International Journal of Learning, Teaching and Educational Research
Vol. 24, No. 3, pp. 383-406, March 2025
https://doi.org/10.26803/ijlter.24.3.19
Received Oct 21, 2024; Revised Mar 12, 2025; Accepted Mar 17, 2025

Program Learning Outcomes of Students in Bachelor of Science and Engineering Degrees: A Systematic Review

Hung The Do
Hung Yen University of Technology and Education,
Hung Yen, Vietnam

Huong Thi Pham*
School of Foreign Languages, College of Economics, Law and Government
University of Economics, Ho Chi Minh City, Vietnam

Abstract. This study aims to explore the assessment of program-level learning outcomes for students in Bachelor of Science and Engineering programs through a systematic review of 65 documents from ERIC, IEEE Xplore, Scopus, Web of Science, and Google Scholar during the past 14 years. The methodology involves synthesizing and analyzing assessment methods, their effectiveness, and the challenges reported in the studies, with a focus on geographic distribution, program types, study designs, outcome types measured, and alignment with accreditation standards. Key findings reveal that direct methods, such as course-based assessments, and indirect methods, such as surveys, are widely used, while mixed approaches emerge as a comprehensive strategy for evaluating technical skills, soft skills, and professional competencies. The studies primarily originate from Asia and North America, aligning with prominent accreditation frameworks. The review proposes an optimal approach—a flexible, mixed strategy integrating direct and indirect tools, technology (e.g., AI), and stakeholder input—to ensure thorough and feasible program-level learning outcomes assessment, providing a practical solution for universities, educators, and researchers to enhance outcome assessment in Bachelor of Science and Engineering programs.

Keywords: assessment methods; engineering education; outcomes assessment; program outcomes; systematic review

1. Introduction

Over the past few decades, engineering education has evolved significantly, driven by the rapid pace of technological advancement and the growing complexity of global challenges. In response to these shifts, Bachelor of Science

* Corresponding author: *Huong Thi Pham, huongpt.2742@ueh.edu.vn*

and Engineering programs have placed increasing emphasis on preparing graduates who possess not only technical knowledge but also a range of interdisciplinary skills, including problem-solving, communication, teamwork, and leadership (Cruz et al., 2019; Passow & Passow, 2017), global competency, ethical reasoning, and interdisciplinary collaboration (Cruz et al., 2019; Exter et al., 2024). This has accelerated the need for comprehensive assessment methods that capture both technical and soft skills (Hatipkarasulu et al., 2012) to ensure globalization and workforce demands. These competencies are essential for engineers to thrive in today's dynamic workforce, where collaboration across disciplines and adaptability are paramount.

In this context, program-level learning outcomes have emerged as critical indicators of the effectiveness of engineering education (Syeed et al., 2022). These outcomes, which often align with national or international accreditation standards (e.g., ABET in the United States), outline the key knowledge, skills, and attitudes that students are expected to acquire by the time they complete their degrees (Forcael et al., 2022; Hussain et al., 2021). As a result, measuring these outcomes is crucial for ensuring that graduates are adequately prepared for both professional practice and lifelong learning (Ali, 2023). Furthermore, accreditation bodies, such as ABET, have established rigorous criteria for program-level learning outcomes, requiring institutions to demonstrate that their graduates meet specific competencies (Alhakami et al., 2020; Forcael et al., 2022). Understanding how various programs meet these standards and what assessment methods are most effective can help guide both curriculum design and program improvement (Rashideh et al., 2020).

However, despite the clear importance of assessing program-level learning outcomes, there are considerable variations in the methods used across institutions and countries (Hatipkarasulu et al., 2012). Traditional methods, such as standardized tests and course-based assessments, have been widely adopted but are often criticized for their narrow focus on technical skills (Alhakami et al., 2020; Damaj & Yousafzai, 2019). While traditional assessments tend to focus on technical proficiency, employers increasingly emphasize the importance of soft skills, such as teamwork, leadership, and communication (Passow & Passow, 2017; Saulnier, 2017). More comprehensive methods, such as capstone projects and portfolios, aim to capture a broader range of competencies but face challenges related to resource demands and subjectivity (Ammar & Rais, 2023; Luzan et al., 2021). Various assessment practices have led to calls for more evidence-based approaches to determine the most effective methods for evaluating program-level outcomes in engineering education (Alzubaidi & Jabur, 2024; Exter et al., 2024). As educational institutions face increasing pressure to do more with less, there is a need to identify assessment methods that are not only effective but also feasible, practical, and resource efficient (Ammar & Rais, 2023; Luzan et al., 2021). The significance of this systematic review lies in its potential to provide a clearer understanding of how engineering programs assess their learning outcomes and offer evidence-based recommendations for improving these practices. As engineering education continues to evolve in response to emerging societal needs, it is increasingly important for institutions to implement effective and reliable methods for measuring the skills and knowledge that graduates acquire.

The primary objective of this systematic review is to identify and evaluate the assessment methods used to measure program learning outcomes in Bachelor of Science and Engineering degrees. In particular, the study maps the range of assessment methods currently employed across different institutions and regions to measure program learning outcomes, evaluates the effectiveness of these assessment methods, and identifies challenges faced by educators and institutions in assessing both technical and soft skills. It also synthesizes best practices in assessment methods and highlights areas for future research. Therefore, the key research question of this review is "How have program learning outcomes been assessed in Bachelor of Science and Engineering degrees?" This review, therefore, offers a comprehensive and evidence-based overview of how learning outcomes have been currently assessed in engineering education and then identifies opportunities for improvement and innovation in the field.

2. Methods

2.1 Review Protocol

This systematic review was conducted following established guidelines, such as those outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). The protocol was developed to ensure a rigorous and transparent process, encompassing the identification, selection, appraisal, and synthesis of studies related to measuring program-level learning outcomes in Bachelor of Science and Engineering degrees (Higgins & Green, 2011).

2.2 Literature Search

Table 1: Process for Literature Search

Search Strategy	Data-based Searched	Search Term	Search Process
A systematic literature search was conducted to identify relevant studies assessing program-level learning outcomes in Bachelor of Science and Engineering degrees. The search process aimed to be comprehensive and transparent, adhering to established guidelines for systematic reviews (Petticrew & Roberts, 2006)	ERIC IEEE Xplore Scopus Web of Science Google Scholar	"program-level learning outcomes" "Bachelor of Science in Engineering" "assessment methods" "engineering education" "measuring student outcomes" "outcomes-based education"	Initial database search Title and abstract screening Full-text review Additional studies from reference lists

Search Strategy	Data-based Searched	Search Term	Search Process
		"learning assessment" "curriculum evaluation" "engineering competency"	

2.3 Inclusion and Exclusion Criteria
The inclusion and exclusion criteria for this systematic review were developed to ensure that only the most relevant studies addressing program-level learning outcomes in Bachelor of Science and Engineering degrees were considered. The criteria were based on guidelines from established systematic review methodologies (Higgins & Green, 2011; Petticrew & Roberts, 2006).

Table 2: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• **Study Focus**: Studies that assessed program-level learning outcomes in Bachelor of Science and Engineering programs • **Publication Date**: Only studies published between 2010 and 2024 were included to ensure that the review focused on recent and relevant developments in assessment practices • **Peer-Reviewed Sources**: Only articles published in peer-reviewed journals, conference proceedings, or government reports were considered to ensure the inclusion of high-quality research.	• Focused solely on course-level learning outcomes or assessments without addressing the program level. • Were non-peer-reviewed sources, such as opinion pieces, editorials, or dissertations. • Dealt with fields outside of science and engineering, ensuring relevance to the review's scope.

By adhering to these criteria, the final pool of studies ensured a focused examination of program-level learning outcomes in Bachelor of Science and Engineering degrees.

2.4 Results of the Literature Search
The literature search results are detailed in Table 3 and the PRISMA flow diagram (Figure 1), which shows the selection process from identification to inclusion.

Table 3: Literature Search Results

Category	Frequency
Total Records Identified	2,163
Duplicates removed	276
Title and abstract screening	1,887
Full-text review	235
Studies included in the review	58
Additional studies from reference lists	7
Total studies included in the review	65

These 65 studies represent a wide range of geographical locations, types of engineering programs, and assessment methods. The studies varied in scope, from single institution studies to multi-institutional or cross-national analyses, providing a broad understanding of how program-level learning outcomes are being assessed in Bachelor of Science and Engineering degree programs.

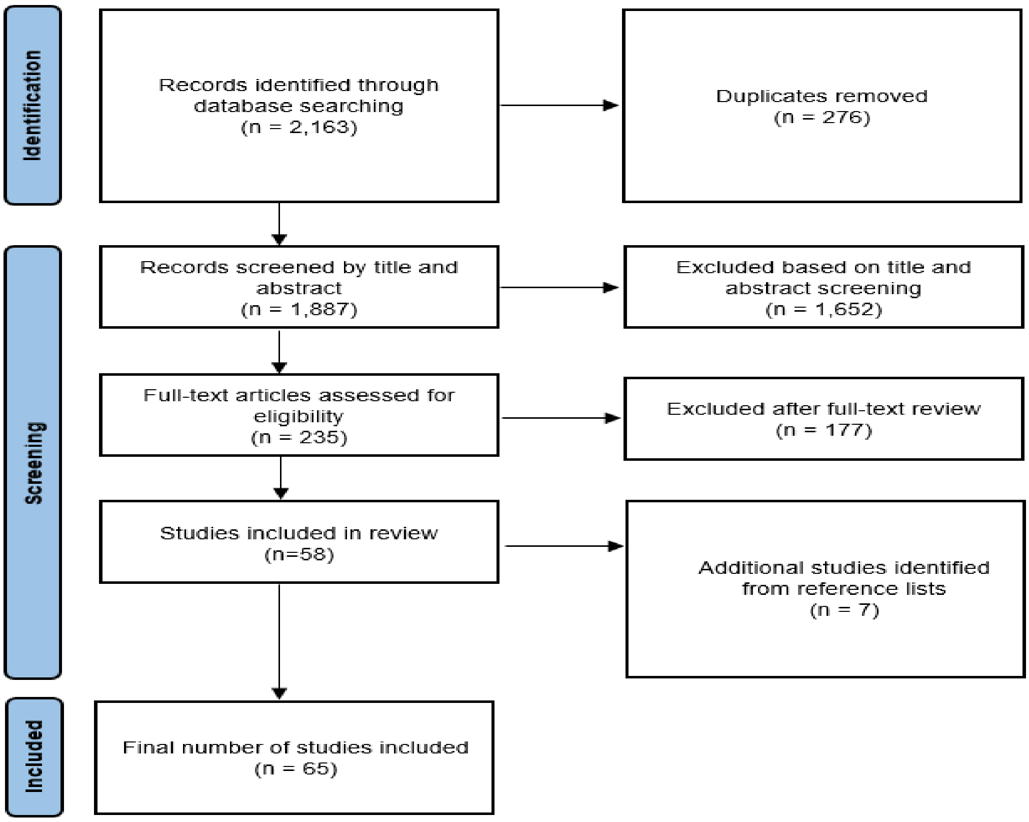

Figure 1: PRISMA Flow Diagram

2.5 Data Extraction

Data extraction was a critical step in ensuring that all relevant information from the selected studies was captured systematically and consistently (Booth et al., 2016). A standardized data extraction form was developed, adapted from previous research in systematic reviews (Arksey & O'Malley, 2005; Briner & Denyer, 2012; Gough et al., 2017; Snyder, 2019). The form included fields to capture key details of each study, including study design: whether the study employed quantitative, qualitative, or mixed-method approaches; sample size and characteristics: information about the participants, such as the number of students, their educational level, and demographic factors; assessment methods: a detailed description of the types of assessment methods used, such as examinations, portfolios, or peer assessments; learning outcomes: the specific program-level learning outcomes that were measured, such as critical thinking, problem-solving skills, or teamwork; findings: key results and conclusions drawn from each study, particularly regarding the effectiveness of different assessment methods; and quality indicators: information on the validity and reliability of the assessment tools used in the study.

Two independent reviewers completed the data extraction process for each study to minimize the risk of bias. Any disagreements between the reviewers were resolved through discussion or, if necessary, consultation with a third reviewer. This process ensured that all relevant data were captured and consistently recorded.

2.6 Quality Assessment

Quality assessment is an essential component of systematic reviews to ensure that the findings are based on high-quality evidence (Gough et al., 2012; Petticrew & Roberts, 2006). For this review, the quality of each study was assessed using a modified version of the Critical Appraisal Skills Programme (CASP) checklist, which evaluates research based on criteria such as methodological rigour, validity, and generalizability (Briner & Denyer, 2012; CASP, 2018). The criteria for assessing the quality of studies included study design, sample size, data validity and reliability, bias and confounding variables, and relevance to the research question (Arksey & O'Malley, 2005; Gough et al., 2012; Gough et al., 2017; Higgins & Green, 2011; Petticrew & Roberts, 2006). Finally, studies that directly addressed the research question of program-level assessment of learning outcomes in Bachelor of Science and Engineering programs were considered of higher relevance and quality.

2.7 Data Analysis

The reviewed studies were analyzed using qualitative and quantitative techniques. Studies were categorized based on their geographic distribution, enabling an analysis of regional variations in assessment methodologies. For quantitative analysis, a descriptive statistical approach was employed to determine the frequency and distribution of different assessment methods to count the number of studies using different methods of assessment. This allowed for an evaluation of the most and least commonly used assessment strategies. The effectiveness of various assessment methods was assessed by examining reported success rates, faculty and student feedback, and alignment with accreditation requirements such as ABET, Washington Accord, National Board of Accreditation, PEC, and East African Community frameworks. To identify challenges, best practices, and areas for future development, content analysis was used.

3. Results

3.1 General Description of the Studies

The 65 studies included in this systematic review were characterized based on several key factors: geographic distribution, types of engineering programs examined, study designs, assessment methods, and alignment with accreditation standards. The characteristics of these studies provide a comprehensive overview of the current state of research on program-level learning outcomes in Bachelor of Science and Engineering programs (Table 4).

Table 4: General description of the 65 studies included in the review

Category	Number of Studies (n=65)
Geographic Distribution (Region)	
North and South America	16 (24.6%)
Asia and Middle East	49 (75.4%)
Types of Engineering Programs	
General Engineering	18 (27.7%) [Studies not specifying a discipline or covering multiple fields]
Electrical and Electronics Engineering	13 (20.0%) [Studies including Electrical, Electronics, Medical Equipment Technology]
Civil Engineering	9 (13.8%)
Mechanical Engineering	5 (7.7%)
Computer Science/Software Engineering	8 (12.3%) [Studies including Computer Engineering, Information Systems]
Construction Engineering	3 (4.6%)
Food Engineering	1 (1.5%)
Materials Engineering	1 (1.5%)
Electromechanical Engineering	1 (1.5%)
Multiple Disciplines	6 (9.2%) [Studies covering more than one specific discipline]
Study Design	
Quantitative	35 (53.8%) [Studies using numerical data, surveys with scores, or statistical analysis]
Qualitative	8 (12.3%) [Studies relying on descriptive analysis, focus groups, or narrative data]

Category	Number of Studies (n=65)
Mixed Methods	22 (33.8%) [Studies combining quantitative and qualitative approaches]
Outcome Measured	**(Studies may measure multiple outcome types)**
Technical Skills	54 (83.1%) [e.g., design, problem-solving, technical knowledge, practical skills]
Soft Skills	34 (52.3%) [e.g., communication, teamwork, ethics, lifelong learning]
Professional Competencies	25 (38.5%) [e.g., professional ethics, project management, sustainability]
Alignment with Accreditation Standards	
ABET-Aligned Studies	25 (38.5%) [Explicitly mentioning ABET standards]
Other Accreditation Standards	23 (35.4%) [e.g., NBA (India): 8, Washington Accord: 6, PEC (Pakistan): 3, EAC Malaysia: 4, Others: 2]
No Specific Accreditation Mentioned	17 (26.2%) [Studies not explicitly tied to a specific standard]

The geographic distribution of the reviewed studies reveals a predominant focus on Asia, which accounts for 49 studies (75.4%), with significant contributions from India (18 studies), Malaysia (10 studies), Pakistan (6 studies), and Saudi Arabia (7 studies), alongside smaller representations from Indonesia (2 studies), Bangladesh, UAE, Kuwait, Bahrain, and Iraq (one study from each country). North and South America contributed 16 studies (24.6%), primarily from the United States (13 studies) and Mexico (2 studies), with one multi-country study spanning India, Mexico, and the USA (Mahrishi et al., 2023). No studies originate from Europe, Australia, or Africa, indicating a geographic bias toward Asian and North American contexts. This distribution aligns with the emphasis on engineering education reforms in rapidly developing economies and established accreditation systems such as ABET in the USA. For instance, Agrawal et al. (2021) and Balasubramani and Chiplunkar (2017) highlight India's focus on NBA accreditation, while Battistini and Kitch (2021) and Kalaani and Haddad (2014) reflect ABET-driven assessments in the USA. The absence of European and Australian studies suggests a potential gap in the global representation of outcome-based education (OBE) practices in engineering.

The systematic review encompasses a diverse range of engineering programs, with 18 studies (27.7%) classified under General Engineering, reflecting broad OBE frameworks not tied to specific disciplines (e.g., Premalatha, 2019; Syeed et al., 2022). Electrical and Electronics Engineering is the most represented specific discipline, with 13 studies (20.0%), including works on electrical engineering (e.g., El-Kady et al., 2014; Hashim & Hashim, 2010) and medical equipment technology (Waly, 2020). Civil Engineering follows with nine studies (13.8%), as seen in Basri et al. (2011) and Davis et al. (2017), while Computer Science/Software Engineering accounts for eight studies (12.3%). Mechanical Engineering is addressed in five studies (7.7%) (e.g., Hasan et al., 2024; Sundararajan, 2014), and Construction Engineering in three studies (4.6%) (e.g., Hatipkarasulu et al., 2012). Single-study disciplines include Food Engineering (Altamirano et al., 2013), Materials Engineering (Hinojosa-Rivera et al., 2015), and Electromechanical Engineering (Nandy, 2022), each at 1.5%. Additionally, six studies (9.2%) focus on multiple disciplines (e.g., Mahrishi et al., 2023). This distribution underscores a focus on foundational engineering fields, with General Engineering studies often serving as theoretical or methodological anchors for OBE implementation.

The study designs employed in the 65 studies demonstrate a preference for quantitative approaches, with 35 studies (53.8%) using numerical data, statistical analysis, or structured assessments such as CO-PO (course outcomes-program outcomes) mapping and survey scores. Examples include Agrawal et al. (2021), who use quantitative CO-PO mapping for NBA accreditation, and Alzubaidi and Jabur (2024), which leverages an ANN model achieving 99.298% accuracy in student outcomes assessment. Mixed methods are adopted in 22 studies (33.8%), combining quantitative tools (e.g., examinations, rubrics) with qualitative insights (e.g., surveys, faculty feedback), as seen in the studies of Battistini and Kitch (2021) and Rajak et al. (2019), which integrate direct and indirect assessments for comprehensive evaluation. Qualitative designs, less common, appear in eight studies (12.3%), relying on descriptive analysis or focus groups, such as that of Nurjannah et al. (2022), which uses focus group discussions to map CO-PLO-PEO (course outcomes-program learning outcomes-program educational objectives) relationships. The predominance of quantitative methods reflects the need for measurable outcomes in accreditation processes, though the significant use of mixed methods suggests an evolving recognition of the value of qualitative insights in capturing nuanced educational impacts.

The outcomes measured across the 65 studies predominantly emphasize technical skills, with 54 studies (83.1%) focusing on abilities such as design, problem-solving, and practical application of engineering knowledge. For instance, Lavanya and Murthy (2022) assess technical design (PO3) attainment, while Naqvi et al. (2019) highlight project-based assessments enhancing practical skills. Soft skills are evaluated in 34 studies (52.3%), encompassing communication, teamwork, ethics, and lifelong learning, often aligned with ABET SOs or POs such as PO8 and PO12 (e.g., Balasubramani & Chiplunkar, 2017; Mynderse, 2022). Professional competencies, measured in 25 studies (38.5%), include professional ethics, project management, and sustainability, as evidenced by those of Mohd Noor et al. (2024) emphasizing PO8 (ethics) and Zain et al. (2012) addressing environmental sustainability. The high prevalence of technical skills aligns with engineering education's core objectives, while the substantial focus on soft skills and professional competencies reflects growing accreditation demands for holistic graduate preparedness, though many studies note challenges in fully assessing softer attributes such as lifelong learning (e.g., Alyahya & El-Nasr, 2012).

Alignment with accreditation standards is a key feature of the 65 studies, with 25 studies (38.5%) explicitly tied to ABET standards, reflecting its prominence in North American and Middle Eastern contexts (e.g., Battistini & Kitch, 2021; Shafi et al., 2019). Other accreditation standards are addressed in 23 studies (35.4%), including India's NBA (8 studies, e.g., Agrawal et al., 2021), the Washington Accord (6 studies, e.g., Kamran et al., 2020), Pakistan's PEC (3 studies, e.g., Bhatti et al., 2023), Malaysia's EAC (4 studies, e.g., Gamboa et al., 2013), and other frameworks (2 studies). Seventeen studies (26.2%) do not specify an accreditation standard, focusing instead on general OBE methodologies (e.g., Premalatha, 2019; Syeed et al., 2022). The ABET-aligned studies often emphasize student outcomes and continuous improvement (e.g., Rashideh et al., 2020), while the NBA and Washington Accord studies prioritize CO-PO mapping and graduate employability (e.g., Jadhav et al., 2022). This distribution highlights the global influence of accreditation bodies in shaping OBE assessments, though a significant portion of non-aligned studies suggests flexibility in applying OBE principles beyond formal standards.

3.2 Effectiveness of Different Methods to Evaluate Program-level Learning Outcomes

The studies included in this systematic review employ various methods to evaluate program-level learning outcomes in Bachelor of Science and Engineering degrees. These methods were broadly categorized into direct, indirect, and mixed methods assessments, as summarized below (Table 5):

Table 5: Assessment Methods for Measuring Program Learning Outcomes

Assessment Method	Number of Studies	Percentage
Direct Assessment Methods	*Total Studies: 65*	
Standardized Tests	11	16.9%
Course-Based Assessments	40	61.5%
Capstone Projects	8	12.3%
Portfolios	5	7.7%
Rubric-Based Evaluations	14	21.5%
Indirect Assessment Methods	*Total Studies: 65*	
Surveys and Self-Reports	34	52.3%
Employer Feedback	11	16.9%
Alumni Feedback	12	18.5%
Faculty Evaluations	8	12.3%
Mixed Assessment Approaches	**Total Studies: 65**	
Combined Direct & Indirect Methods	30	46.2%
AI-Based Assessment Techniques	3	4.6%
Comprehensive Frameworks	12	18.5%

Direct assessment methods, employed to evaluate program-level learning outcomes, are prominently featured across the 65 studies, with course-based assessments leading at 40 studies (61.5%), followed by rubric-based evaluations in 14 studies (21.5%), standardized tests in 11 studies (16.9%), capstone projects in eight studies (12.3%), and portfolios in five studies (7.7%). Course-based assessments, such as examinations, assignments, and laboratory projects, are widely utilized to measure technical skills and align with accreditation standards such as ABET and NBA. For example, Agrawal et al. (2021) apply course-based assessments within a CO-PO mapping framework to determine students' achievement levels at SGGS Institute of Engineering and Technology, India, noting lower attainment in ethics (PO8) and lifelong learning (PO12). Similarly, Lavanya and Murthy (2022) use examinations and projects at GRIET, Hyderabad, to identify deficiencies in technical design (PO3) that necessitate curriculum enhancements. Rubric-based evaluations provide structured assessment, as seen in the study of Battistini and Kitch (2021), where rubrics assess ABET Student Outcomes 1–7 at Angelo State University, achieving successful accreditation. Standardized tests, such as the exit examination in the study of El-Kady et al. (2014), offer reliable measurement of PLOs in electrical engineering at a Saudi Arabian institution, though practical skills remain under-assessed. Capstone projects, highlighted in the work of Sala and Riddell (2012), enhance direct assessment of POs in the AAS-ET program at Baker College, while portfolios, as in the study of Manteufel and Karimi (2016), ensure consistency across multiple courses at a U.S. institution through a course portfolio approach. These methods collectively emphasize measurable, performance-based evaluation, though limitations include their focus on academic settings rather than real-world application.

Indirect assessment methods, which capture perceptions and reflections rather than direct performance, are extensively used, with surveys and self-reports dominating at 34 studies (52.3%), followed by alumni feedback in 12 studies (18.5%), employer feedback in 11 studies (16.9%), and faculty evaluations in eight studies (12.3%). Surveys and self-reports, often from students, provide insights into soft skills and program effectiveness, as demonstrated in the work of Bhatia and Singh (2017), where automated surveys at an Indian institution evaluate POs/COs, though subjectivity and low participation rates pose challenges. Alumni feedback, utilized in Basri et al. (2011), assesses PEOs and POs in civil engineering at Universiti Kebangsaan Malaysia, revealing high ratings (3-5/5) but a need for improved English skills, limited by the absence of direct measures. Employer feedback, as in the study by Hensel and Robinson (2014), evaluates SLOs at a U.S. institution, identifying strengths in teamwork and ethics but weaknesses in technical knowledge, with subjectivity as a noted limitation. Faculty evaluations, such as those in the work of Zain et al. (2012), assess environmental and sustainability outcomes in civil engineering at UKM, Malaysia, but require significant effort and lack standardization across courses. These indirect methods complement direct assessments by offering stakeholder perspectives, yet their reliance on subjective data often necessitates integration with direct measures for a comprehensive evaluation, as highlighted by Ghaly (2020), whose surveys at Imam Mohammad ibn Saud Islamic University show attainment above minimum levels but lack validation through direct assessment.

Mixed assessment approaches, blending direct and indirect methods or innovative techniques, are employed in 30 studies (46.2%) using combined direct and indirect methods, 12 studies (18.5%) with comprehensive frameworks, and three studies (4.6%) incorporating AI-based techniques, reflecting a trend toward holistic and technology-enhanced evaluation. Combined direct and indirect methods, seen in the work of Rajak et al. (2019), integrate examinations and projects with student and employer surveys at KIET Group of Institutions, India, demonstrating slight PO improvements across cohorts, though limited to a single institution and lacking work-based assessment. Similarly, Altamirano et al. (2013) combine graduation theses (direct) with surveys (indirect) at Universidad de las Américas Puebla, Mexico, revealing discrepancies between faculty, student, and employer evaluations of Food Engineering POs. Comprehensive frameworks, such as in Rashideh et al.'s study (2020), develop a continuous improvement process for ABET accreditation of an Information Systems program at IMSIU, Saudi Arabia, enhancing SO and PEO measurement, though not yet extended beyond one university. Awad and Almhosen (2023) propose a five-year framework at Ahlia University, Bahrain, achieving ABET accreditation for BSIT through mixed methods, limited by its single institution scope. AI-based techniques, exemplified by Alzubaidi and Jabur (2024), automate SO assessment with a 99.298% accurate ANN model in the UAE, though restricted to engineering disciplines, while Mishra and Singh (2024) integrate AI in the SPLAM-OBE model in India, requiring significant pedagogical shifts. These mixed approaches enhance assessment robustness but face challenges in scalability, faculty training, and integration with traditional systems, as noted by Bhatti et al. (2023), where Q-OBE software in Pakistan supports accreditation but lacks employer validation.

In addition, this review has evaluated, structured, and analyzed the effectiveness of different assessment methods, summarizing their descriptions, strengths, and limitations, as shown below (Table 6).

Table 6: Summary of Assessment Methods

Assessment Method	Description	Strengths	Limitations
Standardized Tests	Use of exams (e.g., exit exams, FE exams) to measure PLOs or SOs (e.g., El-Kady et al., 2014).	Reliable, quantifiable data; aligns with accreditation standards.	Limited to academic skills, high development cost, poor scalability across disciplines.
Course-Based Assessments	Exams, assignments, and projects within courses to assess COs/POs (e.g., Agrawal et al., 2021).	Widely applicable, leverages existing structures, and measures technical skills effectively.	Time-intensive for faculty may miss soft skills, scalability depends on course consistency.
Capstone Projects	Final projects integrating skills	Assesses practical application, and	Resource-heavy (supervision,

Assessment Method	Description	Strengths	Limitations
	for SO/PO assessment (e.g., Sala & Riddell, 2012).	holistic outcome measurement.	evaluation); limited scalability to large cohorts.
Portfolios	Collection of student work for longitudinal SLO/PO assessment (e.g., Manteufel & Karimi, 2016).	Tracks progress over time and ensures consistency across courses.	Requires significant documentation effort, scalability limited by faculty training needs.
Rubric-Based Evaluations	Structured scoring for SO/PO assessment (e.g., Battistini & Kitch, 2021).	Objective, repeatable; enhances clarity in evaluation.	Initial rubric design is resource-intensive; effectiveness depends on faculty alignment.
Surveys and Self-Reports	Student/alumni surveys for PO/SO perceptions (e.g., Bhatia & Singh, 2017).	Scalable with automation; captures soft skills and perceptions.	Subjective; low response rates; unreliable for direct attainment measurement.
Employer Feedback	Employer evaluations of graduate skills (e.g., Hensel & Robinson, 2014).	Reflects workplace relevance and assesses PEOs effectively.	Subjective, logistically challenging; limited scalability due to data collection issues.
Alumni Feedback	Graduate surveys for PEO/PO evaluation (e.g., Basri et al., 2011).	Long-term outcome insights; moderate scalability via surveys.	Dependent on participation; lacks direct performance data; variable reliability.
Faculty Evaluations	Faculty judgments on outcomes (e.g., Zain et al., 2012).	Expert insight; flexible application.	Inconsistent across assessors; time-intensive; poor scalability without standardization.
Combined Direct & Indirect	Integration of direct (exams) and indirect (surveys) methods (e.g., Rajak et al., 2019).	Comprehensive; measures technical and soft skills; supports accreditation.	High resource demands (coordination, analysis) and scalability limited

Assessment Method	Description	Strengths	Limitations
			to well-resourced settings.
AI-Based Assessment	AI tools (e.g., ANN) for automated SO assessment (e.g., Alzubaidi & Jabur, 2024).	High accuracy; scalable via automation; reduces manual effort.	Discipline-specific; high initial costs; requires technical expertise for implementation.
Comprehensive Frameworks	Structured systems for continuous improvement (e.g., Rashideh et al.., 2020).	Aligns with accreditation; robust outcome measurement, and supports long-term improvement.	Resource-intensive (training, commitment); limited scalability beyond single institutions.

The evaluation of assessment methods for measuring student learning outcomes in undergraduate engineering training programs, as derived from the analysis of 65 studies, reveals a multifaceted landscape where effectiveness and appropriateness hinge on the balance between accuracy in outcome measurement and practical feasibility. Direct assessment methods, such as course-based assessments (e.g., Agrawal et al., 2021) and rubric-based evaluations (e.g., Battistini & Kitch, 2021), demonstrate high effectiveness in quantifying technical skills and aligning with accreditation standards like ABET and NBA, offering reliable, evidence-based data critical for engineering education's focus on competency. However, their resource-intensive nature—requiring significant faculty effort and institutional infrastructure—limits their practicality, particularly for large-scale implementation across diverse programs.

Indirect methods, such as surveys (e.g., Bhatia & Singh, 2017) and employer feedback (e.g., Hensel & Robinson, 2014), excel in capturing soft skills and long-term outcomes such as employability, enhancing appropriateness for holistic graduate development, yet their subjective nature and logistical challenges compromise validity and practicality. Mixed approaches, notably combined direct and indirect methods (e.g., Rajak et al., 2019) and AI-based techniques (e.g., Alzubaidi & Jabur, 2024), offer a promising synthesis, effectively addressing both technical and professional competencies with potential feasibility through automation; however, their appropriateness is tempered by high initial resource demands and context-specific applicability. Comprehensive frameworks (e.g., Rashideh et al., 2020) align closely with accreditation goals, providing robust, continuous improvement, but their practicality is constrained by institutional commitment requirements.

The most effective and appropriate method for assessing student learning outcomes in engineering education is a tailored, mixed approach that integrates direct, indirect, and technology-driven assessments to balance technical rigour with broader insights, as evidenced by the comprehensive evaluation capabilities of combined methods (Rajak et al., 2019). While standardized tests (e.g., El-Kady et al., 2014) and coursework-based evaluations (e.g., Agrawal et al., 2021) remain crucial for measuring technical competency with reliable, quantifiable data aligned with accreditation standards such as ABET and NBA, capstone projects (e.g., Sala & Riddell, 2012), faculty assessments (e.g., Zain et al., 2012), and employer feedback (e.g., Hensel & Robinson, 2014) offer a more holistic perspective on students' practical skills and professional readiness by capturing applied knowledge and workplace relevance. Leveraging AI-enhanced solutions (e.g., Alzubaidi & Jabur, 2024) and competency-based frameworks (e.g., Rashideh et al., 2020) alongside traditional assessment methods can optimize scalability, adaptability, and alignment with industry demands, with AI achieving high accuracy (99.298%) and frameworks supporting continuous improvement for accreditation. However, for these approaches to be successfully implemented, institutions must strategically plan and invest in faculty training to mitigate resource constraints, as noted in the significant time and effort required for rubric development and AI integration (Battistini & Kitch, 2021; Mishra & Singh, 2024). Moving forward, an integrated assessment strategy will be key to developing scalable, adaptive, and industry-relevant engineering education programs that prepare graduates for both technical challenges and evolving workforce expectations, building on the strengths of mixed methods to address diverse outcomes (Awad & Almhosen, 2023).

3.3 Identified Challenges

The systematic review of 65 studies reveals several persistent challenges in assessing program-level learning outcomes (PLOs) in Bachelor of Science and Engineering programs, spanning methodological, resource-related, and contextual domains. A primary challenge is the inconsistency and subjectivity inherent in indirect assessment methods, such as surveys and self-reports, which dominate in 34 studies (52.3%). For instance, Bhatia and Singh (2017) note low participation rates and subjective feedback as limitations that undermine the reliability of measuring actual student attainment, a concern echoed by Ghaly (2020), whose indirect surveys alone fail to capture comprehensive PLOs. Direct methods, while prevalent (e.g., course-based assessments in 40 studies, 61.5%), face scalability issues owing to resource demands, with Agrawal et al. (2021) highlighting the significant faculty time required for CO-PO mapping and Sala and Riddell (2012) pointing to the supervision burden of capstone projects. The geographic concentration in Asia (47 studies, 72.3%) and North America (16 studies, 24.6%) introduces a bias, as noted by the absence of European or African perspectives, potentially limiting generalizability (Mahrishi et al., 2023). Additionally, assessing soft skills such as lifelong learning and ethics remains problematic, with Alyahya and El-Nasr (2012) and Balasubramani and Chiplunkar (2017) reporting lower attainment levels and difficulties in concrete measurement due to their abstract nature. Technology-driven approaches, such as AI-based assessments (Alzubaidi & Jabur, 2024), while promising, are challenged by high initial costs and discipline-specific applicability, restricting broader adoption. Finally, faculty training and institutional commitment pose significant hurdles, with Battistini and Kitch (2021) and Mishra and Singh (2024) emphasizing the time-intensive nature of aligning faculty with new assessment systems, a barrier compounded in resource-constrained settings such as Pakistan (Bhatti et al., 2023).

3.4 Best Practices

The review identifies several best practices for effectively assessing PLOs in engineering education, integrating direct, indirect, and mixed approaches to optimize outcome measurement and practicality. A tailored, mixed assessment strategy emerges as a gold standard, with 30 studies (46.2%) demonstrating its efficacy in balancing technical rigour and broader insights (Rajak et al., 2019). For example, Altamirano et al. (2013) successfully combine graduation theses with surveys to assess Food Engineering POs, revealing strengths in technical skills and communication awareness, while Rajak et al. (2019) use examinations and employer surveys to track PO improvements, supporting accreditation goals. Direct methods such as rubric-based evaluations (Battistini & Kitch, 2021) and course-based assessments (Agrawal et al., 2021) are best practices for technical competency, providing structured, repeatable data aligned with ABET and NBA standards, with rubrics enhancing objectivity across 14 studies (21.5%). Incorporating capstone projects, as in Sala and Riddell (2012), fosters practical skill integration, a practice effective in eight studies (12.3%) for holistic SO assessment. Indirect methods, particularly automated surveys (Bhatia & Singh, 2017), offer scalable insights into soft skills and are adopted in 34 studies (52.3%), while employer feedback (Hensel & Robinson, 2014) ensures industry relevance in 11 studies (16.9%). Technology-driven solutions, such as AI-based assessments achieving 99.298% accuracy (Alzubaidi & Jabur, 2024), and comprehensive frameworks (Rashideh et al., 2020) exemplify best practices for scalability and continuous improvement, with the latter supporting ABET accreditation in 12 studies (18.5%). Strategic faculty training and resource planning, as emphasized by Awad and Almhosen (2023), underpin these practices, ensuring successful implementation over five years at Ahlia University.

3.5 Future Research Areas

The systematic review highlights several future research areas to advance the assessment of PLOs in engineering education, addressing gaps in methodology, geographic representation, and technological integration. First, improving the measurement of soft skills such as lifelong learning and ethics, which show lower attainment in studies such as those of Alyahya and El-Nasr (2012) and Balasubramani and Chiplunkar (2017), warrants investigation into novel direct assessment tools beyond surveys, potentially integrating work-based assessments absent in current studies (Rajak et al., 2019). Second, expanding geographic diversity beyond Asia and North America—where 63 of 65 studies are concentrated (Mahrishi et al., 2023)—requires comparative analyses with Europe, Australia, and Africa to enhance global applicability. Third, the scalability and cost-effectiveness of AI-based assessments, currently limited to three studies, merit further exploration across non-engineering disciplines and resource-constrained settings (Bhatti et al., 2023). Fourth, longitudinal studies tracking graduate outcomes, absent in most current research (e.g., Tshai et al., 2014), could validate PLOs' real-world impact, building on alumni feedback practices (Basri et al., 2011). Fifth, optimizing resource demands through standardized, low-cost frameworks beyond the single institution focus of Rashideh et al. (2020) could enhance practicality and scalability, addressing faculty training barriers noted by Battistini and Kitch (2021). Finally, integrating industry-driven competency models with academic assessments, as partially explored by Hensel and Robinson (2014), could align PLOs more closely with evolving workforce needs, a gap in current accreditation-focused studies (Awad & Almhosen, 2023).

4. Discussion

This systematic review of 65 studies elucidates the assessment landscape for PLOs in Bachelor of Science and Engineering programs, highlighting a predominant reliance on direct methods such as course-based assessments (40 studies, 61.5%)—often involving examinations, projects, and CO-PO mapping—and indirect methods such as surveys (34 studies, 52.3%), typically student self-reports or exit surveys. Mixed approaches, notably combined direct-indirect methods (30 studies, 46.2%), emerge as a significant trend, integrating quantitative tools (e.g., rubric-scored projects) with qualitative feedback (e.g., focus groups), as seen in the studies by Rajak et al. (2019) and Altamirano et al. (2013). Technical skills dominate outcome measurement (54 studies, 83.1%), with soft skills (34 studies, 52.3%) and professional competencies (25 studies, 38.5%) gaining traction, supported by accreditation alignment—ABET in 25 studies (38.5%) and NBA in eight studies within the 23 other-standard studies (35.4%). Geographically, Asia (47 studies, 72.3%) and North America (16 studies, 24.6%) lead, with India (18 studies) and the USA (13 studies) as key contributors. The geographic concentration in Asia and North America suggests that program outcome assessment is popular in the USA as it is the home of ABET. Asian countries, in their efforts to improve education quality, often follow the U.S. model to strengthen their educational systems and facilitate international cooperation through accreditation mechanisms. Asian countries may also use accreditation as a means to demonstrate their quality and enhance their global reputation. Another possibility is that universities in Europe and Australia tend to be more focused on graduate employability than on the assessment of learning outcomes (Clarke, 2017). Methodological nuances include rubric use (14 studies, 21.5%), AI-driven automation (3 studies, 4.6%) such as ANN models, and comprehensive frameworks (12 studies, 18.5%) for continuous improvement (Ali, 2024; Rashideh et al., 2020). Challenges such as resource allocation and soft skill assessment difficulties are evident across studies, which are also aligned with another review (Mistamiruddin & Nasri, 2024).

The heavy use of course-based assessments, often mapped to COs and POs via statistical tools or attainment thresholds (Agrawal et al., 2021; Lavanya & Murthy, 2022), reflects a methodological preference for quantifiable, accreditation-aligned data, suggesting engineering education prioritizes technical rigour over subjective attributes. Surveys, frequently automated or supplemented with Likert scales (Bhatia & Singh, 2017; Sloan & Frank, 2023), indicate an attempt to capture soft skills like communication and ethics, yet their prevalence underscores a reliance on perception over performance, potentially inflating attainment scores. The rise of mixed methods, integrating direct tools (e.g., examinations, capstone projects) with indirect feedback (e.g., employer surveys, focus groups) as in Rajak et al.

(2019) and Nurjannah et al. (2022), translates as a strategic response to accreditation demands for holistic assessment, balancing precision with stakeholder input. The limited but impactful use of AI (Alzubaidi & Jabur, 2024) and frameworks (Rashideh et al., 2020)—employing ANN models or multi-year cycles—signals an innovative shift toward automation and systemic evaluation, though their methodological complexity suggests early adoption stages. Geographic concentration in Asia and North America (Mahrishi et al., 2023) implies that OBE methodologies are shaped by regional accreditation pressures (e.g., NBA, ABET), with gaps in soft skill measurement (e.g., PO8, PO12) persisting owing to abstract constructs and inadequate direct tools (Alyahya & El-Nasr, 2012; Balasubramani & Chiplunkar, 2017).

These findings reinforce the efficacy of mixed assessment strategies, extending prior work by demonstrating their ability to address both technical and soft skill outcomes, a refinement over singular-method studies such as that of Hensel and Robinson (2014). The methodological detail—e.g., rubric-based scoring (Battistini & Kitch, 2021) and AI precision (Alzubaidi & Jabur, 2024)—offers practical blueprints for institutions to enhance objectivity and scalability, contributing to OBE literature by bridging traditional and technology-driven approaches. The regional skew (Mahrishi et al., 2023) implies a need for context-specific adaptations, enriching global OBE discourse beyond the Asian–North American focus of previous reviews. The emphasis on faculty training and resource planning (Awad & Almhosen, 2023; Mishra & Singh, 2024) provides actionable insights for accreditation compliance, while the integration of industry feedback (Basri et al., 2011; Hensel & Robinson, 2014) aligns PLOs with workforce needs, advancing prior calls for relevance (Tshai et al., 2014). Theoretically, this review contributes a nuanced understanding of method interplay—e.g., how rubrics complement surveys—offering a framework for optimizing PLO assessment that balances rigour, practicality, and adaptability, potentially influencing curriculum design and policy in engineering education.

Despite these insights, the review has limitations. The review's scope does not investigate the longitudinal impacts of PLOs on graduate employability, a gap noted by Raihan and Azad (2023) and Tshai et al. (2014). To address these, future research should incorporate multi-regional data, while longitudinal studies could validate long-term effectiveness. The review highlights best practices in assessing program learning outcomes in engineering education, emphasizing a mixed assessment strategy. The review demonstrates the effectiveness of capstone projects for holistic skill assessment, while technology-driven solutions, such as AI-based assessments and comprehensive frameworks, enhance feasibility and accreditation alignment. Faculty training and resource planning play a crucial role in ensuring successful implementations over time. Future research should explore these best practices across diverse educational contexts, integrating technologies and faculty development for outcomes assessment.

5. Conclusion

This systematic review explored the assessment of program learning outcomes for students with Bachelor of Science and Engineering degrees, drawing on 65 studies from the past 14 years to examine the methods, effectiveness, and challenges in evaluating technical and professional competencies. The analysis shows a strong dependence on direct methods like course-based assessments and indirect methods such as surveys, with mixed approaches gaining traction in 46.2% of cases as a way to balance precision with broader insights. Technical skills are the primary focus, measured in 83.1% of studies, though soft skills and professional competencies, assessed in 52.3% and 38.5% of studies, respectively, are increasingly emphasized, often tied to accreditation frameworks prevalent in Asia (72.3%) and North America (24.6%). Innovations such as AI-based assessments and comprehensive frameworks point to a future of scalable, technology-enhanced evaluation. These findings are significant because they highlight the value of integrated methods in meeting both academic and industry needs, offering a practical guide for improving outcome assessment. The review emphasizes the importance of tailored, mixed strategies that incorporate technology and stakeholder perspectives to ensure a well-rounded evaluation, alongside the need for strategic planning to address resource limitations. Looking ahead, the engineering education community should focus on developing appropriate tools for assessing soft skills and conducting long-term studies to confirm the real-world impact on graduates. This review calls for ongoing innovation and integration in assessment practices, ensuring they evolve to equip students with the technical expertise and adaptability required for today's dynamic workforce. Another review could be conducted to compare approaches used in other regions such as Europe, Australia, and Africa.

7. Funding

This study was funded by Hung Yen University of Technology and Education within the framework of the key topic at the University Education Institution level, code UTEHY.L.2024.53.

6. References

Agrawal, E., Tungikar, V., & Joshi, Y. (2021). Method for assessment and attainment of course and program outcomes for Tier-I institutes in India. *Journal of Engineering Education Transformations (JEET), 34*(3), 35–41. https://doi.org/10.16920/jeet/2021/v34i3/157723

Alhakami, H. H., Al-Masabi, B. A., & Alsubait, T. M. (2020). Data analytics of student learning outcomes using ABET course files. *Intelligent Computing: Proceedings of the 2020 Computing Conference, 1,* 309–325. https://doi.org/10.1007/978-3-030-52249-0_22

Ali, Q. I. (2023). Surveying different student outcome assessment methods for ABET-accredited computer engineering programs. *Research Reports on Computer Science*, 56–76. https://doi.org/10.37256/rrcs.2120232577

Ali, Q. I. (2024). Towards more effective summative assessment in OBE: A new framework integrating direct measurements and technology. *Discovery Education, 3,* 107. https://doi.org/10.1007/s44217-024-00208-5

Altamirano, E., Gazca, L., López-Malo, A., & Palou, E. (2013). Direct and indirect assessment of Universidad de las Américas Puebla's Food Engineering program outcomes. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://peer.asee.org/direct-and-indirect-assessment-of-universidad-de-las-americas-puebla-s-food-engineering-program-outcomes.pdf

Alyahya, S., & El-Nasr, A. A. (2012). Outcomes-based assessment of the engineering programs at Qassim University for ABET accreditation. *IEEE International Conference on Interactive Mobile Communication, Technologies and Learning (IMCL)*. https://doi.org/10.1109/IMCL.2012.6396445

Alzubaidi, L., & Jabur, I. (2024). Student outcomes assessments using deep learning. *Journal of Electrical Systems, 20*(7s), 3647–3654. https://www.researchgate.net/publication/384232231

Ammar, K., & Rais, R. N. B. (2023). Outcome-based performance evaluation approach using rubric-based capstone projects assessment. *20th International Multi-Conference on Systems, Signals & Devices (SSD),* 777–783. https://doi.org/10.1109/SSD58187.2023.10411275

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory & Practice, 8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Awad, W. S., & Almhosen, K. A. (2023). A framework of outcome-based assessment and evaluation for computing programs. *International Journal of Advanced Computer Science and Applications (IJACSA), 14*(1), 371–380. https://doi.org/10.14569/IJACSA.2023.0140140

Balaji, N., & Pai, K. B. H. (2020). Course outcome and programme outcome in OBE: An illustration in engineering and technology. *Journal of Engineering Education Transformations (JEET), January 2020*. https://doi.org/10.16920/jeet/2020/v33i0/150188

Balasubramani, R., & Chiplunkar, N. N. (2017). Attainment of programme outcomes through course outcomes in outcome-based education: A case study. *Journal of Engineering Education Transformations (JEET), 31*(2). https://journaleet.in/articles/attainment-of-programme-outcomes-through-course-outcomes-in-outcome-based-education--a-case-study

Basri, N. E. A., Taib, K. A., Jaafar, O., Zain, S. M., Suja', F., Kasa, A., Osman, S. A., & Shanmugam, N. E. (2011). An evaluation of programme educational objectives and programme outcomes for civil engineering programmes. *Procedia - Social and Behavioral Sciences, 18,* 56–64. https://doi.org/10.1016/j.sbspro.2011.05.009

Battistini, A., & Kitch, W. A. (2021, July). Make assessment straightforward: A case study on the successful implementation of ABET student outcomes 1-7. *Proceedings of the 2021 ASEE Virtual Annual Conference & Exposition, Virtual Conference*. https://doi.org/10.18260/1-2--37472

Bhatia, J., & Singh, H. (2017). Indirect assessment of outcomes in education: A review. *International Journal of Computer Sciences and Engineering (IJCSE), 5*(12), 273–278. https://doi.org/10.26438/ijcse/v5i12.273278

Bhatti, S., Memon, M., & Meghji, A. F. (2023). Scrutinizing outcome assessment of outcome-based education using Q-OBE in engineering education. *International Journal of Innovation in Teaching and Learning (IJITL), 9*(1), 1–10. https://doi.org/10.35993/ijitl.v9i1.2609

Booth, A. (2016). Searching for qualitative research for inclusion in systematic reviews: A structured methodological review. *Systematic Reviews, 5,* Article 74. https://doi.org/10.1186/s13643-016-0249-x

Briner, R. B., & Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. In D. M. Rousseau (Ed.), *The Oxford handbook of evidence-*

based management (pp. 112–129). Oxford University Press. http://dx.doi.org/10.1093/oxfordhb/9780199763986.013.0007

Clarke, M. (2017). Rethinking graduate employability: The role of capital, individual attributes and context. *Studies in Higher Education, 43*(11), 1923–1937. https://doi.org/10.1080/03075079.2017.1294152

Critical Appraisal Skills Programme (CASP). (2018). *CASP checklist: For qualitative research*. https://casp-uk.net/casp-checklists/CASP-checklist-qualitative-2024.pdf

Cruz, M. L., Saunders-Smits, G. N., & Groen, P. (2019). Evaluation of competency methods in engineering education: A systematic review. *European Journal of Engineering Education, 45*(5), 729–757. https://doi.org/10.1080/03043797.2019.1671810

Damaj, I., & Yousafzai, J. (2019). Effective assessment of student outcomes in computer engineering programs using a minimalistic framework. *International Journal of Engineering Education, 35*(1), 59–75. https://doi.org/10.13140/RG.2.2.32415.71841

Davis, W. J., Ghanat, S. T., Brown, K. T., & Michalaka, D. (2017, June). Application of indirect and direct measures for student teamwork outcome assessment within an undergraduate civil engineering curriculum. *2017 ASEE Annual Conference & Exposition*. https://doi.org/10.18260/1-2--27597

El-Kady, M., Alsadaawi, A., Al-Zahrani, S., & Ajbar, A. (2014). Assessing learning outcomes in electrical engineering education: A case study from Saudi Arabia. *International Journal of Electrical Engineering Education, 51*(4), 355–367. https://doi.org/10.7227/IJEEE.0007

Exter, M. E., Tagare, D., & Sabin, M. (2024). Develop a competency-based curriculum that purposefully integrates computing skills, cross-disciplinary skills, and dispositions. *Proceedings of the ACM Conference on Computer Science Education*. https://doi.org/10.1145/3626253.3633410

Forcael, E., Garcés, G., & Orozco, F. (2022). Relationship between professional competencies required by engineering students according to ABET and CDIO and teaching–learning techniques. *IEEE Transactions on Education, 65*(1), 46–55. https://doi.org/10.1109/TE.2021.3086766

Gamboa, R., Namasivayam, S., Al-Atabi, M., & Singh, R. (2013). Quantitative measurement of students' PO attainments for Taylor's University engineering programmes. *Procedia - Social and Behavioral Sciences, 103,* 1147–1156. https://doi.org/10.1016/j.sbspro.2013.10.396

Ghaly, S. M. A. (2020). Indirect evaluation of program educational objectives and student outcomes for engineering programs: A case study. *Engineering, Technology & Applied Science Research, 10*(5), 6209–6213. https://doi.org/10.48084/etasr.3751

Gough, D., Oliver, S., Thomas, J., & Bean, M. R. (2017). An introduction to systematic reviews (2nd ed.). *Psychology Teaching Review, 23*(2), 95–96. https://doi.org/10.53841/bpsptr.2017.23.2.95

Gough, D., Thomas, J., & Oliver, S. (2012). Clarifying differences between review designs and methods. *Systematic Reviews, 1,* 28. https://doi.org/10.1186/2046-4053-1-28

Hasan, H., Ambiyar, Rizal, F., Maksum, H., & Putri, T. T. A. (2024). Evaluation on students' achievement for outcome-based education on engineering students. *Journal of Computer Science, Information Technology and Telecommunication Engineering (JCoSITTE), 5*(2), 1–10. https://doi.org/10.30596/jcositte.v5i2.20014

Hashim, N., & Hashim, H. (2010). Outcome-based education performance evaluation on final year degree project. *Latest Trends on Engineering Education,* 1–7. https://www.researchgate.net/publication/228496780

Hatipkarasulu, Y., Gunhan, S., Pishdad-Bozorgi, P., & Patin, J. (2012). Development and implementation of multi-level outcomes assessment plan for construction degree program. *ASEE Annual Conference & Exposition Proceedings*. https://doi.org/10.18260/1-2--21206

Hatipkarasulu, Y., & Hatipkarasulu, G. S. (2021, July). Direct assessment of student learning outcomes. *2021 ASEE Virtual Annual Conference Content Access*. https://peer.asee.org/direct-assessment-of-student-learning-outcomes

Hensel, E., & Robinson, R. (2014). Direct assessment of student learning outcomes by analysis of performance evaluation of student employees. *Proceedings of the 12th LACCEI Conference*. https://www.laccei.org/LACCEI2014-Guayaquil/RefereedPapers/RP193.pdf

Higgins, J. P. T., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions (Version 5.1.0)*. The Cochrane Collaboration. http://handbook-5-1.cochrane.org

Hinojosa-Rivera, M., Reyes-Melo, M. E., & Cazares, J. A. (2015). Educational objectives, outcomes and competencies assessment for a Latin-American materials engineering program. *Proceedings of the ASEE Annual Conference & Exposition*. https://www.researchgate.net/publication/278704389

Hussain, W., Spady, W. G., Khan, S. Z., Khawaja, B. A., Naqash, T., & Conner, L. (2021). Impact evaluations of engineering programs using ABET student outcomes. *IEEE Access, 9,* 46166–46190. https://doi.org/10.1109/ACCESS.2021.3066921

Kalaani, Y., & Haddad, R. J. (2014). Continuous improvement in the assessment process of engineering programs. *2014 ASEE Southeast Section Conference*. http://se.asee.org/proceedings/ASEE2014/Papers2014/4/44.pdf

Kamran, M., Fazal, M. R., Abid, M. I., & Abid, I. (2020). Implementation of the outcome-based education system in engineering programs for Pakistan Engineering Council accreditation under Washington Accord signatory. *Science International (Lahore), 32*(2), 197–206. https://www.researchgate.net/publication/340095539

Lavanya, C., & Murthy, J. N. (2022). Assessment and attainment of course outcomes and program outcomes. *Journal of Engineering Education Transformations (JEET), 35*(4), 104–111. https://doi.org/10.16920/jeet/2022/v35i4/22109

Luzan, P., Titova, O., Kurok, R., & Mosia, I. (2021). The methodology for assessment of engineering students outcomes. *2021 IEEE International Conference on Modern Electrical and Energy Systems (MEES),* 1–6. https://doi.org/10.1109/MEES52427.2021.9598666

Mahrishi, M., Jain, P. K., & Hosseini, S. (2023). Towards assessment and attainment of engineering graduate attributes in outcome-based education (OBE). *Proceedings of the IEEE Conference on Future of Educational Innovation,* 1–7. https://doi.org/10.1109/IEEECONF56852.2023.10104817

Manteufel, R. D., & Karimi, A. (2016, June). Promoting consistent assessment of student learning outcomes over multiple courses and multiple instructors in continuous program improvement. *Proceedings of the 2016 ASEE Annual Conference & Exposition*. https://doi.org/10.18260/p.25986

Mishra, A., & Singh, S. (2024). Smart pedagogical learning and assessment methodologies—Outcome-based education: A novel quality assurance framework with attainment computation. *Journal of Computers in Education, 12*(4). https://doi.org/10.1007/s40692-024-00344-9

Mistamiruddin, E., & Nasri, N. M. (2024). Challenges in integrating outcome-based education (OBE) in higher education institutions: A systematic literature review. *International Journal of Academic Research in Progressive Education and Development, 13*(4), 1135–1150. http://dx.doi.org/10.6007/IJARPED/v13-i4/23378

Mohd Noor, N., Muhamad, N., Alias, R., Alias, A., & Rosli, S. (2024). Analysis of program outcomes attainment for diploma in civil engineering at Universiti Teknologi MARA Pahang. *International Journal of Evaluation and Research in Education (IJERE), 13*(3). https://doi.org/10.11591/ijere.v13i3.26996

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analysis: The PRISMA statement. *PLOS Medicine, 6*(7), e1000097. http://dx.doi.org/10.1371/journal.pmed.1000097

Mynderse, J. A. (2022). Assessing ABET student outcome 7 (New Knowledge) with measurement systems [Paper presentation]. American Society for Engineering Education (ASEE) Annual Conference & Exposition. https://doi.org/10.18260/1-2--40917

Nandy, A. (2022, August). A highly integrated and successful approach to program development and implementation of accreditation strategies for an engineering technology program [Paper presentation]. 2022 ASEE Annual Conference & Exposition. https://doi.org/10.18260/1-2--40640

Naqvi, S. R., Akram, T., Haider, S. A., Khan, W., Kamran, M., Muhammad, N., & Nawaz Qadri, N. (2019). Learning outcomes and assessment methodology: Case study of an undergraduate engineering project. *The International Journal of Electrical Engineering & Education, 56*(2), 140–162. https://doi.org/10.1177/0020720918790108

Nurjannah, I., Cholik, M., Muhaji, Wiyanto, T., Wijanarko, D. V., & Arsana, I. M. (2022). Development of OBE-based learning evaluation model in mechanical engineering education program. *Advances in Engineering Research, 209, International Joint Conference on Science and Engineering 2021 (IJCSE 2021), 7*(12), 2352–5401. Atlantis Press. https://www.atlantis-press.com/proceedings/ijcse-21/125966512

Passow, H. J., & Passow, C. H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education, 106*(3), 475–526. https://doi.org/10.1002/jee.20171

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Blackwell Publishing. https://doi.org/10.1002/9780470754887

Premalatha, K. (2019). Course and program outcomes assessment methods in outcome-based education: A review. *Journal of Education, 199*(3). https://doi.org/10.1177/0022057419854351

Raihan, M. Z., & Azad, M. A. K. (2023). A bibliometric review on outcome-based learning for graduate employability: Mapping the research front. *Journal of Education, 203*(1), 73–91. https://doi.org/10.1177/00220574211016444

Rajak, A., Shrivastava, A. K., & Tripathi, A. K. (2019). An approach to evaluate program outcomes and program educational objectives through direct and indirect assessment tools. *International Journal of Emerging Technologies in Learning (iJET), 14*(23), 110–123. https://doi.org/10.3991/ijet.v14i23.11018

Rashideh, W., Alshathry, O. A., Atawneh, S., Al Bazar, H., & AbualRub, M. S. (2020). A successful framework for the ABET accreditation of an information system program. *Intelligent Automation & Soft Computing, 26*(6), 1286–1306. https://doi.org/10.32604/iasc.2020.012995

Sala, A. L., & Riddell, J. (2012). Successful ABET accreditation of a two-year electronics technology program: Lessons learned [Paper presentation]. Proceedings of the ASEE Annual Conference & Exposition. https://doi.org/10.18260/1-2--21965

Shafi, A., Saeed, S., Bamarouf, Y. A., Iqbal, S. Z., Min-Allah, N., & Alqahtani, M. A. (2019). Student outcomes assessment methodology for ABET accreditation: A case study of computer science and computer information systems programs. *IEEE Access, 7*, 13653–13667. https://doi.org/10.1109/ACCESS.2019.2894066

Sloan, J. A., & Frank, T. E. (2023). Student self-assessment data: An instrument for program assessment. *Intersection: A Journal at the Intersection of Assessment and Learning, 4*(2). https://doi.org/10.61669/001c.84511

Sundararajan, S. (2014). A strategy for sustainable student outcomes assessment for a mechanical engineering program that maximizes faculty engagement. *Proceedings of the ASEE Annual Conference & Exposition*. https://doi.org/10.18260/1-2--20002

Syeed, M. M., Shihavuddin, A. S. M., Uddin, M. F., Hasan, M., & Khan, R. H. (2022). Outcome-based education (OBE): Defining the process and practice for engineering education. *IEEE Access, 10*, 119170–119192. https://doi.org/10.1109/ACCESS.2022.3219477

Thiruvengadam, J., Baskar, S., Jeyamala, C., & Abirami, A. M. (2022). Systematic approach in assessment of course outcomes/program outcomes for undergraduate engineering programs – A case study. *Journal of Engineering Education Transformations, 35,* 270–275. https://doi.org/10.16920/jeet/2022/v35is1/22039

Tshai, K. Y., Ho, J.-H., Yap, E. H., & Ng, H. K. (2014). Outcome-based education – The assessment of programme educational objectives for an engineering undergraduate degree. *Engineering Education, 9*(1), 1–10. https://doi.org/10.11120/ened.2014.00020

Waly, M. I. (2020). A modified evaluation approach for direct assessment of program outcomes: Medical equipment technology program as case study. *International Journal of Emerging Technologies in Learning (iJET), 15*(4), 125–137. https://doi.org/10.3991/ijet.v15i04.11792

Zain, S., Badaruzzaman, W. H. W., Rahmat, R. A. O., Jaafar, O., Basri, N. E. A., & Basri, H. (2012). Learning outcomes for environmental and sustainable development component in the field of civil engineering. *Asian Social Science, 8*(16), 153–162. https://doi.org/10.5539/ass.v8n16p153