COMPARATIVE ANALYSIS OF PROGRAM LEARNING OUTCOMES: THE CASE OF TECHNOLOGICAL AND POLYTECHNIC COLLEGES IN MONGOLIA

Dulmaa Dagvadash [a], Chantsaldulam Ravdansuren[b] and Nyamsuren Purevsuren* [a]

[a] Mongolian University of Science and Technology, Department of Communications Engineering, Ulaanbaatar 14191, Mongolia
[b]Mongolian University of Life Sciences ,Department of Cybernetic,Ulaanbaatar 17029, Mongolia

Nyamsuren Purevsuren* (nyamsuren@must.edu.mn)

The quality of education in technological and polytechnic colleges plays an important role in ensuring sustainable economic development in Mongolia. The Mongolian higher education system is divided into four types: universities, institutes, colleges, and KOSEN technology colleges. Over the past ten years, the Government of Mongolia has been exploring the possibility of introducing the KOSEN-model engineering program—currently being successfully implemented in Kosen-model Technology Colleges—into Polytechnic Colleges. Colleges of Technology, which provide undergraduate and graduate vocational training, and polytechnic colleges, implement programs based on the concept of Education–Research–Production, to determine the results of the program. This study compared the learning outcomes of the "Mechanical Engineering" program of the Polytechnic and the Japanese KOSEN Model College of Technology, measured by performance-based, criteria-based indicators with the participation of stakeholders, and compared the results. This study included programs from 2 polytechnic colleges and 2 KOSEN-model technology colleges that offer similar mechanical engineering curricula. The research was conducted using structural equation modeling, and the SPSS and SmartPLS software were employed for analysis.

The results revealed that the selected factors have a strong influence on the learning outcomes of the mechanical engineering programs. When comparing the learning outcomes of the two types of colleges included in the study, noticeable differences were found between the polytechnic colleges and the Kosen-model technology colleges.

To further improve the learning outcomes of these programs, it is crucial to clearly define expected learning achievements in measurable terms, assess the outcomes at each stage of the training process, and implement continuous improvement mechanisms. These steps are essential to enhancing the competencies of students enrolled in these programs.

Keywords: *Japanese KOSEN-model Curriculum, Engineering Education, Program Learning Outcomes, Polytechnic College / Technical Education, Mechanical Engineering*

1. Introduction

Due to the rapid pace of technological advancement and the impacts of the Fourth Industrial Revolution (Industry 4.0), the global labor market is facing significant challenges, requiring educational systems to respond more effectively and flexibly (Government of Mongolia, 2020). Education plays a crucial role in meeting the demands of the labor market for engineers and technology professionals. In Mongolia's education system, institutions such as universities, institutes, colleges, Kosen-model technology colleges, and polytechnic colleges are engaged in training human resources in engineering and technical fields. The 'National Regional Development Program 2022–2030', approved by the State Great Khural (Parliament) of Mongolia, includes goals to improve the system of vocational and technical education. Furthermore, the Government's Action Plan for 2024–2028 outlines the objective to introduce a '5-year Kosen-model training program based in colleges' in alignment with the priority development directions of regions and local areas, and to prepare graduates with knowledge and skills recognized by the labor market. For example, during the first semester of the 2022–2023 academic year, a total of 38,034 students were studying in 79 vocational and technical education institutions, including 33 polytechnic colleges and 43 vocational training and production centers, across 187 specialties in 16 sectors. However, according to labor market surveys and employer feedback, 36.3% of workers do not meet the required educational qualifications, 32.2% lack the appropriate skills or specialization, and 22.1% lack sufficient work experience.

While graduates of Technical and Vocational Education and Training (TVET) institutions and polytechnic colleges were somewhat recognized for their practical skills, they were noted to be weak in theoretical knowledge, problem-solving abilities, and professional experience. In addition, after being employed, many were found to lack motivation and professional drive, often failing to stay in the same job for long and showing a tendency to leave their positions easily. Therefore, there is a clear need to reform the system of vocational and technical education and develop curricula based on outcome-based approaches (Ministry of Education and Science, 2022). The unique feature of Japan's KOSEN (high-level, advanced) model Technology Colleges is that their curricula are integrated, with knowledge being delivered through practical applications, validated by experiments, and structured to include industry-specific training and internships. In 2014, three KOSEN-model Technology Colleges were established in Mongolia, and over the past 11 years, they have successfully graduated 673 students. More than 80% of graduates from these colleges are directly employed, with employers highlighting their superior knowledge and skills in the workplace.

In the context of implementing Mongolia's development policies, several critical questions emerge: What should be prioritized in the continued development of polytechnic and Kosen-model colleges? What is the current quality of their respective curricula? How do stakeholders evaluate the learning outcomes of these programs? And which competencies will be increasingly important in the future?

To address these questions, this study aims to assess the learning outcomes of Mechanical Engineering programs offered at technological and polytechnic colleges in Mongolia using a stakeholder-inclusive evaluation approach. In the Mongolian context, few studies have employed participatory methods to evaluate program-level learning outcomes. Therefore, this research offers a novel perspective and contributes to a more comprehensive understanding of the challenges and opportunities in engineering education reform.

A comparative analysis of program learning outcomes refers to the assessment of the extent to which students have attained the intended knowledge, skills, and attitudes (learning outcomes) as outlined in the curriculum. This analysis also involves benchmarking those outcomes against similar programs or past performance data. Engaging key stakeholders—such as employers and graduates—in the evaluation process ensures a more realistic and practice-oriented assessment of learning outcomes. Moreover, their feedback plays a crucial role in identifying gaps, resolving challenges, and ultimately contributing to program improvement and relevance in the labor market.

2. Literature review

In recent years, many researchers have demonstrated the importance of implementing outcome-based education (OBE) in engineering education [1,2]. Since 2014, Mongolia has been applying the CDIO (Conceive–Design–Implement–Operate) framework in its engineering education to support the development of outcome-based programs.

Outcome-Based Education (OBE) is an educational approach that aims to achieve clearly defined learning outcomes by actively involving students in the learning process. It encourages learners to take greater responsibility and make more independent decisions regarding the content and direction of their learning [3].

Vocational and technical education institutions play a critical role in preparing the skilled human resources necessary for implementing development policies and programs, while also contributing to economic growth and the sustainability of employment in a country [4-6].

3. Materials and Methods or Pedagogy

This study used two types of research methods: documentary and questionnaire. First, in the documentary research, the main program planning documents of the two colleges were evaluated according to a total of 9 criteria in accordance with the common requirements issued by the Ministry of Education. Second, a comparative study was conducted on the learning outcomes of the programs. The evaluation of the learning outcomes of the training programs and their current performance was conducted with the participation of stakeholders. The evaluation was conducted in two main stages. These are:

a) Outcome-based performance, documentary evaluation (Content analysis)

b). Stakeholder evaluation: student, alumni, and employer evaluation

Comparative research: Although Polytechnic Colleges and Kosen Technology Colleges are two different types of educational institutions, they both provide training in technical and engineering fields. When comparing these two colleges, first, it is possible to compare them using general statistical indicators. Second, with the help of stakeholders, it is possible to evaluate the quality and effectiveness of the programs they offer in similar specialties.

In examining the current state of Polytechnic and Kosen Technology Colleges, we compared the concepts and forms of their educational systems. These institutions are developing in two different directions within Mongolia's education system.

Polytechnic Colleges focus on providing vocational education and skills in specific fields, with training activities centered around science, engineering, and technology. Kosen Technology Colleges, on the other hand, prepare technical and engineering specialists through a system modeled after Japan's education system [7-9]. This study compares the learning outcomes of the Mechanical Engineering Program offered at both types of institutions. This section presents a comparison of the programs offered by the Polytechnic and the Kosen Model College (see Table 1).

The Mechanical Engineering program at the Polytechnic College aims to quickly equip students with technical skills and practical knowledge, enabling graduates to work as technicians in the domestic industrial sector.

Table1.Differences Between Polytechnic and KOSEN-Model College Programs

Metric	Polytechnic College (Mechanical Engineering)	KOSEN Technology College (Mechanical Engineering)
Age of admission	The entrance age for the Polytechnic College is 15.	The average age of admission at Kosen College is 15.
Program duration	2.5 to 3 years.	5 years.
Educational Characteristics	Provides skills training with a focus on practical experience and hands-on practice.	A five-year program designed to train professionals in engineering and technology.
Focus of Training	Technical Skills, Practical Knowledge	In-depth Engineering Knowledge, Research, Projects
Professional Field	Technician, Engineering Assistant, Equipment	Mechanical Engineer, Technology Manager, Researcher
Curriculum Content	Basic Technical Skills, Mechanical Equipment Repair, Manufacturing Process	Mechanical Systems, Robotics, Automation, Component Modeling
Practical and Project Work	Industrial Internship, Working with Mechanical Equipment	Project Management, In-depth Research, Engineering Projects
Graduation Age	17.5 and 20.	around 20.
Professional Degree	Secondary Education Certificate, Professional Diploma	Associate degree in Engineering
Opportunities for Graduates	Working in the Technical Field, Mid-Level Engineering Roles	Senior-Level Engineering Roles, Research, Development

In contrast, the Mechanical Engineering program at the Kosen Technology College focuses on providing deeper and more specialized engineering knowledge, as well as skills in research, analysis, and working in the global market. Graduates are capable of performing high-level engineering work and have opportunities to work for international companies.

Information about Evaluation Participants: The evaluation was conducted over a one-month period beginning on March 15, 2025, in accordance with the proposed methodology. Details of the participants involved in the evaluation are presented in Table 2.

Table 2. Participants in the Evaluation

Constructs	Type	Frequency	Percent
Age	18-24	3	11.5
	25-34	3	11.5
	35-44	9	34.6
	45<	11	42.3
	total	26	100
Colleges	Construction Poly. College	1	3.8
	MONGOL KOSEN	2	7.7
	MUST-KOSEN	5	19.2
	Polytechnic of MUST	18	69.2
	Total	26	100
Organization type	Public	14	53.8
	Non-government	12	46.2
	Total	26	100
Employee Satisfaction	1-Very Poor	1	3.8
	2-Poor	1	3.8
	3-Average	3	11.5
	4-Good	16	61.5
	5-Excellent	5	19.2
	Total	26	100

The study employed a stratified sampling method targeting three key stakeholder groups involved in mechanical engineering programs: current students, graduates, and employers of graduates. A total of 107 student representatives, 81 graduates, and 26 representatives from employer organizations affiliated with the programs participated in the study.

To evaluate the knowledge, skills, and attitudes acquired by students and graduates—aligned with the intended learning outcomes of the Mechanical Engineering program—data were collected through structured questionnaires. A total of 131 items were administered to current students, 102 items to graduates, and 103 items to employers.

Research Methodology: This study aims to systematically analyze the Program Learning Outcomes (PLOs) of the Mechanical Engineering program, considering international trends, national policies, and differences in educational environments. The research is grounded in several theoretical frameworks, including Outcomes-Based Education (OBE), Comparative Program Evaluation, Bloom's Revised Taxonomy, the CDIO Syllabus 2.0, Japan’s Mechanical Engineering Model Core Curriculum (MCC, 2023), and the graduate competency standards of the Washington Accord [10-12]. The study involves two polytechnic colleges and two technological (Kosen model) colleges in Mongolia that offer mechanical engineering programs. It evaluates and compares the learning outcomes of these programs using both quantitative and qualitative data.

The study employed a mixed-methods approach, incorporating document analysis, a questionnaire survey, and structural equation modeling (PLS-SEM). A stratified purposive sampling method was used to select participants based on the type of educational institution (technological or polytechnic), the level of students (graduate level), and stakeholder role (graduate or employer). The survey included an average of 103 items measured on a 5-point Likert scale. Learning outcomes were categorized and evaluated across three domains: cognitive, affective, and psychomotor.

Descriptive statistics, independent samples t-tests, ANOVA, and correlation analyses were conducted using SPSS version 26.0 to analyze the survey data. Additionally, SmartPLS version 4.0 was utilized to perform Partial Least Squares Structural Equation Modeling (PLS-SEM) in order to assess the influence of knowledge, skills, and attitudes on learning outcomes. The measurement and structural models were evaluated using key indicators such as path coefficients, Composite Reliability (CR), Average Variance Extracted (AVE), and R^2 values.

In accordance with research ethics, informed consent was obtained from all participants, confidentiality was strictly maintained, and the reliability of the questionnaire was verified through a pilot test.

4. Results and Discussion

The evaluation was conducted over a one-month period beginning on March 15, 2025, in accordance with the proposed methodology. A total of 107 students, 81 graduates, and 26 employer representatives from the Mechanical Engineering program in Mongolia participated in the survey. Among the student participants, 93.5% were male and 6.5% female; among graduates, 97.5% were male and 2.5% female; and among employer representatives, 84.6% were male and 15.4% female.

Regarding employer feedback, 80.7% rated their experience and satisfaction with hiring program graduates as “Good” or “Excellent.” Additionally, 53.8% of the employer representatives were affiliated with government agencies. Survey participants assessed the implementation level of the Program Learning Outcomes (PLOs) using a five-point Likert scale, ranging from 1 (Very Poor) to 5 (Very Good).

Evaluation of Program Learning Outcomes

A total of 214 participants took part in the study, with up to 103 questionnaire items rated on a 5-point Likert scale. The average rating given by students was 3.20 (standard deviation = 0.952), slightly higher than the graduates’ average rating of 2.60 (standard deviation = 0.817), and close to the employers’ average rating of 3.30 (standard deviation = 0.850). The highest-rated learning outcomes included engineering problem-solving skills (mean = 4.01), technical drawing processing (3.89), teamwork skills (3.78), and analysis of measurement and experimental results (3.76). These outcomes align closely with the core competencies outlined in prominent international curricula, such as the Mechanical Engineering Model Core Curriculum (MCC, JABEE, 2023), ABET (2022), and CDIO (Crawley et al., 2014).

Conversely, the lowest-rated competencies were professional information processing skills in English (2.71), innovative proposal and design skills (2.93), and systems thinking (3.10), suggesting that current program policies and teaching methodologies may be insufficient to adequately develop these skills.

Comparative Analysis of Program Learning Outcomes in Polytechnic and KOSEN Colleges

A comparative analysis of the average Program Learning Outcomes (PLOs) between the Polytechnic and Technology (KOSEN) colleges revealed that the average score for students at the Polytechnic College was 3.49, whereas students at the Technology College (KOSEN) achieved a higher average score of 3.91. An independent sample t-test indicated that this difference was statistically significant ($p < 0.05$).

These results suggest that the KOSEN model—with its emphasis on a stepwise, hands-on approach and the cultivation of an engineering mindset—is more effective in fostering systems thinking and creativity. Conversely, students from the Polytechnic College demonstrated stronger performance in areas related to technical operations and practical work experience, likely reflecting their training in real equipment and production environments.

Results of Structural Equation Modeling (PLS-SEM)

Structural equation modeling (PLS-SEM) was conducted using SmartPLS software to identify the relationships between key factors influencing learning outcomes.

Table 3. Average of program learning outcomes/1-5/

Stakeholders	Number of participants	Average of program learning outcomes/1-5/		
		Knowledge	skills	attitude
Employer	26	3.53	3.24	3.35
Alumni	81	3.17	2.80	3.47
Student	107	3.48	3.69	3.49
Total	214	3.39	3.24	3.44

The results of the study showed that the program stakeholders rated the PLOs of the Mechanical Engineering program as 3.39 for knowledge, 3.24 for skills, and 3.44 for personal soft skills(see table 3).

Alumni Feedback on the Mechanical Engineering Program

A structural equation model (SEM) was employed to estimate the impact of general engineering knowledge, engineering software usage, graphic design skills, coding, application software usage, and soft skills on the learning outcomes of graduates from the Mechanical Engineering program (see Figure 1).

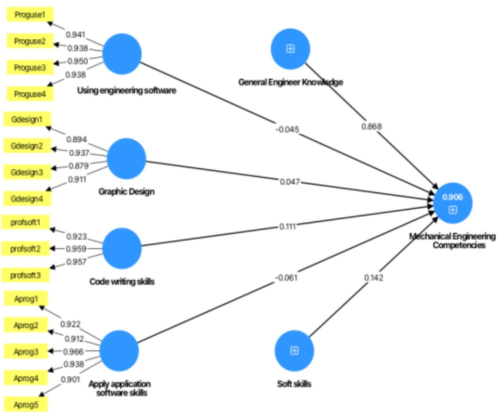

Figure 1. Structural Equation Model (SEM) Path Diagram of Competency Factors Influencing Learning Outcomes in Mechanical Engineering

The metrological evaluation of the measurement instruments used in the study exceeded the recommended thresholds for reliability and validity. Specifically, Cronbach's Alpha values ranged from 0.927 to 0.978, Composite Reliability (rho_a) ranged from 0.927 to 0.988, and the Average Variance Extracted (AVE) ranged between 0.699 and 0.887, confirming acceptable reliability and convergent validity of the constructs (see Table 4).

Table 4. Construct reliability and validity

PLOs	Cronbach's alpha	CR (rho_a)	CR (rho_c)	AVE
Apply application software skills	0.961	0.984	0.969	0.861
Code writing skills	0.942	0.953	0.962	0.895
General Engineer Knowledge	0.978	0.980	0.980	0.699
Graphic Design	0.927	0.927	0.948	0.820
Mechanical Engineering _ Competencies	0.977	0.979	0.979	0.701
Soft skills	0.981	0.988	0.983	0.750
Using engineering software	0.958	0.966	0.969	0.887

Path analysis results revealed that general engineering knowledge ($t = 19.81$, $p < 0.001$), coding skills ($t = 2.43$, $p = 0.032$), and soft skills ($t = 2.90$, $p < 0.001$) had statistically significant positive effects on learning outcomes. In contrast, application software usage, graphic design skills, and proficiency in engineering-specific software did not demonstrate statistically significant impacts. This lack of significance may be due to insufficient instruction in these areas or the possibility that some students had not yet completed relevant coursework.

Student Evaluation Results

A structural model for the evaluation of student program learning outcomes was developed and the factors influencing program outcomes, namely general engineering knowledge, mathematics, natural sciences, humanities, and personal development knowledge and skills, were statistically significantly correlated through regression analysis (Table 5).

Table 5. Regression analysis

Variable	Coefficient	Results
GENG	**0.359**	Positive, strong influence
MATH	**0.246**	Positive, moderate influence
NAT	**0.113**	Positive, weak influence
NUM	**–0.023**	Negative, negligible influence
SOFT	**0.303**	Positive, moderately strong influence

Note: **GENG**- General engineer knowledge; **MATH-Mathematic**; **NAT-** natural science; **NUM**-Humanities; **SOFT**-Soft skills

The results of the analysis confirmed that these factors selected for the study have a strong impact on the learning outcomes of the mechanical engineering program, and the explanatory power (R^2) of the model is 0.775.

Employer Evaluation Results

Based on the evaluations provided by employers, the highest-rated competencies among graduates were "ability to adapt to the workplace" (4.10), "ability to learn independently" (3.95), and "ability to understand and model engineering problems" (3.90). The lowest-rated competencies were "understanding of laws and ethics" (3.02) and "use of English language" (2.76).

These results indicate that certain competencies emphasized in the MCC framework, such as "social understanding" and "communication skills," have not yet been fully developed in the Mongolian educational context. While employers expressed satisfaction with graduates' ability to analyze problems, work in teams, and engage in creative design, they also emphasized the need to improve foreign language skills, particularly for international communication.

Conclusions

This study compared and evaluated the learning outcomes (Program Learning Outcomes – PLOs) of mechanical engineering programs in polytechnic and KOSEN model technical colleges in Mongolia, aligning them with international educational quality standards to determine the implementation and impact of the programs. The research employed a mixed-methods approach, utilizing evaluations from students, graduates, and employers, document analysis, and structural equation modeling (PLS-SEM) to establish the causal relationships affecting learning outcomes in quantitative terms.

Firstly, the results of the study indicate that mechanical engineering programs successfully impart core engineering skills such as problem-solving, technical drawing, measurement and testing, and teamwork. However, higher-level skills such as the use of English, systems thinking, and the ability to propose innovative ideas received lower evaluations. This is linked to factors such as the content of the curriculum, teaching methods, and the level of support from the learning environment.

Secondly, graduates of the Kosen model colleges performed better in terms of learning outcomes compared to students from polytechnic colleges. This indicates that the Kosen program's structured framework and its systematic approach to providing foundational engineering education are more effective. On the other hand, polytechnic colleges have an advantage in their close alignment with industrial environments, focusing on technical utilization and performance through practical training, as confirmed by employers' evaluations.

Thirdly, the results from the structural equation modeling (PLS-SEM) indicated that four key factors—program content alignment, instructor competency, learning environment, and student attitude—significantly influence learning outcomes. Among these, program structure and instructor skills had the highest impact, showing that these factors are crucial for improving the quality of engineering programs.

Fourth, employers rated the graduates' ability to solve engineering problems, learn independently, and adapt to the work environment highly, while skills in ethics, English language, and international communication were rated lower. This highlights the need for engineering education to focus not only on technical skills but also on developing social and communication skills[13].

Fifth, the findings from the research demonstrate the importance of clearly defining learning outcomes, aligning them with the curriculum content and evaluation system, continuously improving the evaluation process, and incorporating feedback from stakeholders to revise programs. Additionally, the Kosen model's structured approach, systematic learning, and real-world practice demonstrate a successful model that can be implemented in Mongolia's educational system.

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