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Enhancing Teaching of Robotics through Computational Modelling

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ABSTRACT
The students need to learn various subjects while studying robotics teaching since it requires computer science, electrical engineering, and mechanical engineering knowledge. There are instances whereby traditional pedagogy needs to include some helpful content or value of robotic theories and their applications. This paper aims to give an overview of the role of computational modeling for robotics learning in the educational process and how it can be implemented. What is specific about computational modeling in teaching robotics is its ability to model the world and complex processes. This paper refers to the current issues concerning robotics education. It explains why robotic modeling can be integrated as an educational tool, to what extent it can be helpful and practical, and what positive and negative aspects it has, emphasizing the practical application of the method. This paper will also explore the topic of robotics education by using this topic to gain insights into the topic and make recommendations for educators intending to advance learning in robotics.
Key Words: *Robotics, Education, Computational Modeling, Interdisciplinary Integration, Practical Application*

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I. INTRODUCTION

Robots are another critical area and one of the developing technologies where their application can be helpful in manufacturing and healthcare environments. It is, therefore, crucial to develop effective and broad-based robotics engineering curricula that are flexible to the evolution of technology. Lecturers who still follow the conventional teaching style in which students mainly spend most of their time theorizing and hardly get practical contact with the robots may need to prepare students to handle the various robotics-related challenges adequately [1]. This paper delves into whether computational modeling can address this gap. Computer-assisted learning entails using computers to develop models of natural systems to simulate these systems utilizing dynamic and interactive models. If computational modeling can be introduced in robotics education, then students learn to apply theory in practice and practical skills they can use throughout their professional lives.

II. CURRENT CHALLENGES

Robotics education is currently characterized by providing a platform for integrating computing and traditional engineering fields like electrical and mechanical engineering [2]. It is customary in traditional education systems to separate these fields from each other, and it becomes difficult for students to understand that these forms are interlinked. To overcome this challenge, a significant change in the design process is required to move to interdisciplinary approaches, focusing on integrating the elements related to the robotics field. Using gimmicks such as project-based learning and group work can also give the student a real sense of interrelatedness between the different subjects involved with robotics. With conventional classroom teaching focusing on expository lecture approaches, engaging the learners to explore through robotics takes much work. To counter this, instructors must employ some of the most advanced teaching techniques focused on encouraging students to participate actively in the learning process [1]. This may include providing opportunities for hands-on experiences and simulations based on robotics and robotics courses, as well as the real-life applications and use of robotics. Further, discussing the value that robots contribute to society and make money in the same field could convince students to continue studying this field. An inherent challenge in robotics education is the transfer from understanding technical concepts to their practical application. It should also be noted that this lack of experience is typical for students who receive all the theoretical knowledge in class and who need a chance to manipulate the equipment in practice [3]. To overcome this, teachers can engage students in laboratory work on the design and construction of robots, internships in related industries, and projects focused on practical applications. It is essential to provide students with robotics kits, access to simulation software, and maker spaces so that students can apply the knowledge they have gotten better and understand robotics well.

One of the significant issues that remain here is that a school employing robotics does need an adequately resourceful and equipped laboratory, which can be expensive for schools where budgeting and space are big problems [4]. To address this challenge, educators can try some of the current options, like 'virtual labs' where the equipment is accessed remotely or in direct collaboration with the industry to resolve the issue. Open-source hardware and software platforms can minimize the program's cost and provide open accessibility in education robotics. Moreover, applying for grants and seeking funding sources will enable one to acquire the financial muscle required to integrate more practical learning sessions in class. The demonstration of existing challenges along with their interdisciplinary integration are presented in Table 1 and 2 respectively.

Table 1: Existing Challenges in Robotics Education

Challenge	Description	Suggested Solutions
Interdisciplinary Integration	Difficulty in integrating CS, EE, and ME fields	Project-based learning, interdisciplinary curriculum design
Engagement and Motivation	Rote learning leading to short-lived interest	Hands-on experiences, simulations, real-life applications
Practical Application	Gap between theoretical knowledge and practical skills	Laboratory work, internships, maker spaces
Resource Limitations	High costs of equipment and laboratory setup	Virtual labs, industry collaboration, open-source platforms

Table 2: Interdisciplinary Integration

Field	Topics Covered	Integration Strategy
Computer Science	Programming, Algorithms	Project-based learning, group work
Electrical Engineering	Circuit Design, Control Systems	Hands-on labs, interdisciplinary projects
Mechanical Engineering	Mechanics, Kinematics	Practical applications, real-life projects

2.1. BENEFITS

Enhanced Understanding: Robotic systems present challenges not only in practice but also theoretically, and computational modeling allows students to understand these concepts. Students will understand the simulation of robots' movement in different situations using simpler models and pictures of complicated systems.

Interdisciplinary Learning: Combining robotics study with learning practices in other subject areas familiarizes students with gaining knowledge from different subject areas [5]. Using simulation, students learn about the connections and dependencies between the fields of computer science, electrical engineering, mechanical engineering, and robotics.

Practical Skills: Learning how to construct and virtualize robots gives insight into the practice necessary for implementing the design [6]. Integrated use of computational modeling fosters mathematical and computational proficiency, problem-solving skills, critical thinking skills, and system thinking to prepare students for the career path in robotics.

Engagement: Leveraging learning by doing and engaging students with project-based learning increases student attentiveness and motivation in robotics. Through its practical application and promotion of inquiry-based learning, computational modeling is effective in motivating students to learn robotics.

III. Implementation

To deal with these challenges, we recommend incorporating the computational modeling concept into the robotics curriculum. The implementation can be divided into several key steps shown in Fig 1. The description of each step is illustrated in Table 3.

3.1. *Curriculum Design:*

This implies the need to create a curriculum that makes it easy to teach robotics using mathematical modeling without alienating the educational concepts in robotics. This requires creating a curriculum that provides the basics of computer science, electrical engineering, and mechanical engineering disciplines and focuses on the interdisciplinary relationships between them. The authors of this article suggest incorporating project-based and interdisciplinary activities as a convenient way to teach students about robotics and how it can be used.

3.2. *Software Tools:*

Students must be introduced to computational modeling software like MATLAB/Simulink and ROS, which face challenges in access to the software and proficiency in their use. Professionals must organize training activities and conduct practices so that users can learn how to work with these products [4], [7]. Moreover, the solution to software compatibility problems and developing support services will improve the application of these tools in the curriculum.

3.3. *Project-Based Learning:*

It is essential to plan the implementation of PBL with care in robotics education to align the projects incorporated therein to the intended learning objectives for students. Issues may emerge while developing projects that could be more complex due to time constraints, resource availability, and students' range of competency. Since all the participants are learners in this case, there is a need to support them throughout the project life cycle and promote the development of collaboration and critical thinking skills.

3.4. *Assessment and Feedback:*

Assessing students' knowledge can be a problem systematically assessing both understanding of theoretical information and practical use of roboticist principles can be difficult. Assessment specialists must create testing instruments that can reflect students' abilities in using computational modeling to solve robotics problems [2]. The insertion of simulations and modeling projects into the assessment process provides an immediate feedback mechanism that allows the students to continue to experiment and correct the deficiencies they may detect.

3.5. *Continuous Improvement:*

Keeping a school robotics program on the cutting edge poses a challenge because the curriculum and tools must be updated frequently due to the changing nature of robotics and computational modeling. Educators must always strive to be aware of what is happening in the field and to renew course content, tools, and techniques. Working with industry partners and attending professional development opportunities can offer insights and resources to improve the curriculum and innovation of robotics study.

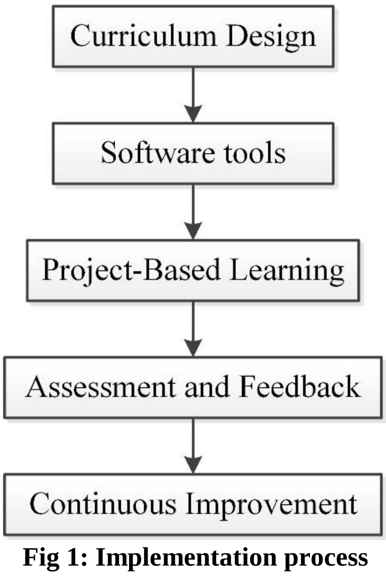

Fig 1: Implementation process

Table 3: Implementation Steps for Computational Modeling

Step	Description
Curriculum Design	Create interdisciplinary curriculum integrating computational modeling
Software Tools	Introduce software like MATLAB/Simulink, ROS, and provide training
Project-Based Learning	Develop projects aligning with learning objectives, provide support
Assessment and Feedback	Develop testing instruments for theoretical and practical skills
Continuous Improvement	Update curriculum and tools frequently, collaborate with industry

IV. Real World Application

4.1. *Industry Simulations*

Computational modeling allows the students to be integrated into an artificial world and inverted reality, which imitates real work in industrial robots without spending money on equipment. With the aid of the materials, the students acquire experience in applying optimization methods and managing the workflow and systems, as well as directing their professional activities to the production industries, logistic companies, and automation technologies. Additionally, students can test drive the setups of the industry and even change them to test different scenarios and imagine how they can deal with problems in the real world of industrial automation.

4.2. *Prototyping*

Computational modeling reinforces special education students' experiences of prototyping because they can prototype their designs using a computer program to test designs and make design changes before actual robot prototypes are built. Students can elucidate their design and test the hypotheses ' performance of ideas through computational models and interactively prove or disapprove new ideas and concepts as fast as possible. This approach enables students to design the product iteratively, thus minimizing time and refining it many times. Before starting the actual development, they can check and rectify the design deficiencies [8]. Moreover, virtual prototyping enables students to test different parameters and configurations of circuitry, materials, and geometric structures, which help them, be creative and innovative in robotic design.

4.3. *Research and Development:*

Computational modeling allows the students to learn how to perform robotics-related tasks that touch on research and development issues. Thus, using simulations of robotics systems allows students to make their experiments, test hypotheses, and evaluate the possibility of implementing original designs of promising technical systems [9]. Attention to this field, especially R&D, offers students solid experience in solving problems and thinking critically and technically for future professions connected with academia, research institutions, and industries. Moreover, computational modeling can enhance students' interdisciplinarity because they use computational modeling to understand problems and solve them, bridging the gap between the fields of computer science, engineering, and mathematics to help children in robotics.

4.4. *Medical Robotics:*

Indeed, computational modeling is an indispensable tool in medical robotics that deals with high-precision procedures, and the developers and manufacturers of medical devices and surgical robots cannot do without it. Students can analyze how a medical device functions and how it can ensure safety in surgical procedures by simulating the surgical process and device interactions in safe parameters and predicting if their functions are indeed safe for patients. Biomechanics, modeling of tissues and organs, and other related surgical procedures will become possible for students if computational modeling is involved. The learning outcomes of this discipline are to ensure that the students are well equipped to handle careers that involve healthcare, biomedical engineering, and surgical robotics, where they can support more efficient and effective ways of treating patients and medical practices using robots.

4.5. *Autonomous Systems:*

Computer simulation as a learning tool applies to students majoring in technologies used in autonomous vehicles or drones to test and prove navigation and the control system in a safe and secure environment [9]. Through virtualization, educators can replicate real-life situations to perfect the algorithm of autonomous machines, assess the efficiency of sensor fusion, and calibrate the control model without the risk of physical experimentation [3]. The explicit deployment of learning strategies in experiential learning for autonomous systems explicitly builds critical thinking, problem-solving solving, and decision-making abilities and skills for creative deployment in choosing the design of the autonomous systems and the scope of the applications – be it in the transport sector, agricultural industries, or surveillance-based monitoring systems. Additionally, this approach provides opportunities to investigate future fields like machine learning, sensor-based networks, human-robot interaction, etc., which helps students prepare for careers in the development and application of autonomous systems in their first years of academic study.

V. Conclusion

The employment of computational modeling in the teaching of robotics presents an excellent remedy to the above problems often associated with conventional teaching methods. Computational modeling can be used as a teaching tool that provides students with an interactive and interdisciplinary learning space for understanding robotic systems' complexity and proficiency in real-world problems. Nevertheless, developing this approach involves considerable amounts of time and work, but in return, it promises to generate more meaningful student engagement, practical know-how, and well-rounded learning. Teachers are advised to investigate the possibility of using computational modeling to help teach robotics in ways that will ensure that many of these students are sufficiently well-equipped to play their part in the future of the scientific advances of robotics. Further research and development in pedagogical approaches for modeling and teaching robotics will continue to benefit robotic modeling education.

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