Work in Progress: Improving economic equity in K-12 robotics exploratory activities

Kasey Moomau, Emily Fitzpatrick, and Jessica Deters
College of Engineering, University of Nebraska-Lincoln

Abstract

This work-in-progress paper presents an initiative to improve economic equity in K-12 robotics exploratory activities through the development of a more affordable educational robotics system and a pilot intervention program. The project aims to enhance STEM identity development for underrepresented middle school students, particularly those from less affluent communities, while also fostering positive attitudes toward service learning among undergraduate engineering students. An undergraduate club at the University of Nebraska-Lincoln is designing a robotics kit with similar functionality to the Lego Spike system but at approximately one-third of the cost. The kit, estimated to be fabricated for less than $130 per unit, will offer opportunities for students to develop coding skills in Python alongside block-coding interfaces. This innovative approach combines cost-effectiveness with expanded coding capabilities, addressing the disparity in access to STEM exploration experiences among K-12 students from different socioeconomic backgrounds. The pilot intervention plan involves implementing these kits in after-school STEM clubs at local middle schools. Undergraduate engineering students will prepare and lead introductory engineering curriculum for middle school students using the kits over a 6-week period. The program aims to reach 30-60 middle school participants, with 10-25 undergraduate volunteers involved in the initiative. Future work will focus on data collection to assess the impact of the intervention on both middle school participants and undergraduate volunteers. This initiative seeks to address the broader issue of underrepresentation in STEM fields by providing more affordable STEM exploration curriculum and assessing the impact of targeted interventions. By fostering positive STEM identity formation in underrepresented students and promoting engineering service activities among undergraduate volunteers, the project aims to contribute to increasing diversity and inclusion in STEM education and careers.

Keywords

Graduate Student Poster; K-12 Outreach; STEM Identity

Introduction

Positive STEM identity formation has been shown to be a key factor in students' choice of and persistence in STEM majors in undergraduate education [1], and lack of STEM identity in underrepresented students is correlated with lower enrollment and success rates in undergraduate STEM programs. Furthermore, underrepresented K-12 students are less likely to develop positive STEM identity without extra support, especially if they experience intersection of two or more traditionally underrepresented identities (i.e. they identify as female and Black) [2]. Middle school has been identified as an important time in forming self-efficacy and identity which will affect career choices made in high school and college [3]. Other work [4] suggests that open-

ended STEM exploration in a group collaborative setting is conducive to positive STEM identity development, due to the identity formation that occurs in the context of relationship-building with peers during STEM activities.

The University of Nebraska-Lincoln is a large, public land-grant university in the Midwest, located in Lincoln, Nebraska, which contains a sizeable public school district, serving approximately 40,000 students. A significant percentage (approximately 30%) of these students are from traditionally underrepresented backgrounds, and/or identify as female. Currently, the availability of exploratory STEM experiences to middle school students in the district is sporadic and appears to loosely be a function of the individual school communities' resources, with more opportunities being available to schools in more affluent communities.

With these factors in mind, we decided to pilot an undergraduate club with the objective of making early positive STEM-identity-building experiences available to local middle-school students, with the goal of enhancing STEM identity development for underrepresented students, especially those from less affluent communities in the district. To accomplish this, the club would first improve on the status quo of middle-school-appropriate robotics educational materials (Lego Spike), and then plan and implement an intervention targeted toward providing collaborative, open-ended STEM exploration activities to underrepresented students whose STEM identities might be most at-risk. This paper details how we plan to make available a less-expensive robotics curriculum and kit and implement an intervention for after-school STEM clubs in the local district. This intervention is expected to have a positive impact on the self-perceived engineering identity of both the middle-school students and the undergraduate club members; future work aims to measure this impact.

Methods

Lego Spike: the status quo

Lego Spike is marketed as an all-in-one solution for robotics activities in the classroom. The findings of a seven-year longitudinal comparison study [5] of participants in the FIRST Lego League suggest that extracurricular participation in Lego robotics activities correlate with greatly increased interest in STEM careers and a significantly increased sense of belonging in STEM. The kit comes with introductory activities on using sensors, driving motors, and programming the robot to respond to sensors to actuate lights and motors. An introductory kit costs, at the time of writing, about $400 USD [6].

Novel Undergraduate-Designed STEM Robotic Exploration Kit

The club members are designing a more affordable educational robotics system with similar utility to Lego Spike systems used in classroom instruction and robotics competition at the middle school level. The design phase is complete, and completed prototypes indicate that the finished product can be fabricated for less than $130 per kit, which is roughly 1/3 of the price of a similar Lego Spike kit. The kit will contain the same functionality with more opportunity for student learners to develop coding skills in python, in addition to the block-coding interfaces which have been shown to be a successful introduction to coding and robotics for K-8 learners.

Club members are developing developmentally appropriate curriculum to support learning goals with advice from K-12 educators and faculty.

Pilot Intervention Plan

Initially, the kit will be used in a pilot intervention which provides robotics activities to the local school district's middle school after-school STEM-focused clubs. Selection of appropriate after-school clubs will proceed on the advice of the public-school administration. Undergraduate engineering student volunteers will prepare and lead an age-appropriate introductory engineering curriculum using the kits. This initial pilot intervention will involve 10-25 undergraduate engineering students and 30-60 middle school STEM club participants and will involve one session per week for 6 weeks.

Undergraduate volunteers will consist of a mixture of core club members and volunteers solicited from a required first-year engineering course focused on developing engineering leaders. The course contains a mandatory service-learning component, reflection activities and presentations on service learning, and engineering leadership throughout the course. Core club members will provide undergraduate volunteers with sample activities and hands-on practice with the kit, as well as training on developmentally appropriate STEM learning goals and the fundamentals of positive classroom management, after which, the volunteers will organize activities for the middle school STEM clubs and lead these activities alongside the core club members over 6 weeks.

Future Work

We are in the beginning stages of testing and deployment. Data on the effect on undergraduate engineering attitudes toward service learning or positive stem identity development in undergraduate engineering students, or middle school participants will be collected during the 6-week pilot session. Specifically, reflection and survey data will be collected from middle school and undergraduate students. The goal of collecting reflection and survey data from the middle school participants is to understand the impact of the pilot intervention on the self-evaluated STEM identity of the participating middle school students. We intend to measure this using a mixed-methods approach based on work by Hughes [7], Ramsey [8], and Singer [2]. Qualitative reflections will guide further investigation and solicitation of students for focus groups to identify the most impactful elements of the intervention and areas for improvement. Quantitative before-and-after self-evaluation data will help us to understand the impact of the intervention over a larger sample of the participants. The goal of collecting reflection and survey data from the undergraduate volunteers is to provide useful insight into the correlation between service-learning experience characteristics and volunteer satisfaction with the experience, as well as self-evaluated effects on the STEM identity of undergraduate volunteers and their desire to engage in further service-learning experiences in the future. In addition, we expect that the volunteers may have additional qualitative insights into the effects of the intervention on the middle-school students, as well as first-hand accounts of pain points and ideas about how to improve future implementations of the intervention.

Despite the project being in an early phase, initial buy-in from stakeholders is enthusiastic. District administrators and educators, the faculty and teaching assistants of the undergraduate

service-learning course, and administrative personnel are eagerly collaborating to plan for the pilot program. In addition, initial funding for the pilot activities has been secured.

To date, this intervention is still in the design stage, and we plan to trial it during the Fall 2024 semester. Prior to that point, we intend to continue working with faculty and primary education stakeholders to tailor our curriculum to the context of the CLCs, and to work with focus groups comprised of K-12 educators and undergraduate engineering student volunteers from other robotics clubs to refine the physical kit and supporting training materials and curriculum.

Our next steps involve proposing our investigation of the intervention to the IRB, finalizing training materials and curriculum, engaging the pre-pilot focus groups, and finalizing data-gathering instruments. The club members will then revise as necessary before fabricating and testing the pilot versions of the kits and training materials. Club members will also give a short presentation to the service-learning course students to solicit volunteers.

Our goal is to empower a significant number of underrepresented middle school students to further explore and ultimately be successful in STEM career fields. In addition, we hope to foster perceptions of engineering service activities as desirable and positive among the undergraduate volunteers involved.

References

[1] R. Dou, Z. Hazari, K. Dabney, G. Sonnert, and P. Sadler, "Early informal STEM experiences and STEM identity: The importance of talking science," *Science Education*, vol. 103, no. 3, pp. 623–637, 2019, doi: 10.1002/sce.21499.

[2] A. Singer, G. Montgomery, and S. Schmoll, "How to foster the formation of STEM identity: studying diversity in an authentic learning environment," *International Journal of STEM Education*, vol. 7, no. 1, p. 57, Nov. 2020, doi: 10.1186/s40594-020-00254-z.

[3] E. Seo, Y. Shen, and E. C. Alfaro, "Adolescents' Beliefs about Math Ability and Their Relations to STEM Career Attainment: Joint Consideration of Race/ethnicity and Gender," *J Youth Adolescence*, vol. 48, no. 2, pp. 306–325, Feb. 2019, doi: 10.1007/s10964-018-0911-9.

[4] J. Çolakoğlu, A. Steegh, and I. Parchmann, "Reimagining informal STEM learning opportunities to foster STEM identity development in underserved learners," *Front. Educ.*, vol. 8, May 2023, doi: 10.3389/feduc.2023.1082747.

[5] T. Meschede, Z. Haque, M. E. Warfield, A. Melchior, C. Burack, and M. Hoover, "Transforming STEM outcomes: Results from a seven-year follow-up study of an after-school robotics program's impacts on freshman students," *School Sci & Mathematics*, vol. 122, no. 7, pp. 343–357, Nov. 2022, doi: 10.1111/ssm.12552.

[6] "LEGO® Education SPIKE™ Prime Set 45678 | LEGO® Education | Buy online at the Official LEGO® Shop US." Accessed: Aug. 05, 2024. [Online]. Available: https://www.lego.com/en-us/product/lego-education-spike-prime-set-45678

[7] Ramsey, L. R., Betx, D. E., & Sekaquaptewa, D. (2013). The effects of an academic environment intervention on science identification among women in STEM. Social Psychology Education, 16, 377–397.

[8] R. M. Hughes, B. Nzekwe, and K. J. Molyneaux, "The Single Sex Debate for Girls in Science: a Comparison Between Two Informal Science Programs on Middle School

Students' STEM Identity Formation," *Res Sci Educ*, vol. 43, no. 5, pp. 1979–2007, Oct. 2013, doi: 10.1007/s11165-012-9345-7.

Kasey Moomau

Kasey Moomau is a second-year mechanical engineering graduate student at the University of Nebraska—Lincoln. Before returning to further his university education with a B.S. in Mechanical Engineering and a serendipitous opportunity for graduate education at UNL, he served for the better part of a decade as a public-school educator, creating and implementing exploratory STEM activities as supplemental curriculum for K-8 students.

Emily Fitzpatrick

Emily Fitzpatrick is a fourth-year mechanical engineering undergraduate student at the University of Nebraska—Lincoln. She served as a teaching assistant for the engineering interpersonal and leadership skills course from Fall 2022 – Spring 2023.

Jessica Deters, Ph.D.

Dr. Jessica Deters is an Assistant Professor of Mechanical and Materials Engineering and Discipline Based Education Researcher at the University of Nebraska—Lincoln. She holds her Ph.D. in Engineering Education and M.S. in Systems Engineering from Virginia Tech, and her B.S. in Applied Mathematics and Statistics from the Colorado School of Mines.