IMPLEMENTATION OF CDIO SKILLS INTO THE MECHATRONICS AND ROBOTICS MAJOR

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ABSTRACT

This research paper focuses on the implementation of CDIO skills corresponding to learning outcomes within the analyzed curriculum of the Mechatronics and Robotics Major. The study aims to identify the extent of alignment between CDIO skills and learning outcomes, providing recommendations for further enhancing the integration of these skills into the curriculum. The study commences by identifying the key CDIO skillspertinent to the mechatronics and robotics domain. These skills encompass Conceiving,Designing, Implementing, and Operating, namely the holistic nature of engineeringeducation. A thorough analysis of the learning outcomes of the mechatronics and robotics curriculum is then conducted to determine the extent of alignment with the identified CDIO skills. A comprehensive review of relevant literature related to CDIO skills, learning outcomes, and mechatronics and robotics education was conducted. In the context of mechatronics and robotics education, several studies have been reviewed to investigate the impact of CDIO-based curriculum on student learning outcomes. The mechatronics and robotics major curriculum was analyzed to identify thespecific learning outcomes associated with each course. The identified learning outcomes were mapped to the corresponding CDIO skills, ensuring that the curriculum provides opportunities for students to develop these essential skills. Additionally, the curriculum incorporates hands-on laboratory activities and design projects, providing students with opportunities to apply their knowledge and skills to real-world problems. (Atayeva, Sh. Garlyyeva, Ch. Orazov, Y. Innovative Approach to Training Sustainable Engineers) Recommendations are provided for strengthening the alignment between CDIO skills and learning outcomes, ensuring that mechatronics and robotics graduates possess thenecessary skills to thrive in the challenging and dynamic world of engineering. The results of this study can serve as a guide for further enhancing the integration of CDIO skills into the curriculum.

KEYWORDS

CDIO Skills Implementation, Mechatronics and Robotics, learning outcomes, curriculum analysis, CDIO Standards: 2, 3, 4

DEVELOPMENT OF MECHATRONICS AND ROBOTICS: A JOURNEY THROUGH TIME ANDTOWARDS THE FUTURE

Current Trends and Prospects in the Field of Mechatronics and Robotics

In the 21st century, mechatronics and robotics are at the forefront of technological innovation, impacting various industries, from manufacturing and healthcare to transportation and entertainment. One prominent trend is the rise of collaborative robots, or cobots, designed to work alongside humans. These robots enhance efficiencyand safety by sharing spaces and tasks with human workers.

Advancements in artificial intelligence and machine learning are driving the development of intelligent robots capable of learning from experience. These robots canadapt to changing conditions, make decisions, and perform tasks beyond their initial programming. The fusion of robotics with AI is opening new possibilities in areas like autonomous vehicles, drone technology, and smart homes.

The Internet of Things (IoT) is another influential trend in mechatronics. Connectingdevices and systems through the internet allows for real-time data exchange and remote control. In robotics, this translates to improved monitoring, diagnostics, and maintenance of robotic systems. Smart factories, powered by interconnected mechatronic systems, are transforming the landscape of industrial production.

Looking ahead, the prospects for mechatronics and robotics are tantalizing. As technologies converge, we can anticipate the development of robots with enhanced sensory capabilities, natural language processing, and the ability to collaborate with each other autonomously. Robotic systems will likely play pivotal roles in addressing societal challenges, such as healthcare support for an aging population and disasterresponse.

In conclusion, the journey of mechatronics and robotics from historical roots to contemporary trends showcases the remarkable evolution of human-machine interaction. From the mechanization of the Industrial Revolution to the intelligent and collaborative robots of today, the field continues to push boundaries. As we stand on thecusp of a new era, marked by AI, IoT, and interconnected systems, the future of mechatronics and robotics promises unprecedented advancements that will shape the way we live and work.

INTEGRATION OF CDIO SKILLS INTO THE MECHATRONICS AND ROBOTICS EDUCATIONALPROGRAM: A FRAMEWORK FOR EXCELLENCE

A Phased Approach to CDIO Integration in Mechatronics and Robotics

We have created a model framework for implementing CDIO principles into the Mechatronics and Robotics major curriculum at our university. This framework outlines a six-year plan (2023-2029) divided into five distinct phases, each with specific actions designed to achieve a successful integration of CDIO.

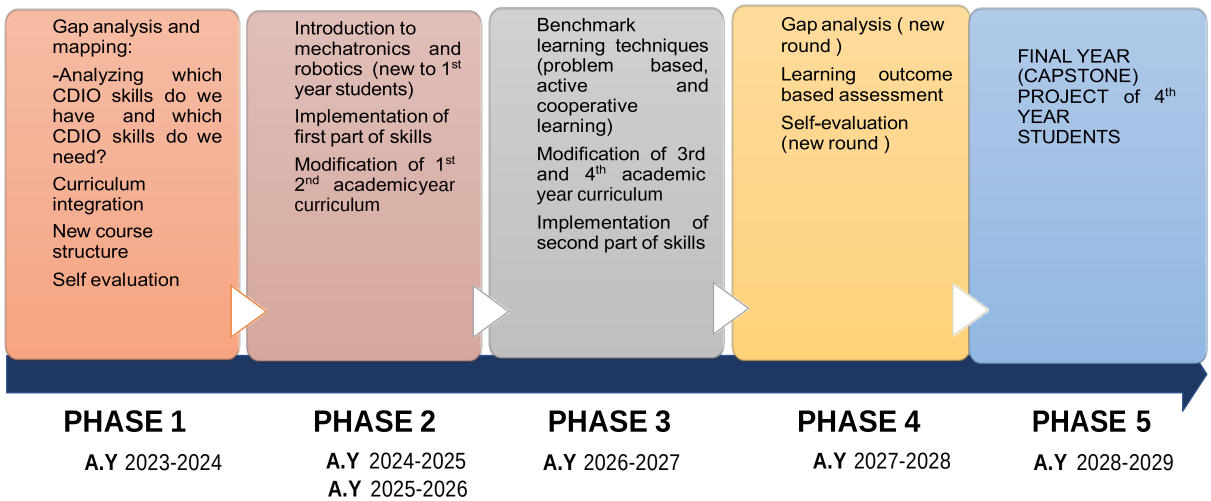

Figure 1. Model framework for Implementation of CDIO

Phase 1 (Academic Year 2023-2024)

The first phase focuses on laying the groundwork for CDIO integration. This includes activities such as a gap analysis and benchmark assessment to identify areas where our current curriculum aligns with CDIO skills and areas where improvement is needed. We will also conduct a review of learning outcomes to ensure they are aligned with CDIO principles.

Phase 2 (Academic Years 2024-2026)

It centers around curriculum modification and the implementation of the first part of the CDIO skills identified in the gap analysis. We will modify the 1st and 2nd academic years curriculum to begin incorporating CDIO skills. This may involve developing new courses or revising existing ones to include elements of Conceiving, Designing, Implementing, and Operating (CDIO).

Phase 3 (Academic Year 2026-2027)

Phase 3 focuses on further curriculum development. We will modify the curriculum of the 3rd and 4th academic years to ensure a comprehensive integration of CDIO principles throughout the program. Additionally, we will begin implementing the initial set of identified CDIO skills into the curriculum.

Phase 4 (Academic Year 2027-2028)

In Phase 4, we will reactivate gap analysis and introduce new courses, if necessary. We will conduct a self-evaluation of the entire CDIO implementation process to identify areas for further refinement and ensure the long-term sustainability of CDIO principles within the Mechatronics and Robotics curriculum.

Phase 5 (Academic Year 2028-2029)

The final phase focuses on capstone-project based assessment. This phase assesses the effectiveness of the implemented CDIO skills and makes adjustments as needed. (Cheah, S.M., Phua, S.T. and Claire H.T. Ng, The Chemical Engineering CDIO Experience After 5 Years of Implementation)

Analysis of the Existing Mechatronics and Robotics Program

Before embarking on the integration of CDIO principles, a thorough analysis of the existing mechatronics and robotics program is imperative. This step involves assessing the strengths and weaknesses of the current curriculum, pedagogical methods, and learning outcomes. Faculty members, industry experts, and students should collaborate in this evaluation process.

The analysis should consider the alignment of the program with industry needs, technological advancements, and the evolving landscape of mechatronics and robotics. It should also evaluate the extent to which the current program fosters essential skills such as teamwork, communication, and problem-solving—qualities that the CDIO program emphasizes. (Cheah, S.M. and Yang, K., CDIO Framework and Skillsfuture: Redesign of Chemical Engineering Curriculum After 10 Years of Implementing CDIO)

Feedback from alumni and industry stakeholders can provide valuable insights into the program's effectiveness in preparing graduates for real-world challenges. Identifying areas for improvement and understanding the unique characteristics of the existing program sets the stage for a targeted and meaningful integration of CDIO principles.

The Table 1 shows a comparison of curriculum of Mechatronics and Robotics major of ETUT and University of Dhaka. Our decision to acknowledge the high level of excellence in both curricula sets a positive tone from the outset. This demonstrates a respectful and objective approach to the comparison. The self-analysis we conducted on ETUT's curriculum showcases our proactive engagement with our own education. By reflecting on the program's strengths and areas for potential improvement, we demonstrate a commitment to continuous learning and a desire to optimize the educational experience. Comparing ETUT's curriculum with a well-regarded university like the University of Dhaka allows we to benchmark our program against established standards. This comparative analysis can reveal areas where ETUT excels and identify potential areas for further development.

Instead of focusing solely on shortcomings, we can frame the gap analysis as an opportunity for growth. By identifying areas where the University of Dhaka's curriculum might offer additional depth or different approaches, we can propose ways to enhance the learning experience at ETUT. This demonstrates a forward-thinking and improvement-oriented perspective. Our comparison has the potential to yield positive outcomes for both universities. Sharing best practices identified through the analysis could benefit both institutions. Additionally, our work could serve as a valuable resource for future curriculum development efforts at ETUT.

Table 1. Comparing of curriculum of Engineering and technology university of Turkmenistan (ETUT) and University of Dhaka

ENGINEERING AND TECHNOLOGY UNIVERSITY OF TURKMENISTAN

Fall semester	Spring semester
Mathematical analysis and differential *equations* Linear Algebra English for profession Mechanics Biology and bionics for engineers Japanese for profession Contemporary computer technologies SFIT	Mathematical analysis and differential equations English for profession Engineering and computer graphics Chemistry for engineers Theoretical mechanics and strength of materials Biology and bionics for engineers Japanese for profession Contemporary computer technologies SFIT
Theory of functions of a complex variable English for profession Control system techniques Electricity and magnetism Digital electronics Computer programming Japanese for profession Ecology and environmental protection SFIT	Fundamentals of mechatronics English for profession Control system techniques Electrotechnics and electronics Digital electronics Computer programming Japanese for profession Life safety SFIT Professional practice
Electrotechnics and electronics Measurement techniques Material science and photonics Computer programming Theoretical Innovatics Communication techniques SFIT	Numerical methods Robotics Artificial Intelligence Applied programming Theory of economics Energy safety and “green engineering” SFIT Metrology, standardization and certification Professional practice
Data mining Image recognition Digital signal processing Digital economy Fundamentals of Biotechnology SFIT Work on graduation thesis	Smart material’s technology Basics of nanotechnology Basics of chemical technology SFIT Work on graduation thesis

UNIVERSITY OF DHAKA

Fall semester	Spring Semester
Differential and Integral Calculus Fundamentals of Mechanical Engineering Fundamentals of Computing Physics Chemistry Physics Lab Chemistry Lab Engineering Drawing Lab Machine Shop and Workshop Practices Lab	Fundamentals of Mechatronics Engineering Fundamentals of Electrical and Electronics Engineering Fundamentals of Programming Linear Algebra Accounting Functional English Fundamentals of Mechatronics Engineering Lab Fundamentals of Programming Lab
Instrumentation and Measurement Digital Logic Circuit and Microprocessor Engineering Mechanics Multivariate and Vector Calculus Managerial and Engineering Economics Society and Technology Instrumentation and Measurement Lab Digital Logic Circuit and Microprocessor Lab	Introduction to Robotics Microcontroller and Programmable Logic Controller Object Oriented Programming Electrical Machines Differential Equations and Coordinate Geometry Statistics for Engineers Introduction to Robotics Lab Microcontroller and Programmable Logic Controller Lab Object Oriented Programming Lab
Artificial Intelligence Advanced Mechatronics Engineering Mechanics of Solids and Fluids Mathematical Analysis for Engineers Industrial Management Artificial Intelligence Lab Advanced Mechatronics Engineering Lab Mechanics of Solids and Fluids Lab	Intelligent Systems and Robotics Manufacturing Process with CNC Programming Power Electronics and Drives Control Systems Design Bangladesh Studies Intelligent Systems and Robotics Lab Manufacturing Process with CNC Programming Lab Power Electronics and Drives Lab
Advanced Robotics Digital Image Processing and Robot Vision Digital Signal Processing Mechanical Power Transmission Systems Advanced Robotics Lab Digital Image Processing and Robot Vision Lab Digital Signal Processing Lab Research Methodology, Technical and Scientific Writing Lab Project	Human Robot Interaction Optional Course I (From Group A) Optional Course II (From Group B) Human Robot Interaction Lab Optional Course I Lab (From Group A) Project

Integration of CDIO Principles and Components into the Educational Program

Figure 2 focuses on mapping of curriculum of Mechatronics and Robotics major. We've created a table that maps curriculum subjects to CDIO skills, taking a strategic approach to ensure students develop the necessary competencies. This visual representation allows for easy identification of subjects that naturally integrate CDIO principles, represented by the red circles. Our analysis has identified subjects which present ideal opportunities for incorporating CDIO skills. This demonstrates a keen understanding of both the CDIO framework and the Mechatronics and Robotics curriculum. We've highlighted the interrelationships between subjects within the curriculum, a valuable contribution. (Cheah, S.M., Integrating CDIO Skills in a Core Chemical Engineering Module: A Case Study) Understanding how subjects connect is crucial for holistic learning. By showcasing these connections, we emphasize the program's ability to provide students with a comprehensive understanding of Mechatronics and Robotics. This mapping exercise serves as a valuable tool for faculty in developing and refining pedagogical approaches to effectively integrate CDIO principles into coursework. By identifying areas of strong CDIO integration, we can build upon existing strengths, while also utilizing the gaps identified to introduce further CDIO elements in other subjects. A curriculum that intentionally integrates CDIO skills equips students with a valuable skillset. They will graduate with the ability to conceive, design, implement, and operate mechatronic and robotic systems – a crucial skillset in today's engineering landscape. Our proactive approach to curriculum mapping for CDIO integration highlights a commitment to providing students with the best possible education in Mechatronics and Robotics. This work has the potential to serve as a valuable resource for faculty and improve the overall effectiveness of the program.

Sem 1F	Sem 2S	Sem 3F	Sem 4S	Sem 5F	Sem 6S	Sem 7F	Sem 8S
Biology and bionics for engineers	Biology and bionics for engineers	Computer programming	Japanese for profession	Computer programming	Artificial Intelligence	Digital economy	Smart material's technology
English for profession	English for profession	English for profession	English for profession	Electrotechnics and electronics	Applied programming	Contemporary Turkmen society	Basics of chemical technology
Japanese for profession	Japanese for profession	Japanese for profession	Computer programming	Communication techniques	Energy safety and "green engineering"	Data mining	Basics of nanotechnology
Law principle of Turkmenistan	Chemistry for engineers	Theory of functions of a complex variable	Life safety	Theoretical Innovatics	Theory of economics	Image recognition	Contemporary Turkmen society
Contemporary computer technologies	Contemporary computer technologies	Ecology and environmental protection	Digital electronics	Material science and photonics	Robotics	Digital signal processing	SFIT
Mathematical analysis and differential equations	Engineering an computer graphics	Control system techniques	Physical education	Measurement techniques	Numerical methods	Fundamentals of Biotechnology	Work on graduation thesis
Linear algebra and analytic geometry	SFIT	SFIT	SFIT	SFIT	SFIT	SFIT	
Physical education	Physical education	Electricity and magnetism	Control system techniques	Political science	Metrology, standardizatio and certification	Work on graduation thesis	
Mechanics	Engineering pedagogy	Digital electronics	Electrotechnics and electronics		Professional practice		
Chemistry for engineers	Theoretical mechanics and strength of materials	Physical education	Philosophy				
	Mathematical analysis and differential equations	Law principle of Turkmenistan	Fundamentals of mechatronics				

Subjects which can include CDIO skills (related with major)

Arrow that shows interrelationship between subjects

Figure 2. Mapping of curriculum of Mechatronics and Robotics major

The integration of CDIO principles into the mechatronics and robotics program is a strategic process that involves aligning the existing curriculum with the core tenets of the CDIO framework. This integration goes beyond a superficial overlay; it necessitates a fundamental shift in pedagogy and educational philosophy. (Crawley, E.F., Malmqvist, J., Ostlund, S. and Brodeur, D.R.,RethinkingEngineering Education)

Continuous feedback loops and regular reflection sessions should be implemented to allow students to learn from both successes and failures. Additionally, faculty development programs may be necessary to equip instructors with the skills needed to effectively implement CDIO principles.

Development of Specialized Educational Modules and Courses

To further enhance the integration of CDIO skills, the development of specialized educational modules and courses becomes essential. These modules can address specific aspects of the CDIO framework, providing in-depth exploration and hands-on experiences.

Consider developing modules that focus on interdisciplinary collaboration, effective communication, and project management—key components of CDIO. These modules can be designed as standalone courses or integrated into existing ones, ensuring a seamless progression through the educational journey. (Bruun, E. and Kjærgaard, C., A Model for The Development of a CDIO Based Curriculum in Electrical Engineering)

Collaboration with industry partners for these specialized modules can offer students exposure to real-world challenges and foster connections between academia and industry. Industry-relevant projects, guest lectures, and internships can complement the theoretical aspects of the program, enriching students' understanding and application ofCDIO skills.

Table 3.a. Relation between anticipated learning outcomes of Mechatronics and Robotics major and skills of CDIO Syllabus

Learning outcomes	Skills
Elementary scientific learning outcome	1.1. Core Engineering Fundamental Knowledge
	1.2. Advanced Engineering Fundamental Knowledge
Enterpreunership/sustainibility learning outcome	4.2. Enterprise and business context
	4.8. Enterpreunership
Communication learning outcome	3.2. Communications
	3.3. Communications in foreign languages
Research learning outcome	4.3. Conceiving, systems engineering and management
	4.4. Designing
	4.5. Implementing
	4.6. Operating
Engineering learning outcome	2.1. Analytical reasoning and problem solving
	2.3. System thinking
Sustainable development learning outcome	2.5. Ethics, equity and other responsibilities

In conclusion, the successful integration of CDIO skills into the mechatronics androbotics educational program requires a thoughtful and strategic approach. By conducting a thorough analysis, aligning with CDIO principles, and developing specialized modules, educational institutions can create a transformative learning experience that produces graduates equipped with the multifaceted skills demanded by the dynamic field of mechatronics and robotics.

Table 3 represents the analysis of curriculum of mechatronics and robotics major. It shows the subjects that can include the defined learning outcomes. The table we've created for our CDIO paper goes beyond a simple listing of subjects. By assigning a distinct color to each of the six learning outcomes and then applying those colors to relevant subjects, we've developed a visually compelling and informative tool. This color-coding system allows for quick identification of which subjects address specific learning outcomes.

Table 3.b. Analysis of learning outcomes of the courses

1	Contemporary computer technologies	Mathematical analysis and differential equations	Mechanics	Chemistry for engineering	Linear algebra and analytic geometry	English for profession	Japanese for profession	Other modules	Scientific fundamentals of innovative technologies
2	Biology and bionics for engineering	Contemporary computer technologies	Engineering and computer graphics	Mathematical analysis and differential	Theoretical mechanics and strength of materials	Chemistry for engineering	English for profession	Japanese for profession	Scientific fundamentals of innovative technologies
3	Computer programming	Theory of a complex variable	Digital electronics	Ecology and environmental protection	Electricity and magnetism	Control system techniques	English for profession	Japanese for profession	Scientific fundamentals of innovative technologies
4	Computer programming	Digital electronics	Fundamentals of mechatronics	Control system techniques	Electrotechnics and electronics	Life safety	English for profession	Japanese for profession	Scientific fundamentals of innovative technologies
5	Theoretical Innovatics	Computer programming	Material science and photonics	Communication techniques	Electrotechnics and electronics	Measurement techniques			Scientific fundamentals of innovative technologies
6	Theory of economics	Energy safety and 'green engineering'	Applied programming	Robotics	Artificial intelligence	Numerical methods	Metrology, standardiza tion and certification		Scientific fundamentals of innovative technologies
7	Digital economy	Image recognition	Digital signal processing	Fundamentals of biotechnology	Data mining				Scientific fundamentals of innovative technologies
8	Smart material's technology	Basics of chemical technology	Basics of nanotechnology	Work on graduation thesis					Scientific fundamentals of innovative technologies

Our analysis doesn't stop at learning outcomes. By further associating each learning outcome with specific CDIO skills, we demonstrate a clear understanding of how our curriculum integrates with the CDIO framework. This color-coded representation offers several advantages. It simplifies the complex task of curriculum analysis by providing a clear visual representation of how subjects contribute to achieving specific learning goals. Faculty can readily see which subjects align with particular learning outcomes and CDIO skills.

This analysis can be a valuable tool for our future curriculum development efforts. By identifying areas where certain learning outcomes or CDIO skills may not be well-represented by existing subjects, opportunities for curriculum refinement can be identified. Additionally, the color-coding system can be used when developing new courses or learning activities to ensure alignment with established learning outcomes and CDIO principles. (Sale, D. and Cheah, S.M., Writing Clear Customized Learning Outcomes with Key Underpinning Knowledge)

CONCLUSION: TRANSFORMING MECHATRONICS AND ROBOTICS EDUCATION WITH CDIO INTEGRATION

The integration of CDIO skills into mechatronics and robotics education represents a transformative journey, enriching the learning experience and producing graduatesready to tackle the complexities of the modern engineering landscape. As we reflect on the key facets explored in this article, it becomes evident that CDIO's principles bring a paradigm shift to educational practices, ensuring a comprehensive and relevant preparation for future engineers.

The advantages of implementing CDIO skills are multifaceted and impactful. Education quality in mechatronics and robotics is enhanced, producing graduates who not only possess technical expertise but also critical skills for success. Teamwork and communication skills are refined through interdisciplinary collaboration, reflecting the collaborative nature of the industry. Strengthened connections with industry stakeholders ensure that educational programs remain relevant and meet the evolving needs of the labor market. (Malmqvist, J., Hugo, R. and Kjellberg, M., A Survey of CDIO Implementation Globally – Effects on Educational Quality)

In conclusion, the integration of CDIO skills into mechatronics and robotics education emerges as a catalyst for innovation and excellence. By embracing the principles of the CDIO program, educational institutions empower students to not only navigate the intricacies of technology but also to thrive in collaborative, dynamic environments. This transformative approach ensures that graduates are not merely recipients of knowledge but architects of solutions, poised to shape the future of mechatronics and robotics. As the educational landscape evolves, the integration of CDIO skills stands as a beacon, guiding the next generation of engineers towards success and leadership in the ever- evolving fields of mechatronics and robotics.

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BIOGRAPHICAL INFORMATION

Gurbanmyrat Mezilov is the rector of Oguz Han Engineering and Technology University of Turkmenistan. He has the academic degree of Doctor of technical sciences. He served as the President of the Academy of Sciences of Turkmenistan from 2010 to 2016. From 2016 he has been working as the rector of Oguz Han Engineering and Technology University of Turkmenistan since its opening.

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