Eight-Year Journey with the FIRST Program: How Robots Build Kids

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Eight-Year Journey with the FIRST Program: How Robots Build Kids (Evaluation)

Abstract

Innovation in Science, Technology, Engineering, and Mathematics (STEM) is essential for the prosperity of the US economy and its job sectors. To equip the next generation of STEM professionals with the skills needed for innovation and to tackle the challenges of globalization, K-12 education plays a key role in laying the groundwork for STEM education. In addition to the significant efforts made by the US government, collaborative community initiatives such as international robotics competitions have emerged as valuable platforms for K-12 students to apply STEM and soft skills within the context of robot competitions. These competitions foster an environment of gracious professionalism, inspiring more students to pursue careers in STEM fields while also ensuring a positively challenging and enjoyable experience. With kids' continuous endeavor to build robots through the annual competitions, robots also build kids by enhancing their self-esteem, forging their identities, and cultivating essential characteristics such as persistence, proactivity, and passion, which are vital for their future academic and career development. Furthermore, diverse themes in annual robotic competitions facilitate project-based learning (PBL) opportunities tailored to children of varying ages. This study explores an eight-year PBL journey of a robotic team, from FIRST Lego League (FLL) to FIRST Tech Challenge (FTC) competitions, detailing their evolution from novices to a globally competitive unit and the personal growth of its members into societal leaders.

Each year, team activities were separated into multiple technical, outreach, or joint projects, with each project incorporating key PBL elements. The FIRST competition manual was carefully read and discussed with the team, fostering open discussions on enhancing robot performance and achieving broader team impacts. Coaches introduced necessary skills during FLL contests for members under Grade 7, while older members independently sought out specific training from professional mentors for FTC challenges. Through document reviews, discussions, and guidance from coaches and mentors, the team identified challenges and solutions, assigned roles to each task collaboratively, and conducted weekly reviews of project milestones and task completions. The team's performance and robot games were assessed by judges in FIRST competitions.

Longitudinal comparisons of PBL outcomes were performed considering the team members' self-evaluation, satisfactory level of team parents, and impacts of team

activities. It recorded 153 training sessions on technical and soft skills, including mechanical engineering, programming, usage of sensors, computer-aided design, and 3D printing, alongside skills in professional communication, oral and written presentation, engineering notebook documentation, and conflict resolution. Each senior member contributed about 3,522 hours to practice and competition, with an additional 780 hours in outreach efforts assisting 10 FIRST teams and engaging thousands of individuals. These efforts underline the team's accomplishments in skill development, career readiness, and community engagement, demonstrating a model of successful PBL with consistently enhanced performance.

By sharing this journey, the study seeks to illustrate the incremental development of technical skills alongside soft skills and the cultivation of essential characteristics such as persistence, proactivity, and passion, which are vital for their future academic and career development. The concept of "Robots build kids" encapsulates a journey of transformation where PBL-guided robotic education has played a pivotal role in shaping well-rounded individuals.

Objectives and Motivation

Advancement of science, technology, engineering, and mathematics (STEM) serves as the foundation for innovation, a pivotal component for future economic success, and fundamental to core employment sectors in the United States (US) [1, 2]. In December 2018, the National Science and Technology Council (NSTC) Committee on STEM Education released "Charting a Course for Success: America's Strategy for STEM Education", a five-year STEM education strategic plan [3]. America's Strategy places particular emphasis on preparing the STEM workforce for future challenges by aiming to improve K-12 education. To fulfill the goal set by America's Strategy, the education of the younger generation should be enriched by integrating advanced technological tools, forging community partnerships, and embracing global perspectives through a transdisciplinary approach. Tremendous efforts have been dedicated by the US government, private foundations, and non-profit organizations to form learner-centered platforms prioritizing collaborative, project-based learning communities [4, 5]. Such a community fosters the development of problem-solving skills, nurtures creativity, and stimulates innovation among young minds.

As a successful example, international robotic competitions have played a key role in attracting children and teenagers to STEM fields [6-9]. These robotic competitions focus on K-12 students, forming an international community where the participants can build robots with hands-on experiences, develop their STEM and soft skills, and most importantly, have fun [10-14]. Participants in robotic competitions are required to apply STEM technical skills along with soft skills such as teamwork, communication, critical thinking, and problem-solving within the context of robotic competitions.

Furthermore, diverse themes in annual robotic competitions facilitate project-based learning (PBL) opportunities tailored to children of varying ages. PBL can serve as an effective vehicle to facilitate student-driven knowledge acquisition, skill practice, and reflective inquiry. The combination of PBL and hands-on robotic competition empowers a promising direction that can go beyond traditional educational models, making STEM fields accessible and appealing to K-12 students. It has been reported that students who gain technical skills in high school are better prepared for both the job market and higher education opportunities [15-17]. Additionally, when students have a clear sense of purpose and understand how their education relates to their future careers, they are often more motivated to excel academically and can see the relevance of their coursework.

This study explores an eight-year PBL journey of a robotic team, FTC 16458 (TechnoWizards), from FIRST (For Inspiration and Recognition of Science and Technology) Lego League (FLL) to FIRST Tech Challenge (FTC) competitions, detailing their evolution from novices to a globally competitive unit and the personal growth of its members into societal leaders. In sharing this journey, the study seeks to illustrate the incremental development of technical skills alongside soft skills and the cultivation of essential characteristics such as persistence, proactivity, and passion, which are vital for their future academic and career development.

Project-based Learning Approach

PBL is a problem-oriented and student-centered form of instruction organized around real-world projects, as opposed to a direct presentation of facts and concepts. Since its initial adoption, PBL has been expanded to various disciplines such as engineering and law, emphasizing problem-solving and critical thinking [18-20]. In the 21st century, it has been refined and adopted for K-12 education [20-22]. Unlike traditional memorization-based methods, PBL allows students to develop practical skills through active participation in exploration, inquiry, and problem-solving and fosters critical thinking, creativity, communication, collaboration, and practical application of knowledge across different subjects [21, 23, 24].

While there is great variety in the models for developing PBL methods of instruction, they typically share several principles or characteristics, including the presence of reflective inquiry, collaborative student-driven projects, and being designed around real-world problems or issues.

Real-world relevance is an essential principle of PBL, as it gives students significance to their learning by bridging classroom learning, scientific practices, and real-world applications. Student-driven learning allows students to take on an active role in shaping their educational experiences [25]. With PBL, students select and work on projects that align more closely with their interests and passions. This connection and independence enhance students' motivation and enthusiasm, empowering them to develop a sense of ownership and responsibility. Additionally, it makes the learning process more meaningful for students [26].

The student-driven learning in PBL also promotes a culture of independence, curiosity, self-discovery, and active engagement [27]. Furthermore, as a core component of PBL, reflective inquiry enhances the learning experience beyond the completion of tasks or projects. It offers the students a valuable opportunity to pause, thoroughly examine, and re-examine the reasons (why), methods (how), and insights (what) achieved during their active participation in their projects [27]. These three fundamental principles of PBL make it a promising approach to facilitate participants in robotic competitions for knowledge acquisition, hands-on practice, and reflective inquiry for both STEM and soft skills.

Methods

Implementing PBL in both FLL and FTC provides a robust framework for engaging teams in real-world problem-solving while integrating STEM education with teamwork, research, and robotics design. FLL served the team during their younger years from K to 6th grade, while FTC has been instrumental from 7th grade to the current 11th, offering a continuum of learning and skill development opportunities. Each competition season spans from September to March or April depending on advancement levels (Regional, State, World Championship), lasting 5 to 7 months. Both FLL and FTC programs release annual game manuals focused on real-world problems, creating an ideal setting for PBL. Core PBL principles are presented as follows.

1) Age-oriented PBL Implementation in FLL Competitions

<u>PBL Key Principle: Real-World Problems</u>

A research project was chosen based on the annual game manuals provided by the FLL program. These projects revolve around global challenges, such as water recycling (2017-2018) or space exploration (2018-2019). Examples of FLL projects are outlined in Table 1.

Table 1: List of 4 project themes for PBL from 2015 - 2019	
2015-2016 Jr. FLL-TRASH TREK	Encouraging students to think about modern waste management solutions.
2016-2017 FLL-ANIMAL ALLIES	Focusing on enhancing human-animal interactions.
2017-2018 FLL-HYDRO DYNAMICS	Exploring issues related to water – how we find, transport, use, or dispose of it.
2018-2019 FLL-INTO ORBIT	Challenging students to think about issues related to long-duration space flights.

The FLL program targets children from kindergarten to 6th grade, utilizing Lego EV3 packages for robot building. Due to the age range, the focus of PBL primarily revolves around fostering STEM interest, promoting STEM identity, and instilling awareness of gracious professionalism.

Table 2. PBL implementation from FLL 2016 to 2018.			
	2016-2017 Animal Allies	2017-2018 Hydro Dynamics	2018-2019 Into Orbit
Grade	4th	5th	6th
Real World Explore & Research	-San Antonio Zoo -Bee house	-Water treatment seminar -Deionized water treatment at Tower Semiconductor -San Antonio Water System field trip -Fire Station-Water application -Inks Lake & Fishery -San Antonio Aquifer	-Residential vehicles store visit -Segway tour -Southwest Research Institute-space division - Carrier ship tour - Mission to Mars Seminar at NASA
Training	FLL summer camp	FLL summer camp	Training by senior FLL teams

Commonly adopted methods to achieve these PBL goals include field trips, guided group discussions, and peer tutoring. Activities related to the research topics are listed in Table 2, which include field trips to explore animal-related research in zoos in 2016, and hydro dynamics for the discovery, utilization, and transporting of water, and processing wastewater in 2017.

Hands-on experiences play a crucial role as children explore and validate their ideas. During the FLL competition stage, basic concepts and block-modules are employed for training, without introducing theoretical knowledge. Specific PBL practices for FLL are listed as follows.

<u>PBL Principle: Student-driven Innovative Solutions</u>

In each annual FLL competition, teams are challenged to find innovative solutions to problems they select, ranging from technological advancements to community initiatives or public awareness campaigns. This creates an optimal environment for PBL, nurturing authentic, student-driven learning experiences. For instance, the 2018 INTO ORBIT challenge focused on space-related issues. Through interviews and field trips to NASA, the team identified astronauts' homesickness as their project theme and aimed to design a solution to ensure astronauts feel happy, comfortable, and calm in space. The team's innovative solution was B.E.A.R (Buoyant, Emotional, Attachment, Response), a bear equipped with video chat capabilities and the ability to convey hugs remotely using onboard Wi-Fi and satellite communication. This integration of technology, including Lego EV3, Arduino, touch sensors, and a Bluetooth module, marked a unique approach to alleviating homesickness in space.

Robotics Design and Programming

In addition to their innovative project, teams are required to construct and program an autonomous robot using LEGO EV3. This robot must complete missions on a themed playing field, allowing participants to apply engineering and coding skills through hands-on practices.

Collaboration, Engagement, and Identity

FLL training focuses on fostering team collaboration and gracious professionalism, where students utilize their strengths, make collective decisions, and tackle challenges together. At competitions, teams showcase their innovative projects and robotic accomplishments, emphasizing their problem-solving journey, creativity, teamwork, and fun. FLL teams are encouraged to share their projects and insights with the community, fostering self-awareness and identity in STEM.

2) PBL Implementation for FTC Competitions

PBL Principle: Real-world Problems

As the children grew older, FTC manuals presented increasingly complex and challenging problems. FTC projects often address complex scenarios that simulate real engineering challenges, requiring teams to apply STEM principles creatively and effectively. Table 3 lists four sample projects from FTC competitions, and Table 4 presents activities in the PBL.

Table 3: List of 4 FTC project themes for PBL from 2019 - 2023

2019-2020 SKYSTONE	Engaging students in robotics challenges inspired by architectural and engineering feats.
2020-2021 FREIGHT FRENZY	Logistics and freight management in a robotics context.
2021-2022 ULTIMATE GOAL	Sports-themed robotics challenges, emphasizing shooting and targeting.
2022-2023 POWERPLAY	Energy management and innovation through robotics.

PBL Principle: Collaborative Student-driven Learning

FTC competitions require a more in-depth exploration of mechanical design, advanced programming, and sensor integration. Each team member must identify the necessary skills to excel in FTC competitions and assume responsibility for tasks aligning their interests with the team’s goal. These tasks encompass various STEM-related and outreach activities, including CAD design, mechanical assembly, programming, electronics, community engagement, business development, social media management, and documentation. Additionally, each team member also assists in other tasks, fostering a collaborative structure with clearly defined leadership and supporting roles.

As an illustrative example, following the first FTC season in 2019, the team recognized the importance of CAD design in achieving effective and efficient robot development. They proactively pursued online CAD training and arranged for in-person sessions with FTC alumni to enhance their skills. Their dedication led to significant improvement, with the team designing their entire robot using CAD by 2022, compared to having none in 2019.

Soft Skills

Alongside STEM skills, the team cultivates essential professional skills, including project management, time management, and oral and visual communication, laying a strong foundation for their future careers in STEM fields. These skills were acquired by seeking mentorship from professionals, arranging regular learning sessions, and practicing with their engineering portfolio, competition presentation, and fundraising activities.

3) PBL Principle for Both FLL and FTC: Reflective Inquiry

Regular reflective inquiry is a fundamental aspect of PBL. Throughout the competition seasons, weekly meetings were conducted for team members to reflect on challenges faced, solutions developed, and learning experiences gained over the 8-year implementation of PBL. Each year, a team sheet was created to document tasks, designate task leaders/assistants, outline expected milestones, and identify challenges and solutions for each step of the project. This inquiry process enables team members to assess project progress, enhance time management skills, and deepen their understanding of their skills and knowledge.

4) Annually PBL Implementation Cycle for FLL and FTC

Each identified project was implemented with six key steps for PBL.

Step 1: Project presentation and idea generation through collaborative brainstorming for game strategy. As soon as the annual game is revealed, the team gathers to collectively brainstorm ideas. This brainstorming session enables us to practice communication and collaboration skills, leading to the presentation and identification of our project.

Step 2: Individual and team research to enhance robot design and game strategies. The team proactively pursues professional training to acquire new knowledge and skills, refining previously brainstormed strategies. Additionally, the team also learns and practices conflict resolution, reaching a final decision on robot design, and setting the stage for the next step.

Step 3: Design and build a robot. Building upon the finalized design, the team constructs new robots annually following the game manual. The team actively encourages innovative ideas for further validation and feasibility assessment. The design development step integrates both STEM skills, such as programming and mechanical design, and soft skills, such as problem-solving and communication. With each iteration, the accumulated knowledge and skills contribute to the authenticity of the robot designs. Over the 8-year journey, the team's experiences with PBL have led to enhanced skills and student outcomes, as well as robot performance, as evidenced by unique longitudinal measures.

Step 4: Building, testing, and evaluation. Robot competitions require extensive hands-on work, such as testing and assessing robot performance to identify areas for improvement. This stage demands real problem-solving skills. It may be necessary to revisit steps 1-3 outlined above to address any challenges encountered.

Step 5: Project delivery. PBL components were integrated into tournaments and subsequent outreach activities. Reflective inquiry sessions were held after each game to identify areas for improvement in future matches. This reflective process also enabled the team to pinpoint reasons for success and enhance contributing factors. Beyond robot competitions, the team shares our experiences with other teams or younger members to foster a collaborative community, thereby advancing robotics education in the long term. Furthermore, sharing and tutoring sessions allow us to make real-time adjustments to our robot, while feedback from others provides fresh perspectives that the team may not have considered before.

Step 6: Documentation. Maintaining comprehensive records such as meeting minutes, engineering notebooks, event reports, and reflections on each game is crucial for reassessing the design process, identifying potential pitfalls, and determining possible solutions to challenges. These records serve as important reference points. For example, documented performance and activities during tournaments allow the assessment of strengths and areas for improvement. This step is integral to the PBL process, as it enables the team to track our progress and ensure continual advancement with each activity.

Despite the increasing complexity of the robots, as the team accumulates experience and knowledge, the integration of PBL principles throughout the previous four seasons in FTC has expanded significantly. Through multiple iterations of the PBL process, the team has continuously enhanced both the robot design and personal communication skills year after year.

5) Data Collection and Analysis

All PBL activities were documented in engineering notebooks, team event reports, and reflections on each activity. Team performances were obtained from the FIRST website.

Quantitative data were analyzed to demonstrate the improved outcomes resulting from the implementation of PBL.

<u>Assessment of the PBL Outcomes</u>

During the eight-year PBL journey, the rookie team participated in two internationally reputable robotics competition programs: FLL and FTC. The PBL experience has shaped 14 young students' STEM journey from 3rd to12th grade. Two sets of data have been collected and analyzed: 1) Competition data with both FLL and FTC, where the robots' performance directly reflects the growth of team members' technical skills, and judge room presentations directly reflecting the growth of both technical skills and soft skills; and 2) individual achievements of team members through their participation in PBL.

RESULTS

Figure 1 shows eight years of PBL experiences and outreach activities, incorporating hours from regular practice, competitions, and outreach initiatives. It highlights the team's increasing commitment to PBL, accumulating a total of 3,522 hours dedicated to robotics construction and skill enhancement over this period.

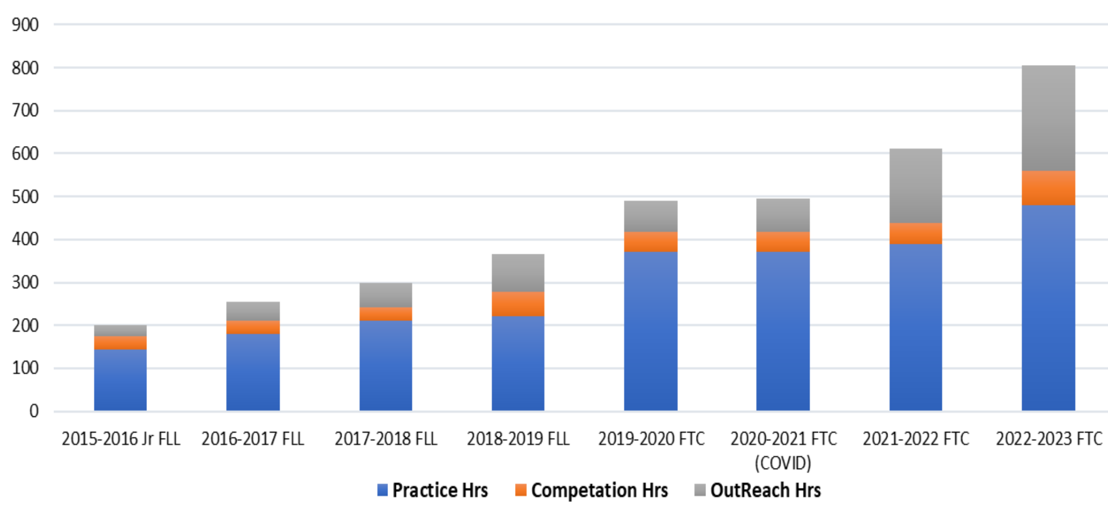
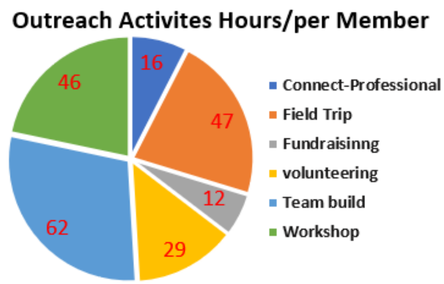


Figure 1. Distribution of PBL hours including practice hours for robot design and skill development, competition hours, and outreach hours of the team from 2015 - 2023, illustrating a steady increase in effort every year.

1) PBL Outcomes in FLL Competitions

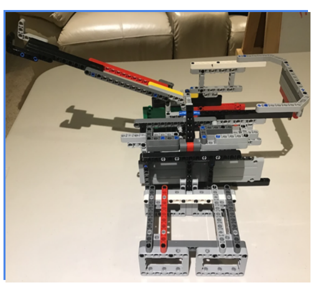
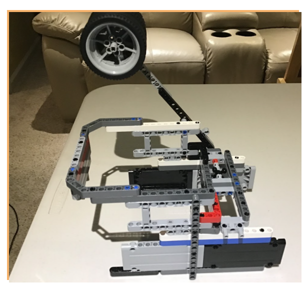
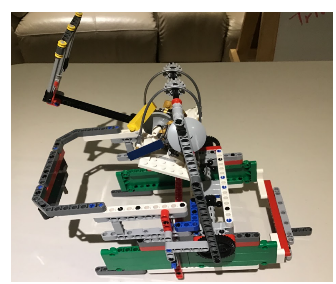
The PBL was first implemented over four years of Jr. FLL and FLL periods, from August 2015 to April 2019, when team members' ages ranged from kindergarten to 6th grade. The team grew from 5 members in the 2015-2016 season to 7 members by the 2018-2019 season. Table 4 details the distribution of PBL hours and outreach activities over the 4 years.

Table 4. PBL hours per member and outreach categories for FLL seasons from 2015 – 2018.



FLL Seasons	Practice hours	Competition hours	Outreach hours	Season hours
2015-2016 Jr FLL	144	32	25	201
2016-2017 FLL	180	32	42	254
2017-2018 FLL	210	32	56	298
2018-2019 FLL	222	56	89	367
Total hours	756	152	212	1,120

Table 5. PBL outcomes for FLL competitions from 2016-2019

Items	2016-2017 Animal Allies	2017-2018 Hydro Dynamics	2018-2019 Into Orbit
Grade	4th	5th	6th
Robot attachment			
Product name	Red-Lights Scaring Animal (RLSA)	BlackKnight Water Treatment System	B.E.A.R
Product	An innovative device that projects two red LED lights to imitate a “monster,” scaring away foxes and raccoons from backyards.	Innovative idea on water recycling water is to be treated for manufacturing use.	
Award	Core Value Award In the League Tournament	Championship 1st place In the League Tournament	Championship 1st Place In the Regional Tournament. Advanced to World Championship

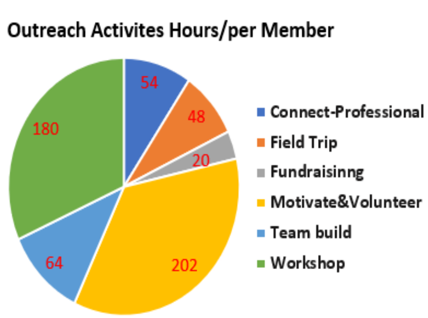
Technical skills acquired included mechanical mechanisms, attachment design, EV3 programming, and utilization of sensors such as ultrasound, touch, and color sensors. Strong soft skills such as teamwork, gracious professionalism, public speaking, and presentation abilities, were also developed. Collectively, the team devoted a significant amount of time to their growth and learning, amassing a total of 1,120 hours in practice and training. Additionally, they engaged in 212 hours of outreach activities, which broadened their experiences through professional connections, field trips, volunteer work, and fundraising initiatives, further enriching their educational journey and community contribution.

Performance steadily improved with PBL implementation, as displayed in Table 5. In the 2017-2018 season, the team won the first-place Champions Award at the League. The next season, 2018-2019, the team earned three awards: the Champions Award 1st place at the league tournament, 1st place in mechanical design/robot performance at the regional tournament, and an invitation to the prestigious Arkansas Razorback International Invitational.

2) PBL Outcomes for FTC Competitions

The PBL has been continuously implemented since 2019. The team grew from 7 members in 2019 to 11 by 2023, with their ages ranging from 7th to 11th grade. The team collectively dedicated 2,402 hours to PBL activities from 2019 to 2023. Table 6 details the distribution of PBL hours and outreach activities over the 4-year period from 2019 to 2023. Outreach activities encompass connecting with professionals for knowledge and skills, field trips, fundraising, volunteering, team building, and workshops.

Table 6. PBL hours and outreach categories for FTC seasons from 2019 - 2023



FTC Seasons	Practice hours	Competition hours	Outreach hours	Season hours
2019-2020 FTC	370	48	72	490
2020-2021 FTC (COVID)	370	48	76	494
2021-2022 FTC	390	48	174	612
2022-2023 FTC	480	80	246	806
Total hours	1,610	224	568	2,402

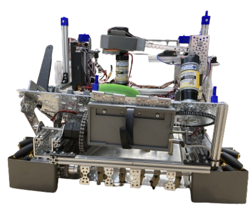
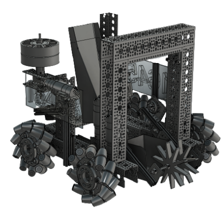
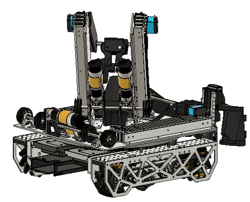
Table 7 depicts the team's growth and evolution in both technical and soft skill development during the four competition seasons from 2019 to 2023. The topics of training and practices were identified through team members' surveys and suggestions by coaches and mentors. Training sessions took place throughout the year, with technical training scheduled in late summer and early fall, and practiced throughout the fall when robots were designed, built, and tested in league competitions. Soft skills training sessions were usually completed and practiced during the offseason, such as summer breaks, and were intensively practiced again when the team prepared for judge room presentations at league, regional, state, and world tournaments.

Table 7. Skills obtained from PBL for FTC competitions from 2019-2023

	2019-2020	2020-2021	2021-2022	2022-2023
Technical Skills	- Solid Works CAD - Onbot Java	- Fusion 360 CAD - Onbot Java - Touch sensors - Encoder drive	-Fusion 360 CAD -Machine Learning -Roadrunner for accurate autonomous movement - Encoder drive - Color sensor - 3D print	- Fusion 360 CAD (100%) - Mechanism Simulation in CAD - 3D Print - CNC Cutting - Roadrunner - External Encoder - Odometry - OpenCV - Adaption to - Android Studio - Finite State - Machines learning - AprilTag learning - Distance sensor -Magnet sensor
Soft Skills	- Poster for presentations - Creating document templates and generating event & weekly report	- PowerPoint presentations - Hosting online seminars (Zoom, Webinar, etc.) - Creating recruit templates	- Hosting Podcast - Launching bubble tea events for league games - Consulting with Maker Spaces to custom make robot parts - Creating and implementing K-6th grades summer camp - Participating in Student Association for STEM Advocacy (SASA) National Conference	- Applying project management App - Creating school robotics clubs - Creating and hosting the Inaugural FTC Central Area Conference & publishing conference proceedings - FIRST Update host - Publishing technical abstracts at ASEE conference - Interviewing training for Dean's List - International outreach

With the accumulation of the number of years engaging in the PBL module, students' technical and soft skills became more specialized and impact-yielding. The soft skills in the first two years focused on oral and visual presentations, often applied by individual team members, while those in the last two years centered on creating and implementing high-impact events that required a range of soft skills, applied by multiple team members at multiple stages, such as time and project management, team coordination, strategic communication, and effective leadership. The earlier skills ensured the team effectively communicated within themselves and with audiences for their specific events. The later skills streamlined the team communication and challenged the team to reach multiple teams and students throughout K-12 across various geographical boundaries. Their output went beyond less-regular webinars to all-time accessible podcasts, FIRST Updates, and journals. Their impact went beyond peers at the FTC to include professionals, policymakers, and educators.

Table 8. Evolution of robot design, innovation, and awards from 2019 - 2023

	2019-2020	2020-2021	2021-2022	2022-2023
Grade	7th	8th	9th	10th
Robot design				
CAD	0%	5%	20%	100%
Innovation	Rubber band intake for flexibility	Active intake for intaking in any orientation	Transfer mechanism to ensure only 1 element is intake	Double Turret for autonomous efficiency and reliability
Award	<u>League Tournament</u> Inspire Award Winner Winning Alliance - Captain" • Promote Award	<u>League Tournament</u> • Finalist Alliance - Captain • Inspire Award 3rd Place • Think Award	<u>League Tournament</u> • Connect Award • Control Award • Dean's List Semi-Finalists • Inspire Award 2nd Place • Winning Alliance - Captain <u>Regional Tournament</u> • Connect Award 3rd Place	<u>League Tournament</u> • Inspire Award Winner • Winning Alliance - Captain <u>Regional Tournament</u> "• Inspire Award • Winning Alliance State Tournament "• Design Award • Finalist Alliance <u>World Tournament</u> • Think Award 2nd Place • Finalist Alliance - 1st Team Selected
World Ranking	344	293	113	8

The technical breakthroughs directly contributed to the improved robot performance during competitions. Before 2019, the team used 0% computer-aided design (CAD). Post 90 hours of CAD training, there was a notable improvement in mechanical design and robot performance. In the 2022-2023 season, the team utilized CAD design for 100% of their robot development. Additionally, programming skills showed significant enhancement, leading to improved performance in the automation aspect of competitions. Accordingly, the team's world ranking jumped from #344 in 2019 to #8 in 2022, as shown in Table 8.

3) Global and National Impacts

Using PBL principles, FLL and FTC robotics programs not only enhance technical skills but also promote community involvement and global impact. The team shares their robot progress, outreach events, and tech-talk podcast series on their YouTube channel, accumulating 18,000 views. Each season, they dedicate 142 hours to promoting STEM and robotics education. They collaborate with experts, including FIRST alumni, university professors, and industry engineers, to expand their knowledge. In the 2022-2023 season, the team organized robot demonstrations for sponsors, positively impacting 280 engineers and inspiring some to enroll their children in FIRST programs or mentor local teams. They successfully hosted Minibot summer camps for two consecutive years, educating over 60 children who expressed a desire to return. Additionally, the team conducted its third annual global podcast event, featuring 15 episodes with 10 mentors, 4 world-class teams, and 40 international teams. They also initiated and hosted the first local FTC conference, with 8 teams, 29 presenters, and published the conference proceedings.

4) Individual Contribution and Accomplishment

As a direct result of the PBL experience, the team has had 1 Presidential Volunteer Service Award Gold Winner for three consecutive years, 1 Congressional App Challenge Winner, 5 FTC Dean's List Semifinalist, 1 FTC Dean's List Finalist, 1 National Junior Honor Society (NJHS) member, 1 Science National Honor Society (SNHS) member, and 4 National Honor Society (NHS) members. 1 member has gained the official Autodesk CAD Certificate. These individual achievements serve to bolster the identity of our students and their engagement in STEM fields. All team members have chosen STEM as their career path. Parents of team members have also dedicated significant effort to support team activities and are satisfied with the outcomes of PBL.

Conclusion and Discussion

The eight-year educational journey through FLL and FTC, structured around the principles of PBL, has profoundly demonstrated that robotic education does much more than teach children how to build robots; it builds the children themselves. This journey has underscored the transformative power of robotics education in developing a full spectrum of skills among its participants. From the initial steps of understanding basic robot design to mastering complex programming challenges, students have evolved into adept problem solvers equipped with a robust set of technical and soft skills. PBL has been instrumental in ensuring that each challenge and project was not just another task but an opportunity for growth, reflection, and real-world application. Reflecting on the impact of these eight years, the PBL structure within FLL and FTC has not only facilitated the acquisition of knowledge and skills but has also inspired a generation of learners to see beyond the confines of their immediate environment. Students have emerged as more than just participants in a robotics program; they are young innovators, ready to contribute to their communities and the broader world.

This study utilized PBL to train a group of 14 students over eight years, providing valuable longitudinal data on PBL practices. Despite our relatively small sample size, our results confirmed the effectiveness of early exposure to STEM in attracting children to STEM fields, fostering early identity, and improving self-esteem. Additionally, our findings supported the concept of a growth mindset, suggesting that accumulating STEM skills from an early age is akin to training an athlete from childhood. Just as it takes time for an athlete to reach the Olympic podium, so too does STEM training require dedication and time to develop STEM skills. Consistent, long-term engagement in robotic competitions plays a crucial role in enriching learning experiences, shaping character, and fostering self-development for children. Factors such as learning from failures, perseverance in competitions year after year, and collaboration among team members despite differences in personality, background, and schedules are not only essential for team success in competitions but also for individuals' future career paths.

Implementing long-term, regular PBL at an early stage presents challenges for educators and parents alike. The PBL approach in this study required extensive resources from professionals, the FIRST community, educators, and parents. We are well aware that disparities in access to professional resources, such as coaching or mentorship, exist between regions and populations. This underscores the need for equitable support across all levels, including government, foundations, and professional communities.

In conclusion, the concept of "Robot build kids" encapsulates a journey of transformation where PBL-guided robotic education has played a pivotal role in shaping well-rounded individuals. As we look to the future, the experiences and lessons gleaned from this journey affirm the vital role of hands-on, project-based learning in education. Through the challenges faced and the milestones achieved, students have not only built robots but have also built a foundation for lifelong learning and success.

Acknowledgement

We acknowledge the partial support from the National Science Foundation Award # 2051113, FTC team 16458 (TechnoWizards), Hackers Inc, Tower Semiconductor, Texas Instruments, USAA, and Toyota Manufacture.

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