Board 211: Building a 'Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics' RET Site (Year 2)

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Xiaowen Gong received his BEng degree in Electronics and Information Engineering from Huazhong University of Science and Technology in 2008, his MSc degree in Communications from the University of Alberta in 2010, and his PhD degree in Electrical Engineering from the Arizona State University in 2015. From 2015 to 2016, he was a postdoctoral researcher in the Department of Electrical and Computer Engineering at The Ohio State University. He is currently an Associate Professor in the Department of Electrical and Computer Engineering at Auburn University. His research interests are in the areas of wireless networks and their applications, with current focuses on machine learning and AI in wireless networks, edge computing, and network security. He received IEEE INFOCOM 2014 Runner-up Best Paper Award as a co-author, ASU ECEE Palais Outstanding Doctoral Student Award in 2015, and NSF CAREER Award in 2022. He is currently an Associate Editor for IEEE Transactions on Wireless Communications, a Guest Editor for IEEE Transactions on Network Science and Engineering, and a Guest Editor for IEEE Open Journal of the Communications Society.

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Her research areas include STEM K12 Inclusive Computing Research and Outreach; Web Applications Design and Development; Education and Assistive Technology; Software Engineering; Web and Software Engineering Usability and Accessibility.

Dr. Marghitu has received funding for research and education projects from National Science Foundation (e.g.Co-PI of NSF RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics; Co-PI of NSF INCLUDES Alliance: The Alliance of Students with Disabilities for Inclusion, Networking, and Transition Opportunities in STEM (TAPDINTO-STEM); Co-PI of NSF EEC "RFE Design and Development: Framing Engineering as Community Activism for Values-Driven Engineering"; Co-PI of NSF CISE "EAGER: An Accessible Coding Curriculum for Engaging Underserved Students with Special Needs in Afterschool Programs"; co-PI of NSF INCLUDES: South East Alliance for Persons with Disabilities in STEM, Co-PI of NSF CE 21 Collaborative Research: Planning Grant: Computer Science for All (CS4ALL)).

Dr. Marghitu was also PI of grants from Center for Woman in Information Technology, Daniel F. Breeden Endowment for Faculty Enhancement, AccessComputing Alliance, Computer Science Collaboration Project, Microsoft Fuse Research, Altova Co., and Pearson Education Publishing Co.

Dr. Marghitu has mentored over one thousand high school, computing undergraduate, graduate students including representatives of underserved/underrepresented communities, women, and people with disabilities.

Dr. Marghitu has participated in numerous administrative activities at Auburn University. Among these activities are the following: Auburn University Board of Trustee Faculty Representative; Auburn University representative for National Center for Women in Information Technology, AccessComputing, Access10K, and AccessEngineering Alliances; Auburn University Persons with Disabilities Committee chair; Founder

and Director Auburn University Laboratory for Education and Assistive Technology; faculty representative Auburn University Core Curriculum Oversight committee and Multicultural Diversity Commission.

Dr. Marghitu also served as World Usability Day Web Site Committee Chair; Alabama STEM Education board chair, Panel member for the National Science Foundation; member of the congressionally mandated Committee on Equal Opportunities in Science and Engineering; member of the Committee on the Future of NSF EPSCoR; and member of the Computer Science for All (CSforAll) Accessibility Board.

Dr. Marghitu published seven Information Technology books at Pearson Publishing Co., articles at International Journal On Advances in Software, International Journal On Advances in Internet Technology, Journal of Women and Minorities in Science and Engineering, National Science Teaching Association Journals, Journal of Computer Science Education,International Journal on Advances in Internet Technology Transactions of the SDPS: Journal of Integrated Design and Process Science, User Experience Magazine, Journal of Computing Sciences in Colleges, International Journal for Virtual Reality, Journal of SMET Education and Research.

Dr. Marghitu has published peer reviewed papers and gave presentations at numerous international conferences(e.g. ACM Special Interest Group on Computer Science Education Technical Symposium, International Technology and Persons with Disabilities Conference, International Conference on Software Engineering Advances, EDUCAUSE, Association for Advancement of Computing in Education, International Society for Technology in Education, Society for Design and Process Science, American Society for Engineering Education, Human Computer Interaction International Conference, and International Academy, Research, and Industry Association) in USA, Canada, England, France, Germany, Spain, Italy, Portugal and Romania. Her work was also presented by co-authors at conferences in Brazil, Taiwan and S. Korea.

Among Dr. Marghitu's honors and awards are the following: 2011 AccessComputing Capacity Building Award, the 2012 Auburn University Access award, the 2012 Society for Design and Process Science Outstanding Achievement Award, the 2013 Microsoft Fuse Research award, the 2015 DO-IT Trailblazer award, the 2017 International Academy, Research, and Industry Association Fellowship, the 2017 Society for Design and Process Science Fellowship, and the 2019 Samuel Ginn College of Engineering 100+ Women Strong Leadership in Diversity Faculty Award.

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Work in Progress: Building a "Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics" RET Site (year 2)

Abstract

This paper is based on a longitudinal project funded by the National Science Foundation Research Experiences for Teachers (RET) in Engineering and Computer Science grant. The primary objective of this project is to develop an RET Site under CISE at Auburn University (AU) in Alabama. The title of the research project is "RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics", and this project provides engaging research experiences to middle and high school science teachers from primarily rural and underserved school districts in Alabama. In-service teachers (7^{th} and 8^{th} grade) participate in a 6-week summer professional development program with an emphasis on machine learning and AI. In addition, to the summer professional development institute teachers lead a weeklong summer camp for middle school students where they have an opportunity to implement curriculum modules they have developed and the project team provides support for teachers to implement the curriculum modules during the academic year as well.

Providing consistent support and professional development for teachers in underserved school districts is essential for preparing students with the 21^{st} century skills they will need to engage in an increasingly technological society. This is also essential for broadening participation in STEM for students from traditionally underrepresented populations. Engaging teachers' innovative content (e.g. AI, machine learning, robotics) enhances their pedagogical content knowledge and provides them the skills to better prepare their students to become scientists, engineers, innovators, and entrepreneurs in these areas.

As part of this RET project, teachers explore various research topics alongside faculty mentors' and learn how to connect their science and mathematics objectives to machine learning, mobile robot, computer vision, virtual and augmented reality concepts and develop curriculum modules using this content. Teachers also engage with science education researchers to better understand how to make the science content more relevant to their students' daily lives. Teachers enhanced their knowledge in inquiry-based, hands-on research pedagogical strategies and structured and designed their lessons through a lens of project-based learning. Key to this project was demonstrating how leveraging an innovative platform of ML-based mobile robots can be friendly and easily accessible to teachers. This project also fosters strong collaborations between in-service teachers, and engineering and STEM education faculty.

Program participants for yr2 included seven teachers, one male and six females. Of the seven teacher participants four identified as African American, two identified as white, and one participant identified as biracial. Surveys instruments included the Project Knowledge Scale, the Patterns of Adaptive Learning Scales (PALS), Computer Self-Efficacy Scale, and the Teacher Self-Efficacy Scale all used to measure teachers' knowledge, attitudes, computer, and teaching

self-efficacy changes pre and post surveys were disseminated to program participates during the summer 6-week professional development institute. Research findings indicated that teacher participant knowledge, attitudes, computer self-efficacy, and teaching self-efficacy increased slightly after the summer professional development institute.

Keywords

Robotics, Machine Learning, Artificial Intelligence, STEM persistence and engagement for underrepresented minorities

Introduction

To promote economic competitiveness and advance health, prosperity, and welfare, it is important for our youth to gain skills and knowledge in science and engineering. Few students from traditionally underrepresented and underserved areas in rural districts pursue careers in the science, technology, engineering, and mathematics (STEM) fields [1], [2].

This project entitled "RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics" motivated by the need to broaden participation in STEM provides unique and holistic research experiences to 30 middle school math and science teachers in the 7th-8th grades from underserved school districts in rural Alabama. The primary research focus is on mobile robots enabled by ML based AI which includes cutting-edge innovations in robotics and ML/AI [3]. Robotics technology has been widely used in numerous applications, including self-automated vehicles, warehouse management, rescue efforts, education, and the entertainment industry. Moreover, within the past few years there has been a significant increase in the role of AI and how it is transforming society.

This project aims to achieve the following two goals:
1) equip teachers with knowledge and skills in robotics and ML/AI and promote their interests in these areas.
2) facilitate teachers' development and implementation of engaging project-based curricular modules on robotics and ML/AI for classroom education at their local schools.

Towards these two goals, this project includes the following five objectives:
1) provide education and training activities on the fundamentals of robotics and ML/AI, and a novel platform for research and education of ML-based mobile robots;
2) engage teachers in hands-on research projects on ML-based mobile robots that match well with faculty mentors' active research projects;
3) allow teachers to collaborate with engineering and STEM education faculty to develop the project-based curricular modules;
4) foster teachers' leadership and pedagogical skills via teacher leader academies and practice of teaching the RET curricular modules;
5) assist teachers to implement the RET curricular modules via academic follow-up.

Activities and Methods

The proposed activities of this RET Site will take place over 3 summers. Our major activities in the second year of this project are described as follows.

Teacher recruitment. The summer program was advertised via email to the superintendents of 9 counties' school districts, mostly in the underserved and rural school districts in the Alabama Black Belt region. The project team also used Facebook and email lists of regional middle schools to recruit teacher participants. We also contacted and visited some areas schools to provide project information to principals to assist with recruitment. An online information meeting was held with interested teachers, to introduce the project and answer questions. As a result of recruitment efforts, 12 teachers applied to the program and the project team interviewed teachers and selected 7 to participate in our summer program. The cohort of teachers were predominantly female (86% female, 14% male), and primarily Black or African American (57% African American, 43% White). The project team also selected 3 mentor teachers from the 9 teachers who participated in yr1 of the RET summer program.

Teacher preparation. For week 1 of the professional development institute teachers participated in content based tutorials, and daily professional development workshops on the fundamentals of robotics and ML/AI. Teachers also participated in 3 half-day tutorials that focused on the fundamentals of ML/AI, robotics, and wireless technologies, respectively. In addition, faculty mentors worked with graduate assistants to provide hands-on training to familiarize teachers with the platforms of mobile robots: 1) Pololu Zumo 32U4, and 2) DFRobot Shop rover with smartphone. To develop teachers' research skills, we arranged a workshop on how to conduct research. In addition, to enhance]teacher knowledge on the content covered throughout the project we also invited several speakers to provide seminars on their expertise and engage with teachers. Seminar topics included information on ML/AI, wireless technologies, and robotics.

The project also included multiple networking events for teachers to collaborate with faculty and peers and started with an inaugural event as a kick-off to the summer program, and a closing ceremony for teachers, student participants and their parents. Teachers also attended an orientation which included a stadium tour and a tour of the College of Engineering.

The mentor teachers shared their experiences from the previous years summer institute with the new cohort of teachers participating in this year's summer program. According to teachers from cohort 2 helped them understand expectations for their summer experience.

Teacher research. Teachers participated in hands-on, inquiry-based research experiences on robotics and ML/AI, and developed and implemented project-based curriculum modules on ML-based robotics for their classroom. In the 1st week of the summer program, each research mentor introduced the research projects, including an overview of the motivation, objective, and approach of the project, and teachers' role in the project. Faculty mentors also presented their own research related to robotics and ML/AI. After the research project introduction, teachers discussed with research mentors, and assigned teacher participants to 2 research teams. Teachers met regularly with their faculty mentor to discuss the progress and get feedback to assist with development of their modules.. Each team also discussed progress with other teams in group

meetings and provided feedback to their colleagues on proposed curriculum modules throughout the process. Teachers presented their curriculum modules at the end of the institute to their peers and the faculty mentors.

To provide teachers with experiential learning for state-of-the-art technologies in real-world applications, this project included several visits to local labs related to robotics and ML/AI, with which the faculty mentors have existing collaborations. Teachers visited 1) AU College of Engineering Design and Innovation Center where they experienced how state-of-the-art 3D printing is used for manufacturing applications; 2) AU MRI Research Center where they learned how ML is used to improve healthcare through advanced magnetic resonance imaging (MRI); 3) AU College of Education Learning Resource Center where they learned how virtual reality is used for classroom teaching. Each visit included tours, demos, and meetings with researchers.

Curriculum module development. To translate teachers' research experiences to classroom STEM education, teachers collaborated with faculty mentors in STEM education to develop curricular modules on robotics and ML/AI from their research experiences. STEM education faculty and faculty mentors provided workshops on project-based learning, curriculum development, including one on accessibility and inclusion for students with disabilities, and one on computer science education for K-12 students. The curriculum modules developed are relevant to teachers' research projects as well as the topics defined by Alabama Course of Study (ALCOS), and also aligned with the Next Generation Science Standards (NGSS).

Curriculum module implementation. Teachers implemented project-based curricular modules they developed during the Computing and Robots for All (CR4ALL) summer camp during the 5th week of the RET program. The CR4ALL summer camp included 16 students at 6th-7th grade level (Figure 1). Teachers had the opportunity to model hands-on, inquiry-based teaching strategies through the project-based RET curricular modules. Faculty mentors also provided demonstrations using their expertise on robotics and AI concepts to the students and teachers as part of the summer camp. As a culminating summer camp experience CR4ALL campers presented their own projects to their parents at an open house (Figure 2), (Figure 3).

Conclusions

The project evaluator conducted surveys and focus group interviews. The preliminary data analysis findings are listed below.

1. Teacher Surveys

Participating teachers were asked to complete pre- and post-RET project surveys. The response rate was 100% for both pre- and post-surveys. Items measured in the survey included ML/AI, Wireless, and Robotics knowledge, motivation, teaching self-efficacy, computer self-efficacy, and attitude toward RET program questions. Their levels of knowledge, motivation, and self-efficacy were increased after the summer camp in general, except the Robotics knowledge and general teaching self-efficacy (Figure 4). Using paired-samples t-tests examine the differences between teachers' responses in pre- and post-survey, results indicating that the teachers' general teaching self-efficacy was significantly decreased (p=.03). The decline in general teaching self-

efficacy may be attributed to teachers recognizing their limitations in instructing ML/AI and Robotics curriculum. They became aware that there was a need to explore and understand these fields to effectively teach these topics. No statistically significant differences were found in all other items between pre- and post-survey. Additionally, participating teachers expressed positive experiences in the RET program (M=4.64 out of 5-point) and believed that the AU RET activities were beneficial for their students (M=4.87 out of 5-point).

When comparing the responses of participating teachers in 2022 and 2023 cohorts in both pre- and post-surveys, no statistical significance was observed in their post-survey responses after controlling their pre-survey responses. Despite the lack of significance, there was a general increase in teachers' levels of knowledge, motivation, and self-efficacy were increased after the summer camp (Figure 5). Further, 2023 teacher cohort reported more positive experiences in the overall AU RET program and exhibited stronger beliefs in the benefits for their students. (Figure 6).

2. Student Summer Camp

Twenty-two middle school students participated in the CR4ALL Summer Camp. The response rate for the pre-survey was 100% while it was 90.9% (n=20) for the post-survey. Seven (31.8%) of the 22 students indicated that they were females, 12 (54.5%) were males, two (9.1%) preferred not to answer, and one student (4.5%) did not indicate his/her sex. Three students (13.6%) reported they were Black, seven (31.8%) were Asian, nine (40.9%) were White, and three (13.6%) were other racial groups. One (4.5%) of the participating students reported as a 6th grader, 12 (54.5%) were 7th graders, eight (36.4%) were 8th graders, and 1 (4.5%) was 9th grader. Five measures, self-efficacy (students' perception toward their performance in the summer camp), peer learning (students' ability to collaborate with their peers), critical thinking (the degree to which students report applying previous knowledge to new situations to solve problems), engineering attitude (students' understanding of technology and engineering concepts), and summer camp content knowledge, were used to examine students' growth after the CR4ALL summer camp. Results indicated that students reported higher level of confidence toward their performance (p = .01), higher degree of the ability to apply knowledge learned to solve problems (p = .002), and content knowledge improved (Pre: 70% accuracy; Post: 76% accuracy; p = .02) after the CR4ALL summer camp (Figure 7).

While comparing the level of self-efficacy, peer learning, critical thinking, and engineering attitudes between 2022 and 2023 campers, no significant differences were found after controlling their pre-survey scores (Figure 8).

The feedback from students regarding the CR4ALL summer camp was very positive. A significant majority, exceeding 80%, reported that they gained valuable insights into robotics, artificial intelligence, and machine learning during the. The students particularly appreciated the hands-on activities, finding them instrumental in facilitating a more accessible and engaging learning experience. Furthermore, they expressed a desire for more hands-on activities within the school curriculum and indicated an interest in participating in future summer camps similar to CR4ALL.

Figure 1. 6th-7th grade students working on their robotics project during the CS4ALL summer camp

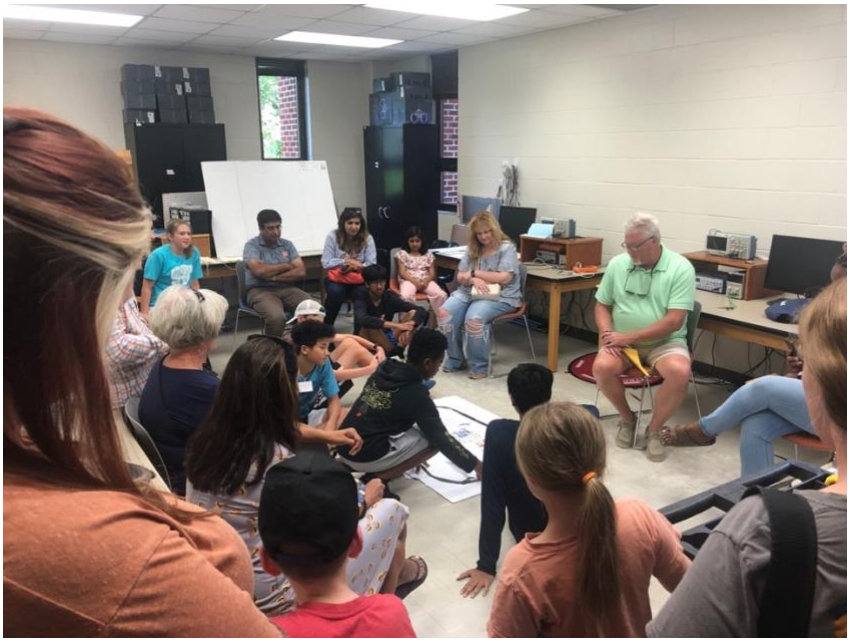

Figure 2. 6th-7th grade students demonstrating on their robotics project to parents during the CS4ALL summer camp

Figure 3. 6th-7th grade students with their RET teachers and teacher mentors in the closing ceremony of the CS4ALL summer camp

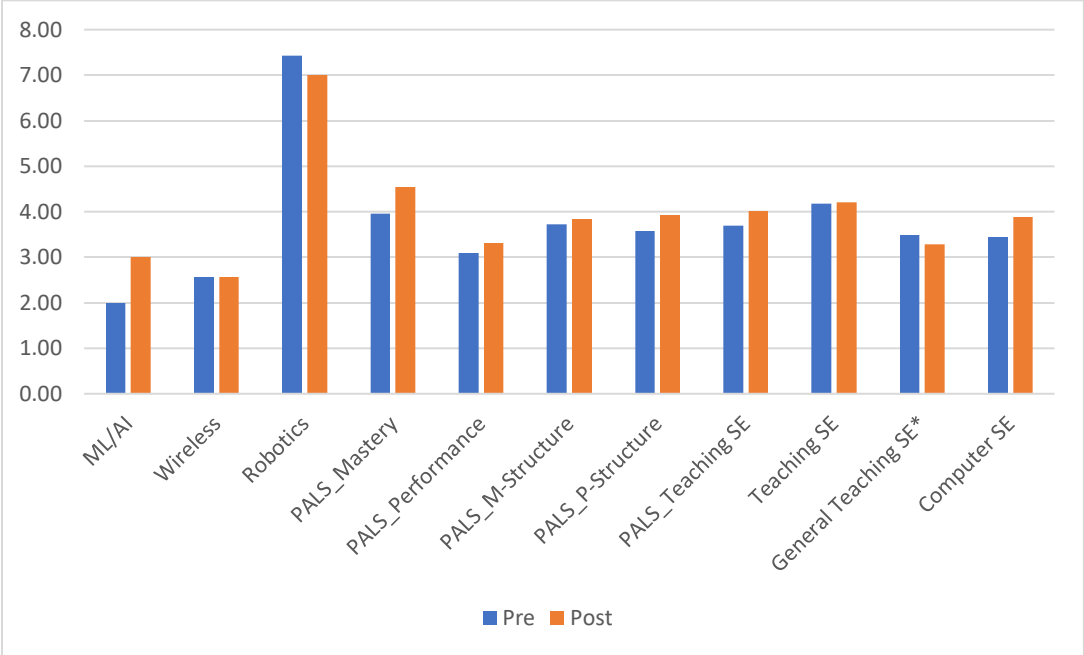

Figure 4. 2023 RET Program Teacher Responses in Pre- and Post-Survey

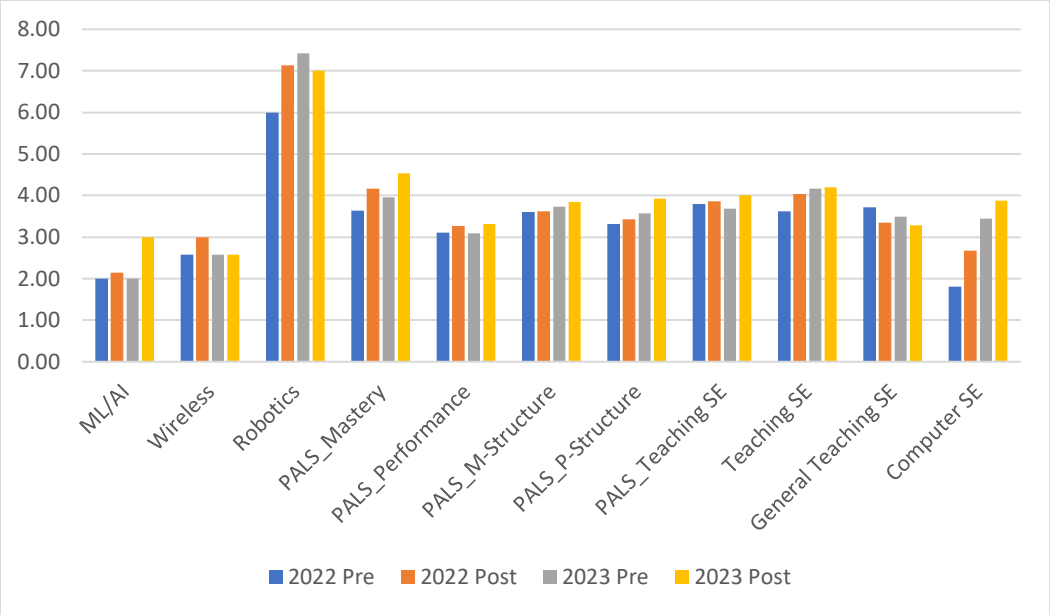

Figure 5. 2022 and 2023 RET Program Teacher Responses in Pre- and Post-Survey

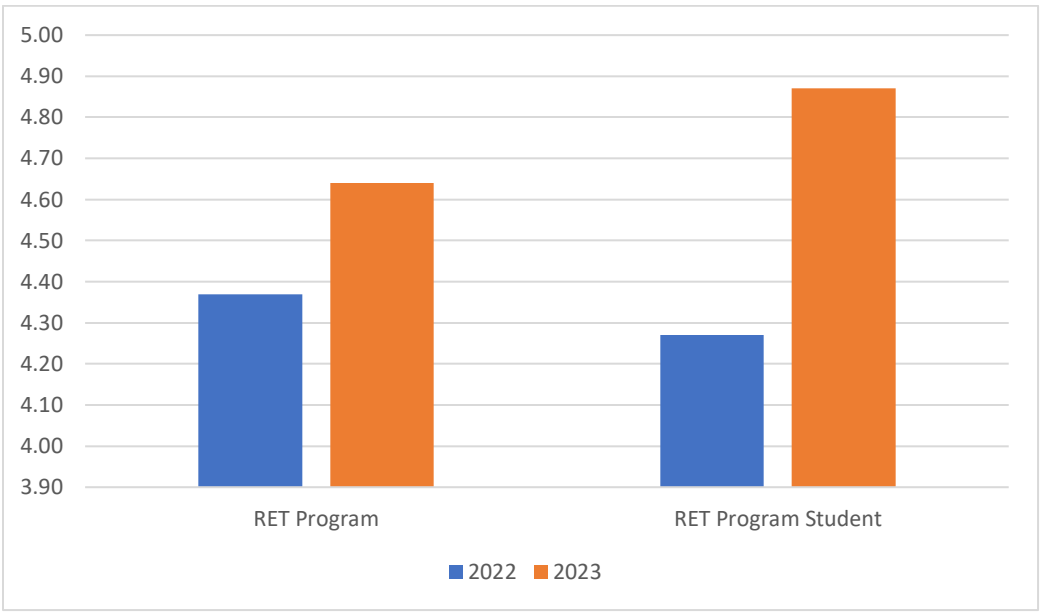

Figure 6. 2022 and 2023 RET Program Teacher Perception toward RET Program

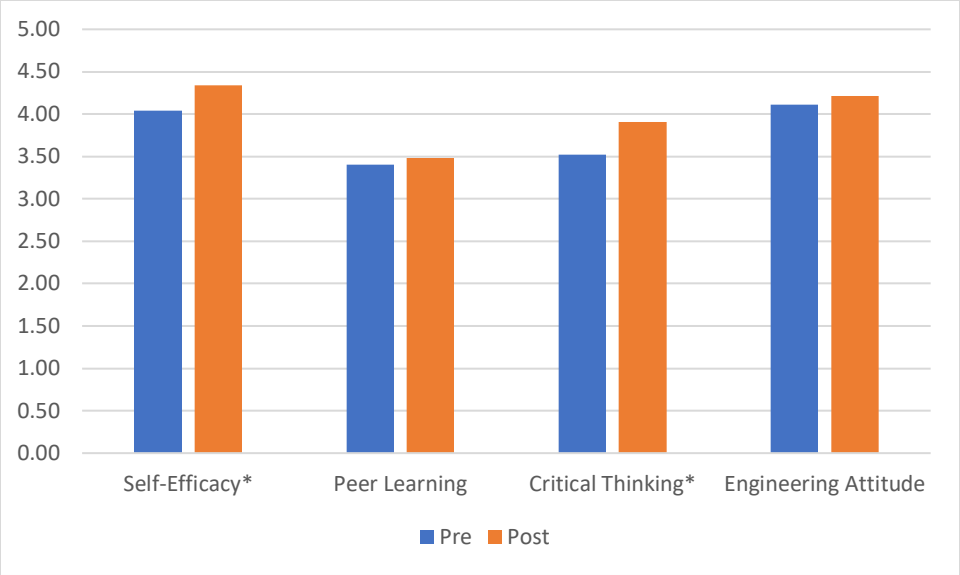

Figure 7. CR4ALL Summer Camp Students' Responses in Pre- and Post-Survey

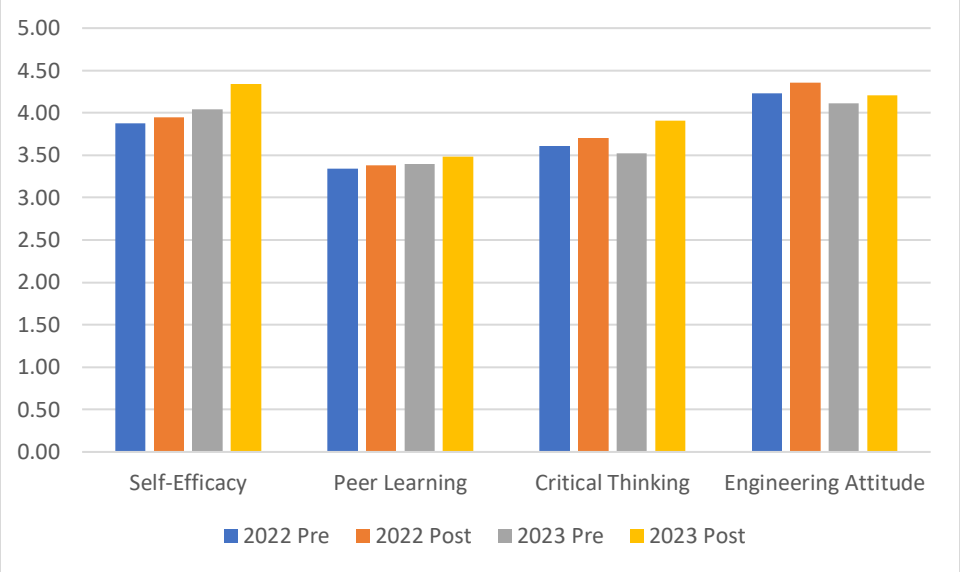

Figure 8. 2022 and 2023 CR4ALL Summer Camp Students' Responses

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