with adults. It appears that adults gave instructions and were available to answer questions, but, in general, they interacted briefly with individual girls, letting the girls direct their learning. One facilitator ex-

*Figure 3. Dominant Level of Behavioral Engagement*




plicitly told her observer that she typically encouraged participants to consult with each other before asking her for help. Structuring the activities to encourage social interaction among peers seemed to promote participant engagement.

### Emotional Engagement

The observation protocol has three data points for participants' affect or emotional state. The first requires the observer to record one of four potential emotional states for each activity recorded during the observation. The second is a rating of the dominant type of affect during the observation. The third is a single rating of the overall affect of the observed participant. Each scale used slightly different measures.

The four primary emotional states used to rate each activity for the first data point were:

1. Positive aroused affect: amazed, joyful, fun, happy, enthusiastic, eager, inspired, determined
2. Positive unaroused affect: alert, calm, relaxed, at ease
3. Negative unaroused affect: bored, drowsy, tired
4. Negative aroused affect: distressed, upset, angry, frustrated, worried

Of the 18 observations, 15 (83 percent) included at least one instance of positive aroused affect, and 12 (67 percent) included at least one instance of positive unaroused affect. Observers saw just one brief incidence of negative unaroused affect. They also recorded one instance of negative aroused affect: A girl got upset when another girl moved her project. The situation was quickly resolved when the girl got her project back right away.

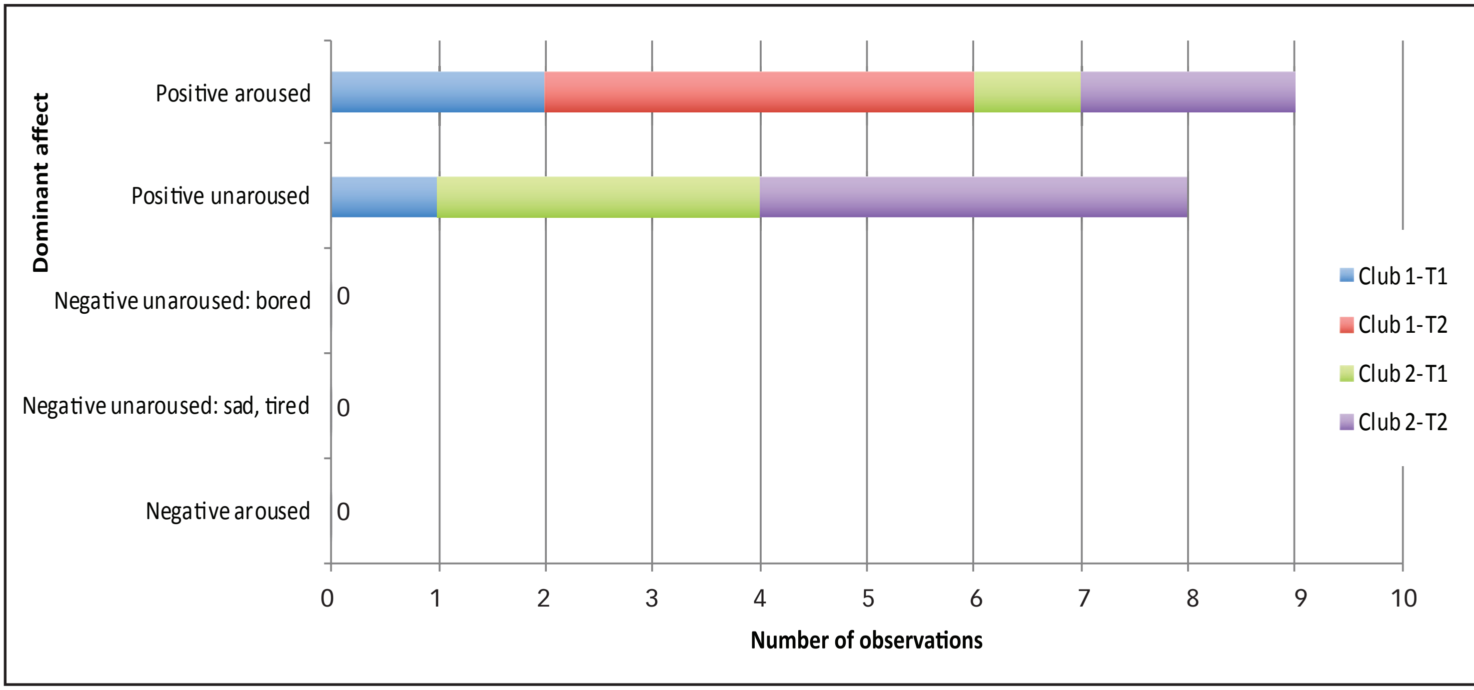
The next data point is the type of affect that dominated the observation, that is, it was observed at least 50 percent of the time. Figure 4 shows the results: Positive aroused affect was dominant in nine of the 18 observations, and positive unaroused affect dominated in eight. None of the negative states were dominant in any observation. One girl showed several emotional states during the observation and so did not have a single dominant affect.

On the third data point, overall rating of affect during the observation, all 18 girls were rated as being positively aroused or positively unaroused; none was rated as flat, mixed, negatively unaroused, or negatively aroused. All measures of affect thus suggest that, with the exception of one brief incident, the girls experienced positive emotions during their GEMS sessions.

## Activating Science Learning

Our observation data suggest that, by the criteria of the science learning activation framework, the GEMS club model can effectively engage girls in STEM. In the observed club sessions, girls engaged in a variety of scientific behaviors, actively participated in STEM activities, and experienced positive emotional states. No negative behaviors were observed. The only instance of negative affect was related to participant interactions;

*Figure 4. Dominant Emotional States*




no girls were observed feeling frustrated, upset, or distressed by any aspect of the STEM activity itself. When they encountered challenges, the girls were activated to solve the problem on their own, connecting with each other when they needed help. They appeared to enjoy the process of engaging in science behaviors and learning STEM content.

These GEMS clubs were found to spark involvement in STEM behaviors and create positive associations with STEM activities. The cognitive, behavioral, and emotional engagement we observed are key components of success as described by the science learning activation framework (Dorph et al., 2016; Dorph et al., 2017). Our observations suggest that the GEMS clubs enabled participants to experience both increased success and increased activation.

The science learning activation feedback loop (Figure 1) suggests that participants who experience activation thereby experience success, which leads to more activation. These participants may, in the long term, be more likely to pursue STEM literacy and STEM careers. Thus, GEMS participants who choose to engage in STEM, have positive experiences, and feel successful at mastering STEM content can be expected to grow in fascination with science, the extent to which they value science, their beliefs in their own competency in STEM, and their ability to make sense of science. Experiencing this growth in the elementary years is likely to lead to more choices to participate in STEM; more cognitive, behavioral, and cognitive engagement; more perceived success; and more mastery of learning content. Thus, GEMS seems to be moving girls toward long-term pursuit of STEM literacy and possibly of STEM careers.

The ability to generalize from this study of two small GEMS clubs in a single rural area is limited. The fact that the two afterschool clubs had differences in activities, formats, and facilitator backgrounds but had similar observation findings suggests that other GEMS clubs might also show similar results. Additional research would be required to discover whether these findings would apply to GEMS programs with different activities and facilitators or that serve children of different ages, racial or cultural groups, and socioeconomic backgrounds. Further research would reveal whether findings are similar in other types of OST STEM programs: ones that are coeducational or boys only, that serve younger or older children, or that are located in urban or suburban communities. Furthermore, this study examined only two of the four components of success in the science learning activation framework: choice and engagement. We did not explore perceived success or learning, so our conclusions about what constitutes "success" may be limited. Future studies might explore young people's own perspectives on choice, engagement, perceived success, and learning.

With these caveats, our findings suggest that an OST STEM approach that combines active engagement with successful experiences may have a positive impact on young people's participation in STEM. However, the science learning activation framework suggests that engagement and success are not enough. To continue on a science trajectory, participants need to experience science activation. OST programs that pay attention not only to behavioral and cognitive engagement but also to emotional engagement in STEM experiences may motivate participants to have more STEM experiences, thereby fostering STEM interest and knowledge in the long run. Ultimately, the science learning activation framework is a youth-driven model. It requires adult STEM facilitators to pay attention to participants' fascinations and to find ways to further that engagement.

OST STEM programs like GEMS, whose content and resources are freely accessible online, are important in rural areas where other informal STEM opportunities may be limited. Such programs can build young people's concrete experiences of STEM success and motivate them to seek more STEM experiences. Inclusive and engaging STEM programs that stimulate the feedback loop between activation and success can not only enrich the lives of individual participants by planting the seeds of lifelong STEM learning, but also feed the STEM pipeline and inspire a new generation of scientists from diverse backgrounds.

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