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Affordable Robotics Solutions for STEM Outreach and Education in Electronics

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Abstract– This paper explores affordable robotics solutions designed to enhance STEM education in Ireland, focusing on both third-level undergraduate courses in electronics and electrical engineering, as well as STEM outreach for primary school children. As the demand for skilled STEM professionals grows, there is a pressing need to provide accessible, hands-on robotic learning experiences that bridge the gap between theory and practice. However, the high cost of traditional robotics platforms remains a significant barrier in this regard. To address this, the paper investigates cost-effective robotics solutions aimed at fostering engagement, practical skills, and problem-solving abilities in students at different educational levels. These include low-cost programmable robotics kits for third-level students to experiment with automation and circuit design as well as open-source robotics platforms that encourage customization and accessibility. Using these for interactive robotics workshops with primary school children to introduce fundamental electronics concepts, as well as collaborative robotics projects promotes teamwork and learning across age groups. The paper considers the effectiveness of these solutions in promoting STEM, assessing factors such as affordability, accessibility, and pedagogical impact. Ultimately, it provides a framework for integrating affordable robotics into educational settings, contributing to a more inclusive and sustainable approach to STEM education in Ireland and beyond.

Keywords—Robotics, Electronics, STEM, Education, Outreach.

I. Introduction

In an era marked by rapid technological advancement and increasing demand for digital literacy, the integration of robotics and electronics into education plays a pivotal role in shaping the future of undergraduate learning and early Science, Technology, Engineering, and Mathematics (STEM) engagement. This paper examines how affordable, scalable robotics solutions can enhance undergraduate education in electronics and electrical engineering, while simultaneously supporting outreach efforts aimed at cultivating STEM interest among primary school students. Considering the situation in the Irish educational setting, this research contributes directly to the themes of curriculum improvement and the application of educational technology, offering practical, hands-on learning experiences for students that bridge the gap between theory and practice.

A core challenge in STEM education remains the accessibility of high-quality, interactive learning tools — particularly in the domain of robotics, where cost and complexity often limit adoption. To address this, the paper considers four robotics platforms that support both undergraduate curriculum enhancement and distance learning or outreach education. These include low-cost, programmable kits that enable undergraduate students to engage deeply with concepts such as circuit design, automation, and embedded systems in a more interactive and engaging way. Simultaneously, tools like LEGO-based robotics are leveraged in e-learning environments and in-person workshops to introduce younger learners to foundational STEM concepts through intuitive and customizable platforms.

The paper also highlights interdisciplinary, collaborative projects that use robotics to promote active learning, teamwork, and critical thinking skills—key competencies for students navigating increasingly hybrid and digital learning environments. These initiatives not only prepare undergraduate students for careers in a technology-driven world but also contribute to a sustainable pipeline of STEM learners beginning from primary education.

Through the lens of affordability, accessibility, and pedagogical innovation, this study emphasizes how technology-enhanced learning—including blended and distance education models—can foster inclusive, future-ready STEM education. Ultimately, this work demonstrates the transformative potential of educational robotics as a tool for curriculum improvement and learner engagement at multiple stages of the educational journey.

II. Literature Review

This literature review examines key background topics related to affordable robotics solutions for STEM education, particularly in the context of electronic and electrical engineering. It provides a foundation for understanding the challenges and opportunities in integrating robotics into both third-level undergraduate courses and primary school STEM outreach programs. The review highlights significant research contributions in several areas, such as robotics in education, affordability of educational technology, STEM outreach for primary education, and the impact of hands-on learning.

A. Introduction to Robotics in Education

Robotics has emerged as an influential tool in educational contexts, offering interactive, engaging, and practical learning experiences. It enables students to apply theoretical knowledge to real-world systems, bridging the gap between classroom learning and engineering practice.

In [1], the authors consider some of the approaches used to teach university STEM subjects with robots. Approaches such as Problem-based, constructionist, and competition-based learning are considered and evaluated in this regard. A complimentary study in [2] provides a systematic review of robotics implementation in primary and secondary school (K–12) classrooms and after-school studies. Topics considered include effectiveness of the robots, students' learning and transferable skills, creativity/motivation, diversity/broadening participation and teachers' professional development.

Elsewhere, [3] report on how robotics affect young learners, the skillsets developed through robotics in young learners and the impact robotics have on STEM education. The authors in [4] concentrated on the learning outcomes and results for robotics-enabled lessons under a design-based research approach for experiential learning. In all cases, the authors have explored how robotics is used in education at primary, secondary and University level, considering its importance, implementation and achievements in this regard.

B. Affordable Robotics in Higher Education

One of the major factors limiting the integration of robotics into third-level education is the associated high costs. Several low-cost or open-source robotics platforms have been presented in the literature to provide students with affordable means to gain practical experience in electronics and automation.

Many high-end, student-focused robots (such as the LEGO Mindstorms) offer features like customizability but at a relatively higher cost [5]. Meanwhile, lower-cost options (such as Makeblock's mBot) lose many of these customization features to lower the price. The Small Education Robot (WitBot) described in [5] was designed as an affordable, open-source, and modular alternative to provide an affordable solution while still providing the required functionality and customizations needed for real-world robotics education.

Taking a step back from this, [6] explores the design process for educational robotics, especially as it relates to promoting STEM education and learning. Teachers were involved in designing and constructing robots. [7] reports on a study and pilot conducted in the US to provide a "hands-on" open-source robotics learning environment that is both inexpensive and reliable. The hardware system and accompanying software architecture for such a bespoke robotics solution are presented. Finally, in [8], the authors present DuBot, describing the design and development of an open-source, low-cost robot for primary and secondary school students, which is suitable for use in educational robotics and STEM subjects.

C. Robotics and STEM Outreach for Primary Education

Early exposure to robotics and electronics can spark interest in STEM fields, helping students develop foundational skills at an early age. Robotics workshops and kits designed for younger learners are central to this initiative [3].

Not all of this exposure needs to be as part of the official curriculum for the students. After-school clubs and robotics outreach activities are considered in [9], with recommendations and suggestions provided to maximize the experiential learning, critical thinking skills and collaborative dynamics fostered by these clubs.

[10] looks at the international "FIRST® LEGO® League (FLL): Challenge", which is a popular educational robotics and STEM competition with entrants from over 110 countries taking part. The competition is designed to promote primary and early secondary/high school students' interests in robotics, STEM and related topics. Also at an international level, [11] discusses the EUREKA STEM Robotics and Artificial Intelligence (AI) educational program. This program has been quite effective at promoting STEM education and cultivating inclusivity among children/young people (especially in underprivileged communities) in Wales, England, Malaysia, Indonesia, China, and Pakistan. Finally, in [12], the authors present an educational robotics (ER) outreach program for early primary schoolchildren, using RoboTito, a robot programmable through tangible elements in its environment designed for kindergarteners.

D. Design Considerations for Educational Robotics Kit

The design and functionality of robotics kits significantly affect their effectiveness as educational tools. Educational robotics (ER) and their effective implementation, as studied in [13], have been used to create interactive and engaging learning environments to develop computational thinking (CT) in primary and secondary school students. Such approaches can be used to develop the appropriate CT skills, robotics kits, and pedagogical approaches suitable for supporting CT development in these young learners. Complimenting this, authors in [14] discuss the aspect of teacher training research in ER and make recommendations for institutions that intend to implement ER teacher training programs. Factors such as requirements, durations, trainer and trainee profiles, pedagogical approaches and best practices are all identified and discussed in the article. At a higher level, [15] classifies the research literature on the ER to identify research trends and gaps, as well as summarizing the experimental findings related to ER and interpreting them according to the claims in the literature. Finally, the study described in [16] examines preschool educators' views regarding the factors that hinder them from incorporating ER into their daily teaching practice. These factors include a lack of experience and knowledge among teachers regarding ER, teacher training in this field and planning ER activities into the regular classroom activities. Key design considerations include ease of use, scalability, and adaptability to different learning environments.

E. Collaborative Robotics Projects in Education

Collaboration in robotics projects fosters teamwork, communication, and problem-solving skills [17]. These skills are crucial for both undergraduate students and younger learners, providing opportunities for cross-age collaboration in educational robotics initiatives. Considering diverse aspects such as focus, effort/contribution, communication, problem-solving, engagement in inquiry, attitude, and responsibility as part of the team dynamic, [17] and [18] show that robotics was particularly useful in developing problem-solving skills and a positive attitude towards teamwork among participants.

Delving deeper into the topic, [19] analyzed the development of computational thinking skills in primary school students through collaborative robotics activities. The study hypothesized that problem-solving skills, intrinsic motivation, and enjoyment were the main predictors of computational thinking skill development in the collaborative team environment. Complimenting this, elementary school students' behavioural patterns were explored while they were working on a collaborative robotics project in [20]. Results showed that ER improves collaborative learning, with contribution and planning behaviours dominating the robotics project development cycle. Finally, in [21], the question of developing school students' computational thinking through collaborative robotics projects in online learning is considered, especially as it related to the online teaching and learning requirements during the COVID-19 pandemic.

F. Challenges and Future Directions in Affordable Robotics for Education

While affordable robotics solutions are increasingly available, challenges remain with respect to scalability, sustainability, and integration into diverse educational systems. Research in this area focuses on overcoming these challenges to improve access to robotics for all learners.

In terms of available resources and training for teachers and students for ER in schools, [22] highlights the growing need to create highly accessible resources to teach and learn robotics. The study revises available online educational material, including videos, podcasts, and coding tools, aimed at facilitating the learning of robotics related topics at different school levels. In [23], even though the advantages of bringing new technologies into schools are clear, the lack of a well-established set of good practices, assessment of experiences, and tools slows down the adoption of robotics into educational courses. Despite the wide availability of continually developing tools and experiences for ER, there is still a certain degree of uncertainty about how to cope with technology in education and how to evaluate the outcomes of such activities.

Artificial intelligence (AI) and its impact on the teaching of robotics in education is also worthy of consideration at this stage. [24] considers the numerous studies which have shown that AI robots may provide new opportunities for learning designs in school settings or professional training. The article also conducts a separate review, examining the role and research focus of AI-Robots in Education. [25] supports this with a review of 17 different international studies, conducted between 1995 and 2021, showing that AI has significantly improved children's concepts regarding AI, machine learning, computer science, and robotics. Furthermore, it has also been shown to enhance other skills such as creativity, emotion control, collaborative inquiry, literacy skills, and computational thinking.

G. Conclusion and Research Gaps/Opportunities

This structured review of the literature highlights the key themes and challenges related to affordable robotics solutions in education. The referenced studies collectively underscore the importance of accessibility, hands-on learning, and cost-effectiveness in advancing STEM literacy through robotics, and provide a solid foundation for the proposed research.

While considerable progress has been made in developing and implementing affordable robotics solutions for STEM education, gaps remain in understanding the broader impacts on educational outcomes, especially in diverse socio-economic contexts. Further research can explore how these solutions could be scaled effectively to reach a wider audience, ensuring that all students, young and older, can engage with robotics and electronics.

III. METHODOLOGY

This study investigates four distinct, affordable robotics platforms—LEGO Mindstorms NXT2/EV3 robots (shown in Fig. 1), LEGO Boost robots (Fig. 2), Arduino-based robots (like that shown in Fig. 3), and remote-controlled (RC) platforms (such as the example shown in Fig. 4). Each offers unique benefits for both third-level undergraduate electronics and electrical engineering courses, as well as for STEM outreach in Irish primary schools. The following sections outline the integration of these platforms into existing curricula and outreach activities in Ireland, with a focus on cost-effectiveness, ease of use, and educational value.

A. LEGO Mindstorms NXT2/EV3 Robots

Undergraduate Courses: - LEGO Mindstorms NXT2 and EV3 robots are known for their flexibility, ease of use, and rich functionality. These kits consist of programmable brick controllers, motors, sensors, and a variety of building pieces. For undergraduate engineering courses, these robots provide a hands-on platform for exploring key concepts in embedded systems, automation, control systems, and sensor integration.

In the classroom, students can use LEGO Mindstorms robots to build and program autonomous systems. They can integrate these robots into projects such as automated assembly lines, robotic arms, or mobile robots capable of navigating complex environments using sensors. The kit's compatibility with both graphical programming environments (such as LabVIEW or the Mindstorms software) and text-based programming languages (like Python) makes them suitable for introducing students to basic and advanced programming skills.

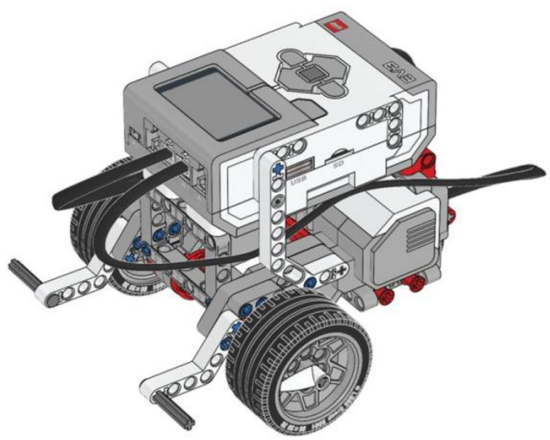

Fig. 1 LEGO Mindstorms EV3 Robot

Primary School Outreach: - For primary school outreach, the LEGO Mindstorms robots provide an excellent balance of engagement and educational depth. These robots can be used in interactive workshops where students construct basic robots and program them to perform tasks like following lines or responding to obstacles. The modular nature of the kits allows for quick construction of different robot types, making the process both fun and educational.

In the Irish context, outreach programs typically focus on introducing primary school students to fundamental concepts of electronics and robotics through simple tasks that engage their creativity and problem-solving skills. The LEGO Mindstorms kits can be used in after-school STEM clubs or summer camps, with teachers guiding students through beginner projects that lay the foundation for more complex engineering concepts in later years.

Fig. 2 LEGO Boost Robot

B. LEGO Boost Robots

Undergraduate Courses: - Although primarily designed for younger learners, and therefore better suited for Primary School Outreach, LEGO Boost robots can be adapted to support introductory modules for third-level courses on robotics, mechatronics, and embedded systems. In particular, the use of Boost robots in a university setting can provide a rapid prototyping tool for simple automation tasks or basic interaction with sensors and motors.

For example, first-year engineering students can use LEGO Boost robots as part of an introductory robotics course. It provides a user-friendly interface, with programming done through an intuitive block-based coding platform that introduces key concepts such as control loops, sensor feedback, and robotic kinematics in an easily digestible manner. Boost's simple platform offers a starting point for students before transitioning to more complex hardware and programming environments.

Primary School Outreach: - LEGO Boost is ideal for primary school outreach, as its colorful blocks and simple drag-and-drop coding environments (such as Scratch) appeal to younger learners. Students can engage in projects like building and programming interactive robots that respond to voice commands or perform basic movements. These activities introduce core principles of STEM (including logic, sequencing, and problem-solving), in a fun and accessible way.

In Irish primary schools, LEGO Boost robots can also be incorporated into STEM outreach initiatives targeting younger students, with workshops tailored to different age groups. These could include realizing maze-themed games such as Pac-Man using robots to interactive storytelling activities where robots are programmed to perform specific tasks related to the story, thereby combining creativity with technical learning.

Fig. 3 Example Arduino-based Robotic Platform

C. Arduino-based Robotic Kits

Undergraduate Courses: - Arduino is a versatile, open-source electronics platform that provides a flexible foundation for building a wide range of robots. Arduino-based robots allow students to design custom systems using microcontrollers, sensors, motors, and actuators, making them highly suitable for undergraduate courses in electronics, electrical engineering, and robotics.

In third-level education, Arduino-based robots are commonly used to teach students about circuit design, programming, and robotics control. Students can develop robots for tasks such as line-following, object detection, or even autonomous navigation. The Arduino environment supports both beginners and advanced users, making it an excellent tool for project-based learning where students build, test, and iterate on their designs.

For instance, a first-year engineering project to design and implement a "CanSat" (can-sized satellite) system using an Arduino is described in [26]**.** Students developed a fully autonomous Arduino robotic system that used sensors to implement a suite of measurement capabilities for the system. The open-source nature of Arduino also encourages students to modify and expand on existing code, fostering creativity and deeper technical understanding.

Primary School Outreach: - Arduino-based robots, while more challenging than LEGO systems, can still be used in primary school outreach with appropriate guidance. Simplified robots built on Arduino boards can be used to teach basic concepts of electricity, circuits, and programming. Platforms like TinkerCAD or Scratch for Arduino (S4A) provide visual programming environments that are well-suited for young learners.

In primary school workshops, students can build basic robots that perform simple tasks, such as moving or sensing the environment. With proper scaffolding, primary school children can engage in projects that teach them how sensors and actuators work while introducing basic logic and programming. Irish STEM outreach programs can use Arduino-based robots to demonstrate real-world applications of electronics, with activities ranging from controlling LED lights to programming small, wheeled robots.

Fig. 4 Example of a Remote-Controlled (RC) Car Platform

D. Remote-Controlled Cars as Platforms for Robotics

Undergraduate Courses: - Using remote-controlled (RC) cars as platforms for robotics is a highly practical and cost-effective approach to teaching robotics at the undergraduate level. RC cars are widely available, and their existing control systems can be modified and enhanced with additional sensors, motors, and controllers to create robotic systems capable of navigating and interacting with their environments.

In third-level education, students can use RC cars as a base for developing autonomous vehicles or robotic platforms that can perform tasks such as following predefined paths, avoiding obstacles, or performing coordinated actions. For example, mechanical/manufacturing engineering students have designed systems allowing RC cars to autonomously follow a line using sensors. Subsequent project ideas include controlling the car's movements using a smartphone app via Bluetooth.

This platform offers students the opportunity to experiment with wireless communication, control systems, and sensor integration, all within a familiar and low-cost framework.

Primary School Outreach: - RC cars provide an exciting and highly engaging platform for introducing robotics to primary school students. In outreach programs, students can modify and control RC cars using simple sensors and motors to create robots that navigate specific obstacles or interact with objects in the environment.

By integrating RC cars into STEM activities, primary school students can gain hands-on experience with mechanics, electronics, and programming. Projects might include teaching students how to make a car move autonomously or program it to avoid obstacles. RC cars offer a tangible and fun starting point for engaging young learners in the world of robotics and can be used effectively in after-school programs or workshops in Irish schools.

E. Methodology Conclusion

Each of the four robotics platforms examined—LEGO Mindstorms NXT2/EV3, LEGO Boost, Arduino-based robots, and remote-controlled cars—offers unique advantages for both third-level engineering students and primary school learners. By providing affordable, accessible, and engaging robotics solutions, these platforms contribute significantly to the development of STEM skills across Ireland. These platforms enable hands-on learning experiences that integrate fundamental concepts of electronics, programming, and robotics, making them ideal for both educational and outreach contexts. The next section discusses in greater detail the relevant advantages and disadvantages of each option.

IV. DISCUSSION

This paper has outlined four possible robotic platforms for electronics/STEM education and outreach in Ireland: LEGO Mindstorms NXT2/EV3 robots, LEGO Boost robots, Arduino-based robots, and remote-controlled (RC) cars. Each of these platforms offers distinct advantages and disadvantages that make them suitable for different educational and outreach applications.

A. LEGO Mindstorms NXT2/EV3 Robots

The LEGO Mindstorms robots (NXT2 and EV3) have long been established as a leading educational platform for teaching robotics. These robots provide a highly user-friendly experience, particularly in STEM education environments. The modular nature of LEGO bricks allows students to easily assemble and modify robots, which encourages creativity and problem-solving. The EV3 system is equipped with motors, sensors (such as color, touch, and infrared), and a programmable brick, offering a wide range of sensor-based interactions. The EV3's graphical programming interface, based on LabVIEW, is ideal for beginners, while the system also allows advanced users to write custom code in Python or other languages, making it scalable across different levels of competence.

The primary drawback of LEGO Mindstorms is its relatively high cost compared to other solutions, which may limit its accessibility in some educational settings, particularly in resource-constrained schools or outreach programs. Additionally, the system's closed ecosystem—while user-friendly—may restrict more advanced users who want deeper control over their hardware and software. Another limitation is the relatively bulky form factor of the robots, which may not be suitable for projects requiring compactness or mobility in tight spaces.

To mitigate the cost issue, educational institutions and outreach programs can seek sponsorships, grants, or bulk purchasing deals. Additionally, for advanced users, open-source projects and the use of third-party components, such as Raspberry Pi or microcontrollers, could be incorporated into the platform to provide more customization options.

LEGO Mindstorms NXT2/EV3 is ideal for elementary to high school students and can be used to introduce basic robotics, programming, and sensor-based applications. It is particularly well-suited for after-school programs, summer camps, or workshops where simplicity and engagement are key priorities. Its scalability also makes it suitable for extending to more advanced concepts such as autonomous navigation, machine learning, and multi-robot systems.

B. *LEGO Boost Robots*

LEGO Boost robots are designed for younger children, making them an excellent option for introducing robotics concepts at an early age (typically primary school, ages 7-12). The platform is extremely affordable and offers a simpler and more accessible experience than Mindstorms. The robots use basic color sensors, motors, and a programmable brick, which is programmed through a block-based visual programming environment. This lowers the barrier to entry for beginners and is ideal for fostering creativity and exploration in younger students. The cost is considerably lower than that of LEGO Mindstorms, which is an important advantage in terms of outreach programs with limited budgets.

The primary disadvantage of LEGO Boost robots is that they are more limited in terms of functionality and complexity compared to LEGO Mindstorms or Arduino-based robots. The sensors and components are simpler, which means that advanced robotics and electronics concepts (e.g., advanced sensing, machine learning, or precise control algorithms) may be difficult to explore. Additionally, the programming interface, while ideal for younger users, may not offer the depth required for older students or those wishing to explore more sophisticated topics.

For older students or those seeking more complexity, LEGO Boost can be used in combination with other platforms like Arduino to bridge the gap between simple and more advanced robotics concepts. Teachers can guide students towards transitioning from block-based programming to text-based languages like Python, enhancing their problem-solving skills and extending the educational value of the platform.

The LEGO Boost robot is an excellent solution for primary school outreach programs, after-school clubs, and introductory workshops aimed at younger students. It is a great entry-level solution for teaching basic robotics, programming logic, and fostering an interest in STEM subjects.

C. *Arduino-based Robotic Kits*

Arduino-based robots offer an incredibly flexible and open-ended solution for teaching robotics and electronics. Arduino microcontrollers are affordable, open-source, and widely used in both academic and hobbyist robotics communities. The sheer variety of components (motors, sensors, and actuators) that can be interfaced with Arduino provides students with hands-on experience in designing and building custom robots. Programming is done via C/C++, which helps students learn text-based coding and software development practices, providing a direct pathway to more advanced computer science education. Arduino-based robots are also compact and versatile, making them suitable for a wide variety of projects, from simple line-following robots to complex robotic arms or drones.

While Arduino robots provide more flexibility, they also require a higher level of technical skill and knowledge. Students need to be familiar with electronics (e.g. understanding circuits, sensors, and actuators) and programming in C/C++. For absolute beginners, this could be overwhelming, and the steep learning curve may discourage some students. Moreover, unlike LEGO systems, Arduino-based robots often require more time to assemble and troubleshoot, as they do not provide the same "plug-and-play" experience.

To address the steep learning curve, educational kits can be provided that include detailed guides and tutorials, helping students navigate the complexities of Arduino programming and circuitry. Supplementing Arduino projects with additional educational resources or workshops on basic electronics and programming could also help bridge the knowledge gap.

Arduino-based robots are best suited for secondary school or university-level students who have already gained some understanding of basic electronics and programming. They are ideal for projects that require customization and advanced learning, such as robotics competitions, academic research, or more complex outreach programs that aim to foster deeper engagement with STEM topics.

D. Remote-Controlled Cars as Platforms for Robotics

Using remote-controlled (RC) cars as a platform for robots is an inexpensive and accessible option for robotic education and outreach activities. RC cars are widely available, cheap, and can be easily modified to include sensors, cameras, and other electronics. This platform is particularly appealing for outreach programs with limited budgets, as the base hardware is relatively low-cost. Moreover, RC cars provide an immediate, tangible sense of control and fun, which can increase engagement and motivation among students.

One major disadvantage of using RC cars is the limited scope for complex tasks. Most RC cars are pre-built, with a focus on mechanical operation, and therefore may not offer the same degree of flexibility as other platforms like Arduino. Adding sensors or actuators requires modifying the car's electronics, which may require a good understanding of electronics and circuit design. Furthermore, since the car's original design is not focused on robotics, the modification process can be cumbersome and time-consuming.

To overcome the limitations, RC car platforms can be combined with additional sensors and control boards, such as Arduino to provide more advanced functionality. Offering workshops on how to modify and control the RC cars through custom electronics can also enhance students' learning experiences.

RC cars are ideal for hands-on workshops or introductory robotics courses that focus on mechanical and control systems rather than complex sensing or autonomous behavior. They are especially useful in outreach programs targeting younger students or those with limited exposure to robotics.

Each of the four robotic platforms—LEGO Mindstorms NXT2/EV3, LEGO Boost, Arduino-based robots, and RC cars—offers unique advantages and disadvantages, making them suitable for different educational contexts. LEGO Mindstorms provides an excellent balance of ease of use and complexity, making it ideal for structured STEM programs. LEGO Boost offers an accessible entry point for younger children but lacks the depth needed for more advanced concepts. Arduino-based robots, while challenging for beginners, offer unparalleled flexibility and depth for advanced learners, making them ideal for more sophisticated educational projects. Finally, using RC cars provides an affordable and engaging way to introduce basic robotics concepts, although it lacks the extensibility of other platforms. By understanding the strengths and limitations of each platform, educators can choose the solution best suited for their specific educational goals, ensuring a balanced and effective approach to STEM outreach in Ireland.

V. Conclusion & Further Work

This paper has examined the role of four affordable robotics platforms — LEGO Mindstorms NXT2/EV3, LEGO Boost, Arduino-based robots, and RC cars — in enriching STEM education across undergraduate and primary education settings in Ireland. These tools have proven highly effective in translating abstract theoretical concepts into meaningful, hands-on learning experiences. Whether enabling undergraduate students to experiment with embedded systems and automation or introducing young learners to foundational electronics through playful interaction, the solutions presented offer scalable, engaging, and cost-effective entry points into robotics education.

Looking ahead, the landscape of educational robotics presents exciting possibilities for deeper integration into STEM curricula and more transformative learning models. One promising direction is the incorporation of artificial intelligence (AI) and machine learning (ML) modules into existing robotics platforms. Emerging microcontrollers and edge computing devices, such as the Raspberry Pi 5 and NVIDIA Jetson Nano, now allow students to explore vision systems, autonomous behavior, and data-driven decision-making—key skills in an AI-driven world. Embedding AI into robotics education not only raises technical proficiency but also prepares students for interdisciplinary challenges in fields such as smart systems, healthcare, and environmental monitoring.

In addition to advancing technical content, there is a compelling opportunity to innovate on pedagogical frameworks too. Future work could explore the co-creation of adaptive robotics curricula, for example - courses that respond to individual learning styles and progress, integrating elements of gamification, personalized feedback, and online collaboration. Robotics platforms could also serve as vehicles for cross-disciplinary learning, where engineering intersects with art, ethics, or sustainability, encouraging holistic problem-solving and creativity. Platforms such as Micro:bit and Tinkercad Circuits (paired with cloud-based simulators) could support remote or hybrid learning environments, ensuring continuity in practical education regardless of geographic or infrastructural limitations.

Crucially, broader impact studies are needed to measure how robotics-based interventions affect long-term learning outcomes, motivation, and equity. Longitudinal research across socio-economic and gender-diverse cohorts could help identify the most inclusive strategies for fostering sustained interest in STEM careers. Moreover, initiatives that leverage community partnerships, industry mentorship, and international collaboration can help scale successful models beyond local contexts and build resilient learning ecosystems.

In conclusion, the use of affordable robotics in education is not merely a technical solution — it is a gateway to reimagining how we teach, learn, and inspire. By embracing emerging technologies, designing inclusive pedagogies, and rigorously evaluating impact, we can ensure that educational robotics continues to evolve as a cornerstone of innovative, equitable, and future-focused STEM education.

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