Purdue Journal of Service-Learning and International Engagement

Volume 10 | Issue 1 Article 8

2023

Indianapolis GEMS Club: Engagement in Informal Mathematics and Science Learning.

Maria Eloisa Nuguid
Purdue University

Indianapolis GEMS Club: Engagement in Informal Mathematics and Science Learning.

Cover Page Footnote

To the Lew Wallace School teacher Amy Sun and the first group of Indy GEMS girls, thank you for your collaboration, engagement, and commitment to making STEM fun. Thank you, Laura Reasoner Jones, for the initial GEMS activities and for your ideas. Thank you to the Indy GEMS facilitators and my colleagues, Yi Zhu, Grace Gochnauer, and Dr. Elizabeth Suazo-Flores, for all your hard work and dedication. To Catalyst and the Purdue GEMS research team, thank you for sharing your ideas, feedback, and endless support. Thank you to Carrie Brier and her team for helping us purchase materials. Thank you to my writing mentor, Dr. Elizabeth Suazo-Flores, for your energy and dedication and for driving the team to Indianapolis for every session. To my adviser, Dr. Signe Kastberg, thank you for believing in me and for joining us at Indy GEMS. To my parents, thank you for your love and encouragement.

INDIANAPOLIS GEMS CLUB

Engagement in Informal Mathematics and Science Learning

Maria Eloisa Nuguid *(Mathematics Education)*

STUDENT AUTHOR BIO SKETCH

Maria Eloisa "Lisa" Nuguid is a PhD student in mathematics education at Purdue University. She has been a research assistant for Girls Excelling in Math and Science (GEMS) since the fall 2021 semester. As a research assistant, Lisa has worked on science, technology, engineering, and mathematics (STEM) identity and curriculum research. Before GEMS, she was an instructor for an informal mathematics after-school program, Math Circle, at San Francisco State University, California. Informal spaces are meaningful to Lisa because they are spaces for students to have fun with STEM activities while creating community and seeing themselves as doers of STEM.

INTRODUCTION

There continues to be a need for the representation of women in science, technology, engineering, and mathematics (STEM) fields (George-Jackson, 2011; Griffith, 2010; Mayakis & Robinson, 2018; Shapiro & Williams, 2012). The literature also supports that informal learning spaces effectively contribute to girls' success in STEM fields (Richardson et al., 2021). To address this need, the Girls Excelling in Mathematics and Science (GEMS) research team at Purdue where I am a graduate research assistant started an after-school GEMS club at Lew Wallace School in Indianapolis, referred to as the Indy GEMS Club. When I joined GEMS as a research assistant in the fall of 2021, I learned that the team has been eager to start a GEMS club, and we are happy to have had the opportunity to launch the Indy GEMS Club this year. This essay is a description of the first Indy GEMS Club experience, which consisted of hands-on activities from preestablished curricula. By facilitating these initial activities, our objectives were to inspire the girls to be confident doers of STEM and believe in the opportunities of pursuing STEM in college and as a career. My objectives as a facilitator included gaining more experience in leading informal activities, learning from my colleagues, and collaborating with the community.

I was a San Francisco Math Circle facilitator in San Francisco, California. Math Circle is an after-school mathematics enrichment program in which students engage in mathematics games and puzzles based on abstract mathematics courses typically taught to mathematics majors. My experience as a Math Circle facilitator paved the way for Indy GEMS because it was my first informal learning experience in which I engaged in mathematics with students and with cofacilitators in ways that I did not have in my own elementary schooling. I remember elementary mathematics classes heavily consisting of worksheets, textbook problems, and timed mathematics tests. Doing mathematics through games and puzzles in Math Circle felt creative and challenging. I explored mathematics in ways that were not procedural, and I learned how to appreciate mathematics with

students and cofacilitators through play, art, and tactile activities. It was daunting at first to play mathematics games because there was no step-by-step procedure, so the exploration included diving into uncertainty. By doing so, I learned how to engage in mathematical tasks freely without knowing the outcome, make observations, ask questions, and be a better problem solver. Informal learning spaces such as Indy GEMS are opportunities for students to do math and science in this way.

Informal after-school spaces are amazing enrichment opportunities for learners. Some features of informal spaces include play, socialization, and collaboration in which "participants hone their existing knowledge and skills and also innovate, developing new ideas and skills" (Rogoff et al., 2016, p. 360). Learners can use their lived experiences and skills to inform what they do and engage in new ways at informal spaces. Based on an informal after-school club with bilingual Latina/o students, some aspects of that space included "traditional borders of age (parents and children), domains of expertise (e.g., traditional school subjects, community knowledge), and communicative modalities (e.g., use of formal language, everyday vernacular, Spanish, English) [that] were deliberately blurred" (Razfar, 2012, pp. 55–56). There is flexibility in how to participate in informal spaces. One communicative modality relevant to my research is body-based movement used to communicate mathematics (Alibali & Nathan, 2012; Nathan, 2021). This means using parts of one's body to learn, communicate, and make meaning of mathematical concepts. One example is counting on fingers. Research shows that body-based learning activities contribute to students' development of a mathematics identity as doers of mathematics (Nathan, 2021). Identifying as a doer of mathematics and science has been one of the GEMS goals.

DESCRIPTION

Participants

Lew Wallace School in Indianapolis is highly diverse in terms of ethnicity and race. Reported from the 2020–2021 school year, there were 42.9% Black/African American, 44.9% Hispanic, 6.6% White, 5.3% multiracial, and 0.3% Asian students (Indiana Department of Education, 2020). In addition, 87.5% of students were economically disadvantaged (Indiana Department of Education, 2020). Our participants ranged from 12 to 16 girls of all non-White backgrounds. Our Purdue GEMS team introduced the first GEMS club at Lew Wallace School. According to the school's vision, "Lew Wallace School is a diverse neighborhood school that believes in equitable high-quality education for all students with a focus on collaboration, inclusion and growth mindset" (Lew Wallace School 107, n.d.). Given that Purdue University in West Lafayette is 75 minutes away, there are few opportunities for these girls to engage with Purdue, and this was a unique opportunity to do so. We wanted to model that going to Purdue, being a researcher, and working in STEM careers are all possibilities. We wanted to help inspire the girls to be confident doers of STEM and believe in the opportunities of pursuing STEM in college and as a career.

Activities

During our preparation for Indy GEMS, the GEMS founder had preestablished activity plans for activities she had previously used. The activities were called Hidden LEGOS, Cup Stacking, Building a Zipline, Creating a Water Filter, Maps, and Making a Coin Battery. My colleague and I met with the founder on Zoom to learn about any challenges, highlights, and points of emphasis. We planned to switch who would lead each activity and practiced with each other. We planned what we would say, what questions to ask, the transitions between tasks throughout the activity, a whole group debrief with preselected questions from the founder, and cleanup. We are thankful to have received the Purdue Student Service-Learning Grant used to purchase materials for each activity. Our faculty mentor took time every weekend to buy materials for the girls, and she assisted us during every session. Then, once a week for four weeks, the Purdue GEMS team met with a group of 12 to 16 energetic third- and fourth-grade girls ready to engage in these informal STEM activities together.

The facilitators mainly included active GEMS research assistants and faculty. Since then, we have recruited outside of GEMS to expand our volunteers. The participant-to-facilitator ratio for each day was 4:1. The facilitation structure for each session involved a lead facilitator, a video data collector, and two "floaters," people who circulated among groups. One of the Lew Wallace teachers also took time every afternoon to help us facilitate every activity and assist with the drop-off procedures at the end of the day when the girls went home. The lead facilitator gave activity instructions, transitioned from task to task, stayed within the time frame, and also circulated to assist the girls during the activity. The video data collector set up the iPad and Swivl (a robotic iPad platform that rotates and captures audio through wireless microphones) to capture the whole group including the lead facilitator, who wore a microphone tracked by the Swivl. We decided to keep

the iPad and Swivl on the side or corner of the room in order to get a wide angle of the whole group. There were also a couple of microphones on the table to capture the girls' conversations during the activity. The floaters were facilitators who circulated during the activity, making sure the girls understood the directions. They helped the girls execute the activity while also asking questions about mathematics and science to help them make connections. Regardless of who led the activity or set up the video recording equipment, all of the facilitators circulated and helped the girls with the activities. We aimed to facilitate by creating a student-led atmosphere where the girls did the activities with their group or partner with little to no interference from adults aside from asking supporting questions to further the girls' thinking. We wanted the girls to make their own observations about what sparked their curiosity.

The first part of an average day at Indy GEMS included Dr. Suazo-Flores picking up the facilitators from Purdue University in West Lafayette and driving to Lew Wallace School in Indianapolis. During our carpooling, we shared stories and got to know each other outside of a university context. Upon arriving at Lew Wallace School, the facilitators arranged recording equipment and put the desks into groups of three to four. When it was time for the club to officially begin, all of the girls eagerly rushed into the room and greeted us with laughs, smiles, and hugs. We provided snacks and water to give the girls a chance to recharge after a long day of school, get to know each other, and transition into activities.

The first activities were Hidden LEGOS and Cup Stacking. These activities were intentionally created to facilitate collaboration and teamwork, major factors in STEM careers. The girls also had the opportunity to experience what a difference communication styles make, including nonverbal communication. For Hidden LEGOS, the girls worked in pairs with a folder separating them so they could not see each other's structures (Figure 1). Each pair received a set of two identical bags filled with a handful of LEGO Technics and two pie pans to contain the pieces. LEGO Technics sets were an intentional choice due to the variety of LEGO pieces, such as gears, rods, and windows. To start, one of the girls built a LEGO structure. Then, she gave her partner verbal instructions while her partner had to rebuild the structure. In addition to not being able to see what each other was building, one more restriction was that the girls could not say colors. They had to describe their LEGOS with different attributes other than saying, for example, "red LEGO." This activity allowed for communication, reexplanation, building, creation, and imagination. The challenge of explaining and describing

Figure 1. The Girls Worked on the Hidden LEGOS Activity

Figure 2. Cup Stacking Involved Stacking Cups without Using Hands

LEGO pieces enabled the girls to persevere in finding a way to communicate with their partners and work on their spatial reasoning, as the listener needed to imagine what was being said.

The following activity was Cup Stacking, with the girls working in pairs or groups of three. The task was to build a stack of cups in a pyramid arrangement without touching the cups with hands. The girls had string and rubber bands to assist with the stacking. They also got creative by trapping the cup with their forearms to pick it up and stack it (Figure 2). We heard a loud excited shriek at the end of the activity from one of the girls, who was so happy that she was successful in making a pyramid.

On day two the girls built a zipline, with my working in pairs or groups of three. The goal was for the girls to build a gondola that traveled down a line and safely transported items. The intention was for the girls to engage in the engineering design process, which involved designing and redesigning based on changing the materials. Materials for the gondola included cups and coffee filters. The line was made out of a variety of string, fishing line, and yarn. The items to transport in the gondola were toy cars, golf balls, and rocks. We gave the girls one type of string, a cup, and one item to transport. Within minutes, the girls were swapping out the material for different strings and different gondolas, asking us to cut holes in the cups to attach the string, and testing out their ziplines. The girls enjoyed tinkering and watching the gondola travel from various heights by holding the string at desk level and shoulder level (Figure 3). If this activity is to be repeated and improved, I learned that I needed to be more explicit about instructions in order to engage in the engineering design process.

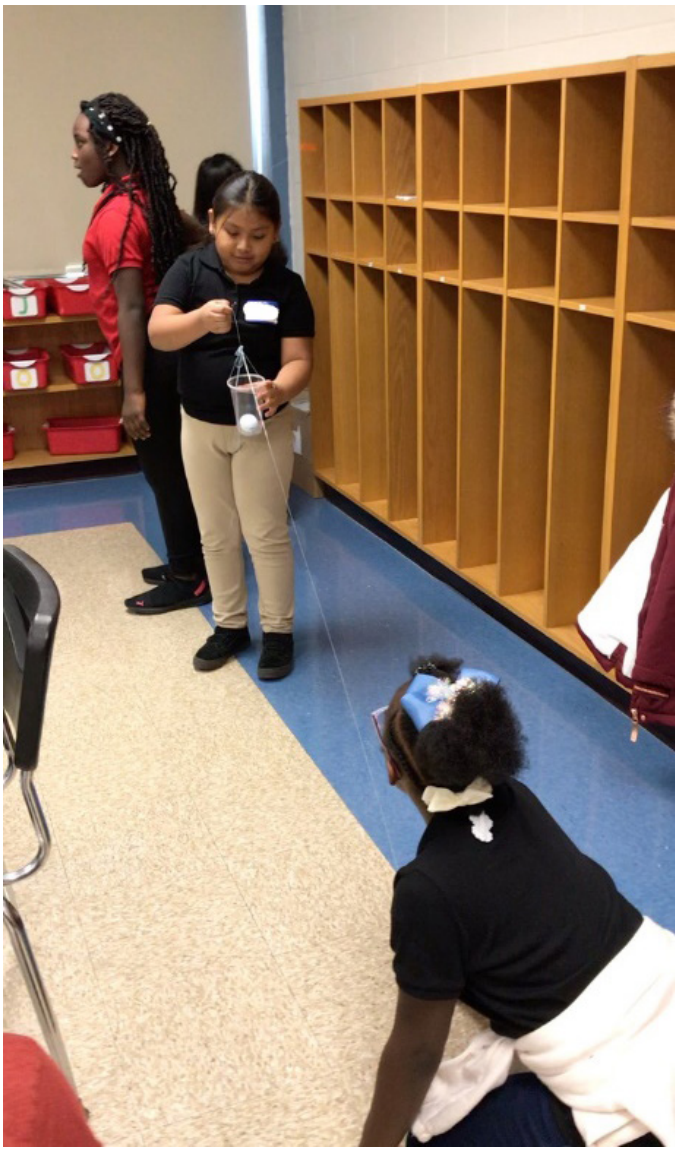

Figure 3. The Girls Built a Zipline

The next activity was creating a water filter, with the girls working in pairs. We gave the girls halves of water bottles as the container where they layered materials (Figure 4). We also had a guest facilitator, Dr. Signe Kastberg, who observed and engaged with the girls. The girls went outside and layered cotton balls, sand, activated charcoal, aquarium rocks, pebbles, and large rocks in the water bottle. Then, facilitators poured dirt water into the filter to observe how clear the water looked after it traveled through the layers of the filters and collected into the other half of the bottle. The girls wanted to see the water poured multiple times to try their best and clear out the impurities. To improve this activity if it is to be repeated in the future, Dr. Kastberg suggested involving measurement; the girls could measure how much of each material they used.

On our last day of the semester, the girls did two activities. For the first activity, Maps, Dr. Suazo-Flores asked the girls to think individually about how long it took for them to get to school in the morning. Then, she gave each

Figure 4. The Girls Made a Water Filter

Figure 5. The Girls Drew Maps from Their Homes to School

girl strips of paper to draw maps depicting their travel from home to school (Cohrssen & Pearn, 2021), with each strip of paper depicting five minutes of travel time (Figure 5). We are currently analyzing these maps for evidence of visuospatial reasoning, which involves space and place; recognizing shapes, combinations, and their properties; symmetry thinking; and comparing quantities and using ratios, spatial capabilities, locating, intention, attention, and noticing (Owens, 2020). The last activity was illuminating a mini light bulb with a coin battery created out of vinegar-soaked paper and stacked pennies and nickels. Because we were running out of time, the girls were rushing to create a large enough stack of coins and paper to light the bulb. They were cupping their hands around the bulb to see if it glowed even a little bit. Their perseverance was palpable.

COMMUNITY IMPACT

Indy GEMS Club was our first experience of a GEMS club in Indianapolis (Figure 6). We had a preestablished set of activities given to us by the GEMS founder. The outcomes were that the girls engaged in activities that some of them had never done before, they had fun, and we were invited back for the following semester. For a tangible outcome, we are currently planning to repeat the Maps activity and have the girls draw a map from their homes to school again. The GEMS team will analyze them in comparison to their previously drawn maps for any changes in their drawings. Facilitators had their own facilitation style and were adequately prepared to work with the students. Our team also had a mix of experience in both formal classroom and informal after-school settings. One challenge was navigating different facilitation styles. In Math Circle, I was used to one facilitator per group of learners for the entire activity with little whole group instruction. At Indy GEMS, there was more of a whole group structure whereby all the facilitators circulated to every group instead of staying with one group. Although our styles differed, I learned a lot about different facilitation techniques such as using attention getters, giving more explicit instructions, and having a

Figure 6. On the Last Day, the Girls Wore Their Safety Goggles for a Group Picture

specific procedure for cleanup at the end of activities. Some of these initial activities presented us with challenges. I experienced having too many materials to juggle for the zipline activity and struggling with science and engineering background knowledge, since mathematics has been my focus area. The coin battery activity was also challenging to achieve because it took a number of attempts for me to make a powerful enough coin battery to light a lightbulb. Gathering faculty and student help has been a challenge due to the time commitment of going to Indianapolis, running Indy GEMS, and returning to Purdue. Transportation to Indianapolis was also a challenge, since our faculty mentor was the only one of us who had a vehicle available. To address such challenges, we recruited outside of GEMS at Purdue for the spring 2023 semester and presented the option of different roles that volunteers could undertake besides facilitator such as driver or video person. To sustain this project, we started creating facilitator guides so that teachers can re-create GEMS club activities at their schools.

STUDENT–AUTHOR IMPACT

GEMS at Purdue University was my first research assistantship experience and continues to be a major part of my PhD journey every year. I learned how to organize, develop activities and curriculum, and analyze data. Going to Lew Wallace School for Indy GEMS has allowed me to form connections with the community, share my love of informal activities with the girls, and bond with my colleagues. I am thankful to be part of a team that supports my growth as a researcher, educator, and leader.

I was prepared for the atmosphere of an informal afterschool space such as the collaborative energy and enthusiasm of the students because of my experience in Math Circle. For Indy GEMS, I had more responsibility as a research assistant and an activity facilitator simultaneously. For this project, I learned how to write a grant for materials and coordinate with Purdue staff to get the materials delivered. I learned that Indy GEMS activities

needed to involve connections to STEM careers while also being currently relatable to students. Engaging third and fourth graders in activities was sometimes challenging if the activities were not relatable to them. I also learned in a previous integrated STEM course at the University of Minnesota that mathematics can be overshadowed in integrated STEM lessons. Coincidentally, one of the girls asked, "Where is the math?" For future STEM curriculum, I aim to be mindful that emphasizing mathematics is a continued effort to ensure that it is still at the forefront in science and engineering activities. I also learned from the zipline activity that shifting from tinkering or playful exploration to design and redesign in engineering activities is challenging as well. I was and continue to feel grateful to have a team of people, for I could not imagine Indy GEMS as an individual effort.

We were invited to do Indy GEMS again in the spring of 2023. Since we would work with the same girls, we chose new activities. To address the challenges above, the team and I decided to choose new activities for the semester that focused more on visuospatial reasoning such as drawing, building, visualizing, and modeling (Owens, 2020). Through activities that allow for creativity while also incorporating lived experience, we anticipated that the girls would be more engaged and would further develop their visuospatial reasoning. Two new people also joined our team to help with activity planning, transportation, and facilitation. Through this experience, I learned how to be a better leader, collaborator, facilitator, and researcher, which are all transferable skills for my aspirations to become a tenured professor.

CONCLUSION

Indy GEMS contributes to inspiring girls to be confident doers of STEM and believe in the opportunities of pursuing STEM in college and as a career. Further student involvement includes researching with GEMS as a research assistant or through the Undergraduate Research Training program. This experience is helpful in learning informal STEM facilitation, research-based curriculum design, and collaboration with a research team. GEMS enhanced reciprocity because it built community among the girls at Lew Wallace School, their teacher, and our Purdue GEMS research team. The girls always showed excitement and enthusiasm when they saw us, and we were invited back for a second semester for Indy GEMS. Reciprocity could also be enhanced through more visuospatial reasoning activities (Owens, 2020) such as the Map activity, in which students drew maps from home to school. Visuospatial reasoning allows for the girls to draw from their lived experiences to engage in STEM (Owens, 2020). I wrote this essay to highlight and celebrate the girls at the first Indy GEMS Club at Lew Wallace School and the GEMS team at Purdue. Currently, the team is working on activity facilitator guides for teachers to launch GEMS activities with their students. I want to invite teachers to engage in GEMS activities with their students and start GEMS clubs at their schools.

ACKNOWLEDGMENTS

To the Lew Wallace School teacher Amy Sun and the first group of Indy GEMS girls, thank you for your collaboration, engagement, and commitment to making STEM fun. Thank you, Laura Reasoner Jones, for the initial GEMS activities and for your ideas. Thank you to the Indy GEMS facilitators and my colleagues, Yi Zhu, Grace Gochnauer, and Dr. Elizabeth Suazo-Flores, for all your hard work and dedication. To Catalyst and the Purdue GEMS research team, thank you for sharing your ideas, feedback, and endless support. Thank you to Carrie Brier and her team for helping us purchase materials. Thank you to my writing mentor, Dr. Elizabeth Suazo-Flores, for your energy and dedication and for driving the team to Indianapolis for every session. To my adviser, Dr. Signe Kastberg, thank you for believing in me and for joining us at Indy GEMS. To my parents, thank you for your love and encouragement.

REFERENCES

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences*, *21*(2), 247–286. https://doi.org/10.1080/10508406.2011.611446

Cohrssen, C. & Pearn, C. (2021). Assessing preschool children's maps against the first four levels of the primary curriculum: Lessons to learn. *Mathematics Education Research Journal, 33*(1), 43-60. https://doi.org/10.1007/s13394-019-00298-7

George-Jackson, C. E. (2011). STEM switching: Examining departures of undergraduate women in STEM fields. *Journal of Women and Minorities in Science and Engineering*, *17*(2), 149–171. https://doi.org/10.1615/JWomenMinorScienEng.2011002912

Griffith, A. L. (2010). Persistence of women and minorities in STEM field majors: Is it the school that matters? *Economics of Education Review*, *29*(6), 911–922. https://doi.org/10.1016/j.econedurev.2010.06.010

Indiana Department of Education. (2020). *Lew Wallace Elementary School (4479), student population*. Data set, 2020–2021 school year. https://inview.doe.in.gov/schools/1047104479/population

Lew Wallace School 107. (n.d.). *About us*. https://myips.org/lewwallace/about-us/

Mayakis, C. G., & Robinson, J. (2018). Girls in STEM K–12 subjects: Exploring the confidence and hindrance of pursuing STEM careers. In M. C. Grant (Ed.), *Equity, equality, and reform in contemporary public education* (pp. 110–125). IGI Global. https://doi.org/10.4018/978-1-5225-4960-4

Nathan, M. J. (2021). *Foundations of embodied learning: A paradigm for education*. Routledge.

Owens, K. (2020). Transforming the established perceptions of visuospatial reasoning: Integrating an ecocultural perspective. *Mathematics Education Research Journal, 32*(2), 257–283. https://doi.org/10.1007/s13394-020-00332-z

Razfar, A. (2012). ¡Vamos a jugar counters! Learning mathematics through funds of knowledge, play, and the third space. *Bilingual Research Journal*, *35*(1), 53–75. https://doi.org/10.1080/15235882.2012.668868

Richardson, S. E., Suazo-Flores, E., & Rice, M. (2021). Developing STEM identity: Beyond STEM content knowledge in an informal STEM club. In D. Kollosche (Ed.), *Exploring new ways to connect: Proceedings of the Eleventh International Mathematics Education and Society Conference* (Vol. 3, pp. 839–848). Tredition. https://doi.org/10.5281/zenodo.5457236

Rogoff, B., Callanan, M., Gutiérrez, K. D., & Erickson, F. (2016). The organization of informal learning. *Review of Research in Education*, *40*(1), 356–401. https://doi.org/10.3102/0091732X16680994

Shapiro, J. R., & Williams, A. M. (2012). The role of stereotype threats in undermining girls' and women's performance and interest in STEM fields. *Sex Roles*, *66*(3–4), 175–183. https://doi.org/10.1007/s11199-011-0051-0M

Nuguid, M. E. (2023). Indianapolis GEMS Club: Engagement in Informal Mathematics and Science Learning. *Purdue Journal of Service-Learning and International Engagement, 10*, 44–51. https://doi.org/10.5703/1288284317692