The Design and Implementation of a Results-Based Curriculum in Higher Education in Mongolia

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Abstract

Mongolia aims to develop a system for training highly skilled professionals and specialists to meet the demands of both domestic and international labor markets by implementing results-based education standards and methodologies. To address challenges in engineering education, the adoption of CDIO (Conceive-Design-Implement-Operate) standards is necessary for curriculum improvement and content reform. This study examines the globally recognized CDIO framework as an advanced and effective approach in modern engineering education, analyzing its fundamental principles and the challenges faced by educators in developing a results-based curriculum tailored to Mongolia's unique needs and cultural context.

A systematic review of the theoretical foundations, methodological approaches, and primary objectives of CDIO-based programs is crucial for effectively implementing outcome-based education. As part of this research, CDIO syllabus-based learning activities were integrated into undergraduate programs, adapting the 12 standards of the CDIO framework (Version 2.0) to the Mongolian education system. An external evaluation was conducted on 445 programs across 55 universities in Mongolia, and a content analysis was conducted by comparing program criteria with results. The effectiveness of the result-based CDIO model in engineering education was assessed to determine whether it achieved its intended objectives and contributed to meaningful progress. In the context of Mongolia, where the labor market is evolving rapidly, particularly in engineering, mining, Information Technology, and renewable energy sectors, the CDIO model is highly practical. By integrating project-based learning, interdisciplinary collaboration, and real-world applications into the curriculum, CDIO supports the development of transferable skills such as design thinking, systems integration, and iterative prototyping. These capabilities are increasingly critical in responding to employer expectations for graduates who are not only technically proficient but also adaptable and innovation-oriented. This analysis provides valuable insights for future improvements in Mongolia's engineering education system.

Keywords: CDIO, curriculum, engineering education, result-based education

1. Introduction

Mongolia's higher education development policy is designed to accelerate economic development, enhance human and social well-being, and promote educational equality (State Education Policy, Mongolia's Sustainable Development Vision-2030). The National Program for Results-Based Education (Resolution № 52, 2018) was approved, which is intended to develop a framework for training highly qualified specialists that meet the needs of the domestic and foreign labor markets by introducing standards and methodologies for results-based education (Øien, 2021). These standards emphasize the development of industry-relevant competencies, such as problem-solving, critical thinking, and adaptability; alignment of learning outcomes with occupational standards. When formulating educational policies, it is crucial to consider a country's history, traditions, customs, lifestyle, and socio-economic and cultural development. Additionally, the development needs and potential of its citizens, the nation's current and future status, as well as global trends, must be taken into account (Chu. Baigalmaa, 2021). In Science, Technology, Engineering, and Mathematics (STEM), this translates into the development of technical proficiency; strong problem-solving and design capabilities; effective teamwork and communication skills; a commitment to ethical and professional responsibility; proficiency in using modern engineering tools and technologies; an awareness of the global and societal impacts of engineering solutions; and a mindset oriented toward lifelong learning in a rapidly evolving technological landscape.

The CDIO approach, initially introduced by the Massachusetts Institute of Technology in 2000 in collaboration with three Swedish universities under the leadership of Professor Edward Crawley, is now implemented in over 200 leading universities worldwide. This framework integrates theoretical and practical components, fostering essential engineering competencies such as teamwork, professional ethics, and the ability to assess external influences. These skill-building tasks are a valuable part of engineering education and continue to benefit students even after graduation (Spingmeni, a graduate of the Massachusetts Institute of Technology).

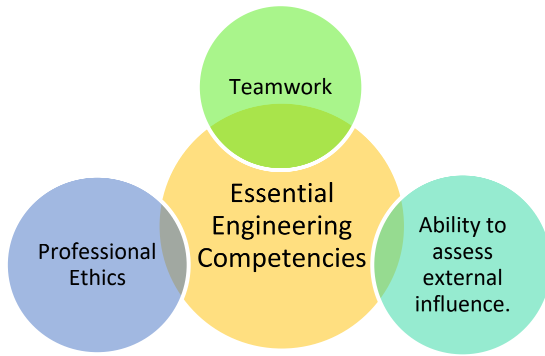

Figure 1. Engineering Competencies

The CDIO methodology provides a structured system focused on learning outcomes (Initiative, 2013). It ensures alignment with accreditation standards while offering a comprehensive approach to engineering education reform (Crawley, 2014). The successful implementation of CDIO-based programs demonstrates the potential to tailor engineering education models to national contexts, producing graduates with the necessary polytechnic skills, specific learning outcomes, and competence for professional success.

Foreign countries primarily adopt the theory and concept of outcome-based education (OBE), which centers on human-centered learning principles and evaluates learning outcomes based on the knowledge, skills, and attitudes students acquire. The OBE framework has been integrated into the education systems of several countries, including Australia (1990), the United States, South Africa (1994), Canada, Taiwan, India, Japan, South Korea, Singapore, Turkey, the United Kingdom (2005), Malaysia, Vietnam, and Hong Kong (2008).

In the 1980s and 1990s, a new approach to engineering education emerged in the United States, emphasizing the relationship between technology, society, and industry. In contrast, engineering schools in Europe, particularly in Germany and France, had a strong foundation in engineering science but were limited in their practical application and experimentation with technical innovations. Since the 1990s, however, engineering schools have increasingly received funding from industry and business for research and development. This shift has led to a greater focus on product design, development, innovation, and engineering problem-solving, creating a demand for enhanced skills such as design, problem-solving, and project-based learning in the curriculum.

The concept of outcomes-based education outlines learning outcomes at various levels, as defined in the countries mentioned above. These outcomes are as follows:

<u>Vision and Mission:</u> Defined in terms of the long-term policy and strategic direction of the higher education institution in the field of education.

<u>Program Educational Objectives (PEOs):</u> Defined by the level of knowledge, skills, and attitudes that graduates of the program are expected to possess.

<u>Program Learning Outcomes (PLOs):</u> Defined in terms of the knowledge, skills, and attitudes students will acquire throughout the entire duration of the program.

<u>Course Learning Outcomes (CLOs):</u> Defined by the knowledge, skills, and attitudes that students are expected to gain in each specific course within the program.

Topic/Chapter Learning Outcomes (TLOs): Defined in terms of the knowledge, skills, and attitudes students acquire from individual chapters or topics within a course.

This framework allows for a detailed understanding of the results-based education system, its structure, and the relationships and coherence between these various levels of learning outcomes.

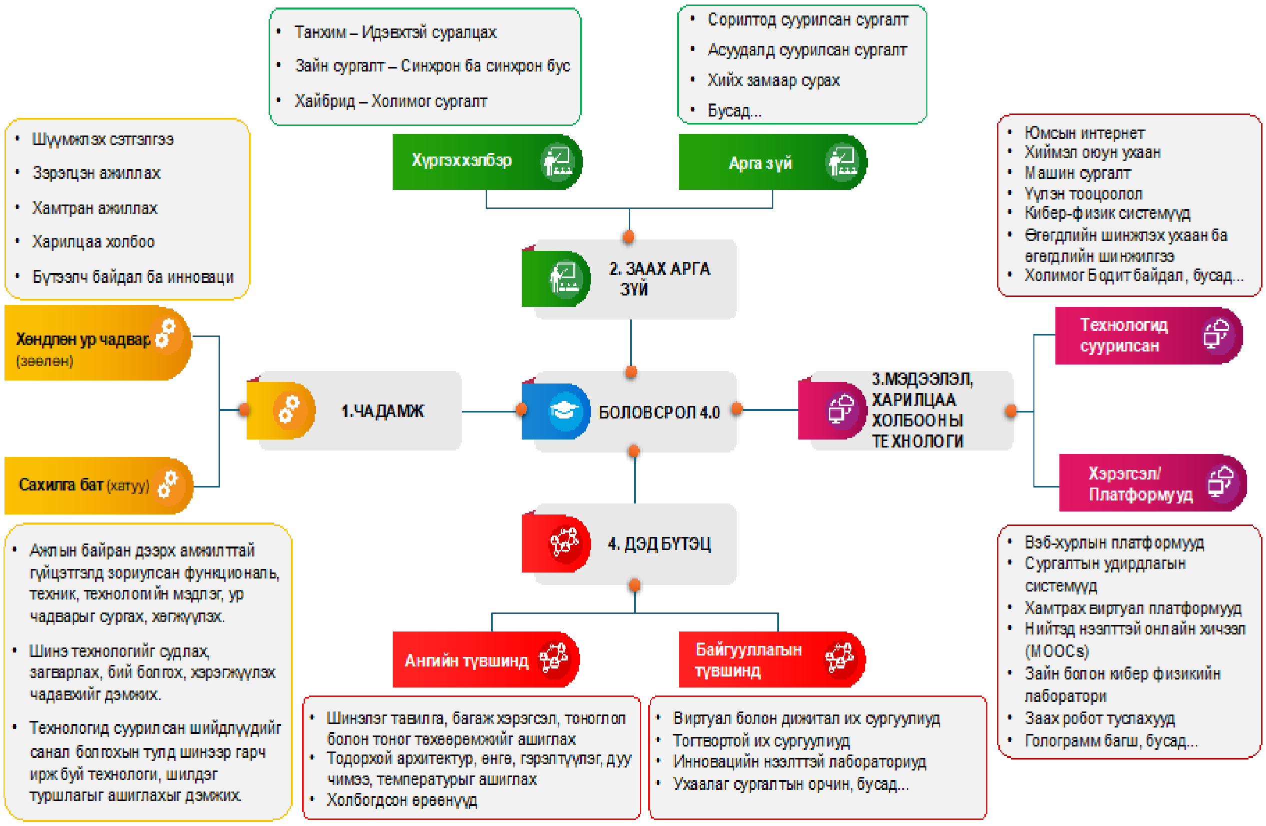

Figure 2. Output of CDIO program

Many countries recognize the advantages of integrating engineering design models into the development of CDIO programs. As illustrated in Figure 2, the CDIO methodology ensures that learning assessments are closely aligned with intended outcomes. The assessment process consists of four key stages: (1) defining clear learning objectives, (2) aligning assessment strategies with the curriculum, learning outcomes, and instructional methods, (3) employing diverse assessment techniques to effectively measure student achievement, and (4) utilizing assessment data to enhance teaching practices and learning experiences.

The CDIO programs offer several advantages in engineering education. First, it provides a practical, hands-on learning environment that bridges the gap between theoretical knowledge and real-world application. It enhances students' problem-solving abilities, teamwork, communication, and project management skills—competencies that are highly valued by employers. The CDIO framework also aligns well with outcome-based education (OBE) models and accreditation standards, such as those of ABET, by focusing on clearly defined learning outcomes and continuous improvement. However, the CDIO approach also presents certain challenges. Implementing the full CDIO cycle can be resource-intensive, requiring significant investment in laboratory infrastructure, industry partnerships, and faculty training. Additionally, it may be difficult to apply uniformly across all disciplines or institutions, particularly those with limited resources. Despite these challenges, when adapted effectively, CDIO can significantly enhance the quality and relevance of engineering education.

Since the 1990s, amidst broad social, economic, and political reforms, Mongolia's higher education sector has been guided by the strategic goal of aligning its system with international standards. Recognizing education as a key driver of national development, the Ministry of Education, Science, and Technology prioritized higher education reform. In this effort, the Ministry of Higher Education and Science implemented the Higher Education Reform

Strategy (2012–2019, later extended to 2020), aimed at improving the employability and global competitiveness of university graduates.

The strategy led to notable improvements in the quality and relevance of academic programs, strengthened institutional governance, financial management, and increased access to higher education. Guided by national and global policy frameworks—namely the Global Sustainable Development Agenda 2030 and Mongolia's Sustainable Development Vision 2030—the Government of Mongolia introduced and finalized key legislative reforms.

On July 7, 2023, the Law on Higher Education was officially approved by the State Great Khural. The revised law includes progressive provisions, such as the establishment of Program Committees with clearly defined roles and responsibilities. These committees are required to include representatives from employers, professional associations, civil society organizations, and alumni, thereby promoting greater stakeholder involvement in aligning academic programs with labor market needs and enhancing the overall quality of education.

The overarching policy vision for higher education by 2030 is to ensure that all students gain competencies related to sustainable development, including sustainable lifestyles, human rights, gender equality, global citizenship, peace, and cultural diversity. Through education, graduates are expected to actively contribute to building a more just, inclusive, and sustainable society.

2. Research Methodology

The analysis of students' program selection reveals that 127 students (50.8%) chose their program based on personal interest, which is a positive indication of student motivation and alignment with career goals. Meanwhile, 67 students (26.8%) reported choosing their program due to others' advice, 34 students (13.6%) cited influence from family business connections, 18 students (7.2%) selected their program for its relevance to the family business, and 4 students (1.6%) stated they had no other option. While the high percentage of interest-based choices is encouraging, the proportion of students who selected programs due to external influence or lack of alternatives may impact program engagement and learning outcomes.

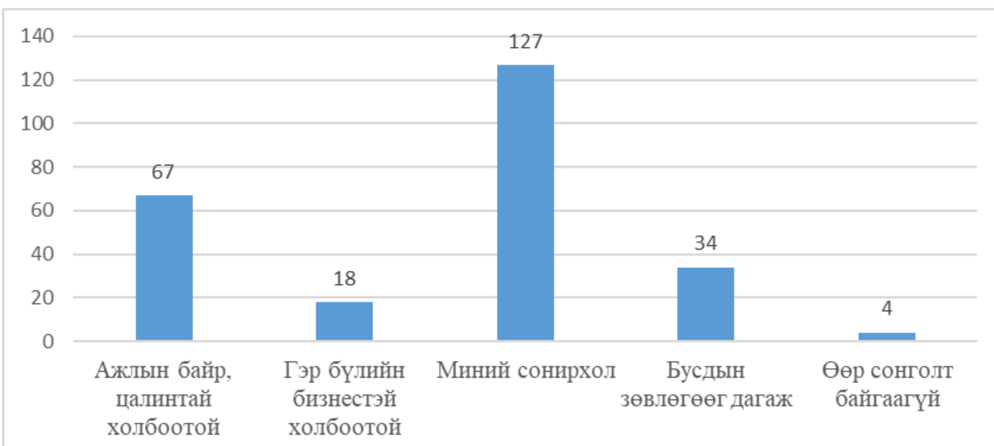

Figure 3. Program selection of students

According to the satisfaction survey, teacher knowledge and skills received the highest satisfaction rating, with 80.4% of students expressing satisfaction. However, the learning environment and assessment system were rated lowest, with only 61% of students satisfied in these areas. Additionally, 10% of students identified aspects of the program they considered insufficient. These results highlight the need for targeted improvements in the learning environment and the evaluation system to enhance overall educational quality.

To assess the effectiveness of the CDIO curriculum, this study developed and implemented CDIO-based programs using the internationally recognized Version 2.0 of CDIO standards, which was updated and refined from Version 1.0 framework (2000s), with key improvements on innovation and entrepreneurship within the curriculum, adaptation of CDIP standards, and enhanced focus on sustainability, ethics and glodabl perspectives. It provides a structured set of guidelines for implementing the CDIO framework, which woul help institutions benhcmark and evaluate progress more systematically. The framework emphasizes clearly defined learning outcomes that align with the skills needed in engineering practice. The CDIO-integrated curriculum encourages students to think holistically about systems, considering all aspects from conception to operation. The 12 CDIO standards provide detailed guidance on various aspects of implementation, including curriculum design, learning experiences, and assessment methods.

The questionnaire was evaluated for both reliability and validity in alignment with CDIO standards. Internal consistency was assessed using Cronbach's Alpha, with a threshold of $\alpha \geq 0.7$ considered acceptable for reliability (DeVellis, R. F., 2016). To determine content validity, the questionnaire was reviewed to ensure it adequately reflected the 12 CDIO standards and corresponding learning outcomes. Criterion-related validity was assessed by comparing the results from the CDIO-based questionnaire with those from other established assessment systems, including employer and graduate evaluations. The methodology was guided by established research frameworks and literature, including Hair et al. (2019) for multivariate data analysis and Crawley et al. (2014) for the theoretical foundations of the CDIO approach.

CDIO Standards (Version 2.0)

	Standard	Description
1	The Context	Adoption of the CDIO approach as the context for engineering education, recognizing that engineering graduates should be able to conceive, design, implement, and operate complex systems in a modern, team-based environment.
2	Learning Outcomes	Clearly defined learning outcomes based on the CDIO Syllabus, which includes technical knowledge, personal and professional skills, interpersonal skills, and system-building skills.
3	Integrated Curriculum	A curriculum that integrates personal, interpersonal, and system-building skills with disciplinary knowledge, providing a coherent learning experience across courses.
4	Introduction to Engineering	An introductory course that sets the engineering context and motivates students early in the program by exposing them to engineering processes and practices.
5	Design-Implement Experiences	Opportunities throughout the curriculum for students to conceive, design, implement, and operate products, processes, and systems.
6	Engineering Workspaces	Modern, creative, and hands-on workspaces that support design-implement experiences, innovation, and active learning.
7	Integrated Learning Experiences	Learning experiences that simultaneously develop disciplinary knowledge and CDIO skills through active and experiential learning methods.
8	Active Learning	Teaching methods that engage students directly in their own learning process, promoting deeper understanding through activities like problem-solving, discussion, and reflection.
9	Enhancement of Faculty Competence	Faculty development in both technical knowledge and pedagogical skills, especially those required to teach personal, interpersonal, and system-building skills.
10	Enhancement of Faculty Teaching Competence	Faculty are trained and supported in adopting active and experiential learning strategies aligned with CDIO principles.
11	Learning Assessment	Assessment of student learning in both disciplinary and CDIO-specific outcomes (e.g., teamwork, design thinking), using a variety of methods that provide feedback and guide improvement.
12	Program Evaluation	A system of continuous program evaluation and improvement, ensuring that the CDIO implementation remains effective, relevant, and aligned with educational goals and industry needs.

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The study addresses two primary research questions:

1. How effectively is the CDIO curriculum being implemented in Mongolia?
2. What are the measurable results of its application?

The Ministry of Education of Mongolia (Resolution A/405, 2019) conducted an external evaluation of 445 programs in 55 universities, comparing program evaluation criteria with actual performance outcomes.

3. Results

Figure 4. Program evaluation criteria scoring scale

An evaluation system was developed based on the requirements of undergraduate engineering programs. The criteria included:

1. Program introduction
2. Program curriculum
3. Course structure
4. Teaching methodology
5. Learning environment
6. Admission requirements
7. Faculty qualifications
8. Graduate competencies
9. Student assessment
10. Program quality assurance
11. Management information systems
12. Communication and collaboration

Figure 3 presents the weighted evaluation criteria, highlighting Program introduction (1) and Program quality assurance (10) receiving slightly higher weighting. The other criteria also contribute meaningfully to managing and supporting skills competency training, such as Program curriculum (2), Faculty qualifications (7), and Communication and collaboration (12) supporting the development of both technical and soft skills through active learning and practical experiences. In contrast, Course structure (3), Learning environment (5), Admission requirements (6), and Graduate competencies (8) consistently received lower scores across the board.

4. Findings by Evaluation Indicators

Figure 5. The average score among universities on Program Introduction

Indicator 1. *In the program introduction section, the average score among universities was 17.7 points out of 25 (Figure 5),* with a deviation of 7.3 points. The findings indicate that most curricula were developed without clear alignment with institutional vision, mission, or policies, likely due to irregular program committee activities and limited stakeholder involvement.

Indicator 2. Curriculum Structure

The required score for this criterion was 15, while the average score was 13.5, with a deviation of 1.5 points.

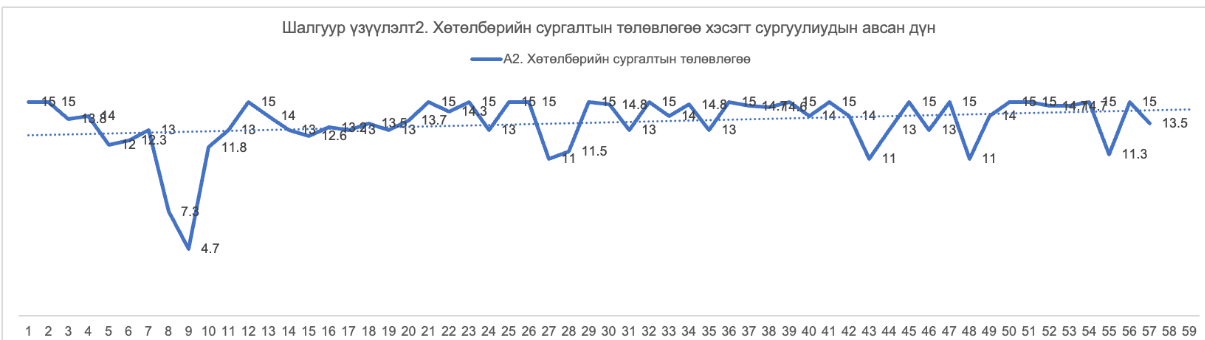

Figure 6. The average score among universities on Curriculum Structure

Indicator 3. Curriculum Development

The average score among universities was 3.9 out of 5, with a deviation of 1.1 points (Figure 6). The results suggest that learning objectives were not consistently well-defined, leading to gaps in course continuity and unclear assessment methods.

It can be concluded that the proportion of hours allocated to professional courses, as reflected in the curriculum, has been reduced.

Figure 7. The average score among universities in Curriculum Development

Indicator 4. *In the Teaching Methodology section*, universities received an average score of 7.8 out of 10, with a deviation of 2.2 points (Figure 7).

Figure 8. The scores among universities in Teaching Methodology

It can be seen that the lack of clarity in teaching strategies and delivery methods was a common shortcoming.

Indicator 5. Learning Environment

The average score of 4.4 out of 5 suggests inadequate learning environments. It indicates insufficient practical training and limited employer engagement in curriculum development.

Figure 9. Scores among universities in Learning Environment section

Indicator 6. Figure 10 shows the results of the admissions and teacher requirements.

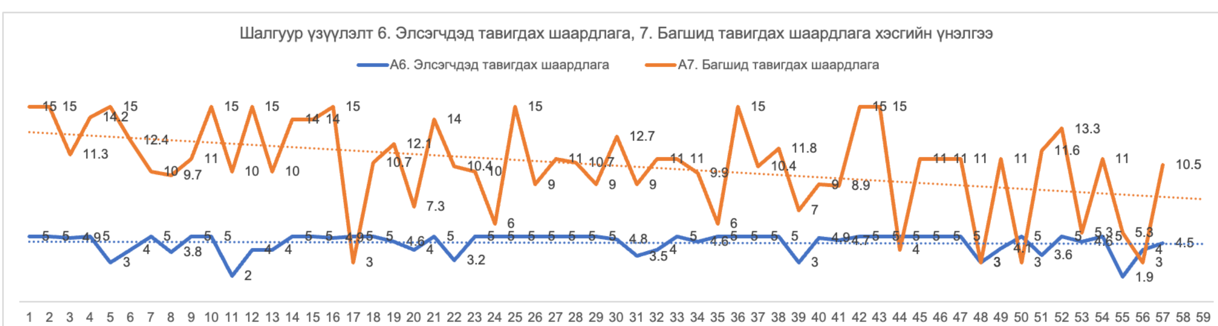

Figure 10. University ratings in the Admissions and Teacher Requirements section

Teacher requirements vary significantly across schools, contributing to a widespread shortage of qualified educators. In many cases, a single teacher is responsible for teaching at 2-3 schools. There is a common shortage of teachers with basic qualifications and academic degrees, and the admission requirements are often inadequate. Additionally, many schools lack proper guidance for students, leading to overcrowded admissions and no research on the effectiveness of a results-based curriculum.

Indicator 8. Graduate Competencies

Universities scored an average of 8.2 out of 10 on graduate competencies, with a deviation of 1.8 points. It indicates common deficiencies in identifying graduates' personal, professional, critical, and analytical skills.

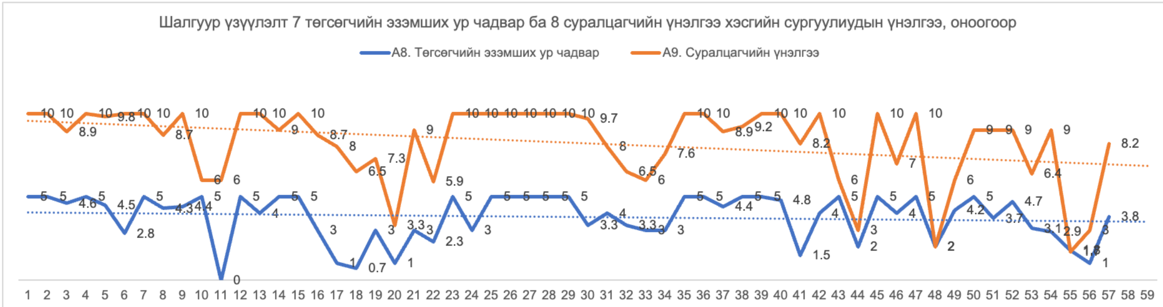

Figure 11. University average scores and results

The blue line represents graduates' competencies and the orange line represents students' evaluation.

The student assessment section received an average score of 3.8 out of 5 (76% satisfaction), indicating a lack of measures to determine the program evaluation methods in line with the learning outcomes and highlighting the need for improved evaluation frameworks.

Indicator 10. Program Quality Assurance

Figure 12. University ratings on Program Quality Assurance

In the quality assurance section, universities scored an average of 20.5 out of 30 (68%), as shown in Figure 11. This indicates inadequacies in quality assurance practices and the need for universities to focus on. Strengthening quality monitoring systems, such as designated personnel and operating rules and principles, and enforcing stakeholder feedback mechanisms, including surveys and feedback of the staff, students and graduates is necessary for continuous improvement.

Indicators 11, 12. Management Information systems, and Communication and Collaboration

Figure 13. Indicators 11, 12. Ratings in the Management Information System, and Communication and Collaboration sections

The blue line represents Management Information Systems and the orange line represents Communication and Collaboration.

Indicator 11, Management Information Systems received a commendable score of 7.8 out of 10 (78%), although further development is needed to apply it as a key tool for internal quality assurance.

Indicator 12, Communication and Collaboration scored 9.9 out of 15 (66% rating), indicating a lack of collaboration and feedback in the higher education sector, especially between academia and industry.

Figure 14. Average scores of universities across the indicators

5. Research Results

Relevant research results support the effectiveness of the CDIO methodology in engineering education, particularly when applied across four key stages: identifying learning outcomes; aligning assessment with curriculum and teaching methods; using diverse assessment tools; and applying assessment results to improve teaching and learning. These principles help ensure that instruction is aligned with desired competencies and that student progress is continuously monitored through formative and summative evaluations. A study analyzing 276 academic programs from 55 higher education institutions used a six-level rubric based on 12 evaluation criteria aligned with CDIO standards.

The findings showed that over 50% of institutions reached Levels IV or V in key areas such as program introduction (72.7%) and curriculum planning (54.5%), indicating strong alignment with outcome-based education principles. However, weaker performance was observed in areas such as teaching methodology, program quality assurance, and communication and collaboration, where over 65% of institutions remained at Level III or below, suggesting a need for further development in these domains.

The analysis also revealed disciplinary distribution, with Engineering, Manufacturing, and Construction programs comprising 17.3% of the total, highlighting the significance of applying CDIO principles in STEM fields. These findings confirm the value of the CDIO framework in guiding curriculum design, assessment practices, and continuous improvement processes in competency-based engineering education.

6. Conclusion

As shown in Figure 13, the overall performance of the evaluated programs was 75% (112.5 out of 150 total points). The blue line is the criteria, and the orange line is the indicators of the universities. The highest-performing areas were Indicator 2. Curriculum Structure (90%) and Indicator 6. Admission Requirements (90%), while the weakest were Indicator 12. Communication and Collaboration (66%) and Quality Assurance (68%).

Since 92% of the universities surveyed in this study are engaged in engineering education based on market principles, research materials from 55 schools were analyzed without distinction by program.

The CDIO framework's "learning-by-doing" approach emphasizes competency-based education, focusing on what competencies the students will require rather than what they will learn. Hence, it requires structured planning for curriculum development and continuous improvement.

7. Recommendations

Based on the study findings, the following recommendations are proposed:

1. When developing a result-based curriculum, align curriculum and syllabus goals and objectives in line with the institutional vision and mission as well as national policies.
2. Benchmark Mongolian curricula against international and domestic best practices and make constant improvements to the program.
3. Define student learning outcomes as competency-based skills and enhance student-centered learning, incorporating individual and interpersonal skills.
4. Provide continuous training for faculty in a structured manner based on needs to prepare teachers for the program and enhance instructional methods.
5. Conduct regular program evaluations to maintain curriculum quality and results, evaluate whether they meet the goals, objectives, and intended outcomes, develop a quality assurance system, and foster a culture of excellence.
6. Engage employees and graduates in competency framework development.
7. Establish an electronic platform and create opportunities for open-access resources.
8. Implement systematic employer and graduate feedback mechanisms and use the results to improve the program.
9. Support faculty in conducting self-assessments and organizing methodological training workshops.

By implementing these recommendations, Mongolia's engineering education can further align with global standards, improving graduate employability and overall educational outcomes.

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