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Improving learning outcomes in engineering education with a closed-loop control system method

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Abstract: Education plays a critical role in equipping individuals with the knowledge, skills, and competencies necessary for success. However, traditional educational approaches often struggle to address the diverse learning paces, styles, and needs of students. This challenge is particularly pronounced in technical fields such as engineering, where personalized and adaptive learning methods are essential. This study proposes a new approach leveraging closed-loop control systems to enhance the attainment of course learning outcomes. The proposed method is demonstrated through a case study on Circuit Analysis, a fundamental course in Electrical and Electronics Engineering. The study quantifies and systematically implements course learning outcomes using various assessment tools, including quizzes, exams, projects, and laboratory evaluations, all integrated into a closed-loop control framework. A numerical correlation is also established between course learning outcomes and broader program outcomes. Unlike traditional systems where assessment results are isolated, the proposed method incorporates adaptive mechanisms that adjust subsequent assessments and learning interventions based on earlier performance. This closed-loop approach enables personalized tracking of students' progress, tailored learning materials, and adaptive teaching strategies that address individual strengths and weaknesses. The findings indicate that closed-loop control systems can transform educational methodologies, offering a robust framework for personalized learning and maximizing students' potential, particularly in technical disciplines. Furthermore, this approach aligns seamlessly with quality accreditation processes, making it applicable across a wide range of courses.

Keywords: Engineering Education, Learning outcomes, Evaluation methodologies, Improving classroom teaching, Lifelong learning.

1. Introduction

Education is undergoing a profound transformation, driven by dynamic and multifaceted challenges that reflect the evolving needs of society, institutions, and individual learners. Accreditation bodies are mandating increasingly rigorous standards to ensure quality and consistency across educational programs [1]. Simultaneously, government authorities emphasize heightened transparency, accountability, and measurable improvements in educational outcomes to address public and economic expectations [2]. On another front, students are demanding a more pragmatic, career-oriented education that equips them with the skills and knowledge necessary to excel in rapidly changing professional environments. These forces collectively call for a paradigm shift, prompting a reevaluation of traditional teaching methodologies and an emphasis on innovative, outcome-focused approaches. This transformation signifies a transition from conventional, lecture-based instruction to a more student-centered framework grounded in measurable, actionable learning objectives [3]. At the heart of this shift lies Outcome-Based Education (OBE), a pedagogical model designed to foster active student engagement and produce concrete, sustainable learning outcomes [4, 5, 6, 7]. Unlike traditional models that prioritize the delivery of content, OBE centers on what learners achieve at the end of their educational journey. This approach is grounded in the principle that education should not merely impart knowledge but also develop critical skills and lasting understanding [8]. Albert Einstein's timeless observation, "Education is what remains after one has forgotten what one has learned in school" [9], underscores this philosophy, pointing to the limitations of passive, short-term learning methods. By adopting active, experiential learning strategies, educa-

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tors can better prepare students for the complexities of the modern world.

OBE flips this model by prioritizing clearly defined and measurable learning outcomes that students are expected to achieve by the end of their educational experience. These outcomes are usually framed in terms of skills, competencies, and knowledge that students can demonstrate, rather than simply the content they have been exposed to [10]. This results-oriented approach allows educators to design curricula and teaching methods that are explicitly aimed at achieving these desired outcomes [11]. In practice, OBE encourages a shift from passive learning, where students are receivers of information, to active, engaged learning, where students actively participate and are held accountable for their progress [12]. This model is especially beneficial in fields such as engineering, healthcare, and business, where the application of knowledge is critical to professional success [13]. By making the learning process more transparent and goal-oriented, OBE ensures that students develop the practical skills and cognitive abilities necessary to meet the demands of modern industries. Furthermore, OBE places a strong emphasis on assessment methods that are directly linked to the defined learning outcomes, allowing for continuous feedback and improvement [14]. Traditional assessments such as exams or quizzes may only measure a narrow subset of student learning, often focusing on recall or basic understanding. In contrast, OBE incorporates diverse assessment techniques, including formative assessments, project-based learning, and real-world simulations, which provide a more comprehensive view of a student's ability to apply their knowledge in various contexts [15]. These assessments are designed to measure theoretical understanding, and also the application, analysis, and synthesis of knowledge. Importantly, OBE allows for flexibility in how students achieve the learning outcomes, accommodating diverse learning styles and pacing [16]. It also involves a cyclical process of evaluating and adjusting teaching strategies and learning objectives based on student performance and feedback. As a result, OBE fosters a more personalized learning experience, where students are supported in reaching their full potential. Indeed, this adaptive approach is particularly valuable in higher education and vocational training, where students often need tailored guidance to succeed in complex and rapidly changing fields.

The relevance and efficacy of OBE are increasingly supported by empirical research. Logan et al. (2021) proposed an innovative teaching strategy based on self-regulated learning theory, enabling students to learn at their own pace while addressing their unique educational needs [17]. Applied in graduate nursing education, this approach demonstrated significant improvements in engagement and learning outcomes, highlighting the importance of personalization in modern teaching. Similarly, Yamarik's comparative study of cooperative learning versus traditional lectures in intermediate macroeconomics revealed that collaborative methods led to higher exam scores, providing evidence of the benefits of active learning on academic performance [18]. In the context of global educational reforms, Isusi-Fagoaga et al. (2023) explored the impact of teaching methodologies on competency development among higher education graduates in Belarus [19]. Their findings emphasized the critical role of adaptable, skill-focused education in meeting the demands of a transitioning market economy, particularly as Belarus seeks to cultivate a competitive workforce. Additionally, Clark and Hsu (2023) examined the optimization of Program Learning Outcomes (PLOs) to improve assessment, curriculum design, and overall student experiences in undergraduate biology programs. Their work highlights the value of aligning educational goals with practical, measurable outcomes [20].

Further supporting these trends, Marín-Vinuesa and Rojas-García (2023) investigated the adoption of e-learning platforms and their impact on student performance [21]. Their study revealed that the acceptance and integration of digital tools into traditional and blended learning environments significantly enhanced learning outcomes, underscoring the importance of technology in contemporary education. Building upon these perspectives, this study explores the role of OBE in developing global competencies, particularly within the context of engineering education. Engineering graduates today face challenges that extend beyond technical expertise; they must navigate diverse, multicultural, and highly competitive global markets. This necessitates an educational approach that imparts technical knowledge as well as fosters adaptability, problem-solving, and cross-cultural communication skills. By emphasizing these competencies, OBE equips students to thrive in an interconnected, globalized world. To structure and evaluate educational objectives systematically, Bloom's Taxonomy serves as a foundational framework. Developed by Benjamin Bloom and colleagues in 1956, this taxonomy organizes cognitive objectives into hierarchical levels, from basic knowledge recall to complex analysis and synthesis. Widely applied in engineering education, Bloom's Taxonomy aids in designing targeted learning experiences, assessing student progress, and fostering higher-order thinking skills [22]. Additionally, in a different study highlights the positive perceptions of both teachers and students toward MMLA in healthcare simulations, noting its effectiveness in enhancing feedback, reflection, and adaptive learning behaviors. However, it also identifies key challenges, including the system's complexity, trust in data accuracy, and the need for more qualitative insights to fully support collaborative learning [23].

This study also integrates the principles of systems engineering, specifically the concept of closed-loop control systems, into the educational domain. A closed-loop system operates on feedback and iterative adjustments to maintain alignment with desired targets. Similarly, effective education requires continuous assessment, real-time feedback, and iterative refinements to ensure that learning objectives are met. This systems-based approach reinforces the adaptability and resilience of educational frameworks, enabling them to respond to dynamic challenges and disturbances. Through a comprehensive analysis of these themes, this study aims to illuminate the essential steps for implementing student-centered, outcome-focused education. By integrating educational theory, empirical research, and systems thinking, it offers actionable insights for educators and educational administrators. The future of education is undoubtedly oriented toward active engagement, measurable outcomes, and continuous improvement, and this study serves as a roadmap for successfully navigating this transformative journey.

2. General Definations

2.1. Course Learning Outcomes

Each course is designed with a specific set of learning outcomes that outline the knowledge, skills, and competencies students are expected to acquire upon completion. For instance, the learning outcomes of a *Control Systems* course might include:

i) Understanding the fundamental concepts and principles of control systems.

ii) Developing mathematical models for various systems.

iii) Implementing controller design strategies.

iv) Analyzing and evaluating the performance of control systems.

These outcomes are crafted based on the course objectives and content, providing students with a clear roadmap of what they are expected to learn and achieve. Indeed, while a university's mission and vision define broad institutional goals, the missions of faculties and departments adapt these goals to their specialized fields [24]. Course-specific learning outcomes, in turn, establish precise objectives for individual courses. Together, these outcomes support educational institutions in fulfilling their overarching goals and addressing the diverse needs of students.

The process of determining and implementing course learning outcomes involves a systematic series of steps designed to align instructional objectives with measurable student achievements. The step-by-step process for defining these outcomes is illustrated in Figure 1. Initially, the general objective of the course must be defined (Step 1), summarizing the core knowledge and skills intended for student acquisition. This objective, often outlined in the course description or curriculum document, serves as the foundation for subsequent planning. Next, the main topics and headings that constitute the course content are identified (Step 2). This step entails detailing the critical areas of knowledge and understanding that students must master, along with examining the importance and interrelationships of these topics. Once the content structure is established, specific learning outcomes are determined for each heading (Step 3). These outcomes clearly articulate the knowledge, skills, and understanding that students should achieve by the end of the course, ensuring alignment with the overall course objective.

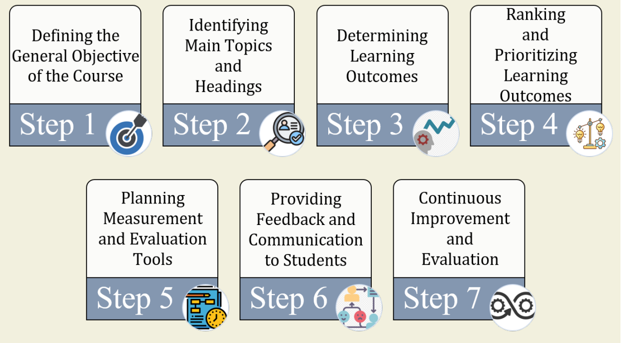

Figure 1. Step-by-step framework for defining and implementing course learning outcomes, highlighting key stages from establishing course objectives to continuous improvement for aligning instructional goals with measurable student achievements

Subsequently, the learning outcomes are ranked and prioritized (Step 4) based on their relevance to the course's core purpose and their significance for students' academic and professional development. This prioritization guides the organization of course content and instructional strategies. In Step 5, appropriate measurement and evaluation tools are planned to assess the achievement of each learning outcome. These tools, which may include exams, projects, assignments, or presentations, are designed to effectively evaluate students' mastery of the intended outcomes. Clear communication of these learning outcomes and associated assessment processes to students is also essential (Step 6). Typically, this is achieved through course syllabi or initial instructional sessions, ensuring transparency and engagement by informing students when and how they will achieve the outcomes. Lastly, continuous improvement is integral to the process (Step 7), involving the ongoing monitoring of student performance, evaluation of learning outcomes, and iterative adjustments to course delivery to optimize student achievement. This iterative approach enhances the course, as well as ensures that students meet the intended outcomes. Learning outcomes thus form the cornerstone of course planning and student assessment, necessitating careful definition and implementation. In Turkey, for instance, the Association for Evaluation and Accreditation of Engineering Programs (MÜDEK) establishes Engineering Program Outcomes in alignment with the Bologna Process and the Turkish Higher Education Qualifications Framework, providing a standardized foundation for the accreditation of engineering programs [25].

2.2. MÜDEK – Engineering Program Outcomes

In alignment with the Bologna Process, the MÜDEK engineering program outcomes define the essential skills and knowledge that students should acquire during their engineering education. These outcomes are typically categorized into two primary areas: Technical/Engineering Competence and Professional/Soft Skills Development, as illustrated in Figure 2. This dual categorization highlights the dual focus of engineering education: equipping students with robust technical expertise while fostering professional adaptability and interpersonal skills.

The Technical/Engineering Competence category emphasizes the core technical knowledge, skills, and methodologies necessary for engineering practice. Students are expected to develop a strong foundation in the theoretical principles of their engineering discipline, enabling them to understand and apply fundamental concepts effectively. A key component of this foundation is the ability to analyze complex engineering problems using principles from mathematics and physical sciences, such as differential equations, physical laws, and statistical methods. In addition to analytical capabilities, students must hone their problem-solving skills, which involve identifying, formulating, and solving engineering challenges through modeling and simulation. Engineering education also prioritizes design competence, equipping students with the ability to conceptualize and execute projects, whether in product development, system design, or process optimization. Furthermore, proficiency in technological tools is vital, as students must learn to use software and tools commonly employed in engineering, such as computer-aided design (CAD), simulation platforms, and data analysis software. Moreover, experimental work skills are essential, encompassing the design and execution of experiments, data collection, and the interpretation of results in both laboratory and fieldwork contexts.

The Professional/Soft Skills Development category focuses on fostering interpersonal and professional competencies that complement technical expertise. Effective teamwork is a critical skill, requiring students to collaborate within both discipline-specific and interdisciplinary teams, often involving leadership and communication abilities. Communication skills extend beyond teamwork, as students must be adept at conveying complex engineering concepts through written reports, oral presentations, and technical documentation. Ethical awareness and sustainability are also central to modern engineering practice, with students expected to understand the environmental impacts of their work and adhere to ethical standards. Lifelong learning ability is another essential outcome, ensuring that graduates remain current with technological advancements and continuously enhance their skills in an ever-evolving field. Additionally, knowledge of workplace practices, including project management, risk assessment, and change management, prepares students for real-world applications of their expertise. Social and environmental awareness further enriches this category, encouraging students to consider the societal, environmental, and legal implications of their engineering projects.

Together, these learning outcomes form the foundation of engineering education, preparing graduates to achieve professional success and contribute meaning-

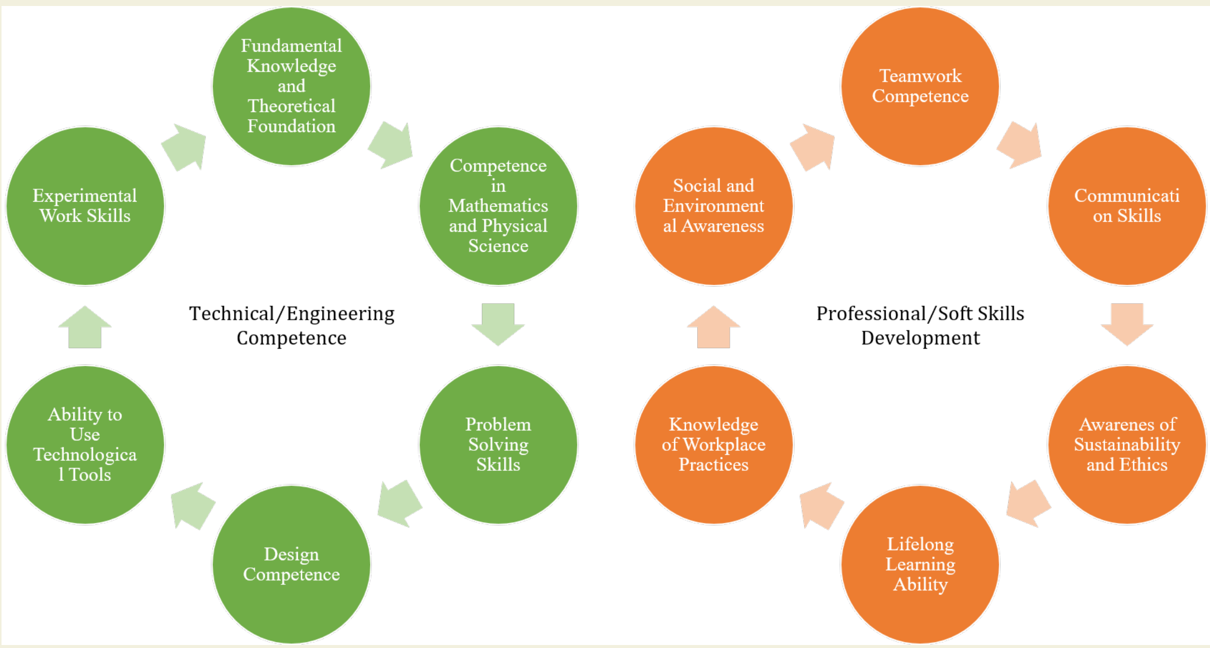

Figure 2. Categorization of engineering program learning outcomes into two primary domains: Technical/Engineering Competence and Professional/Soft Skills Development, highlighting the dual focus of engineering education on technical expertise and professional adaptability

fully to society. Each engineering program builds upon these principles, tailoring specific learning outcomes to align with program requirements and goals. Moreover, the integration of ethics and social responsibility into these outcomes indicates the importance of professional integrity in the engineering profession. Designing effective educational programs to achieve these outcomes, however, presents challenges, as students learn at different paces and possess unique needs. Innovative approaches, such as integrating closed-loop control systems into educational design, can offer new perspectives to enhance learning outcomes and improve the overall educational experience. This study explores how such methodologies, supported by assessment frameworks such as Bloom's Taxonomy, can help optimize student learning and competency development.

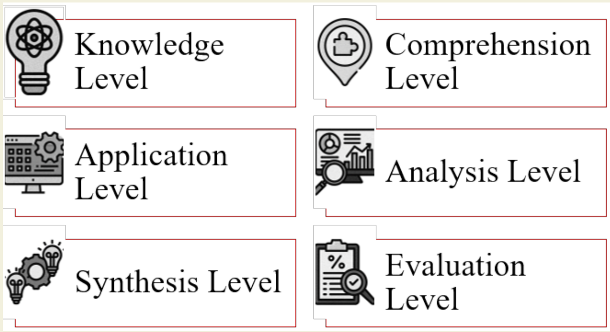

Figure 3. Hierarchical representation of Bloom's Taxonomy cognitive domain levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Each level builds upon the previous, progressing from foundational knowledge to higher-order thinking skills, emphasizing understanding, application, critical analysis, creation, and evaluation

2.3. Bloom's Taxonomy (BT)

Bloom's Taxonomy, introduced by Benjamin Bloom in 1956 as the "taxonomy of educational objectives," outlines a hierarchical framework for understanding how individuals process information and develop cognitive abilities. It classifies cognitive achievements into six distinct levels, progressing from basic knowledge acquisition to higher-order thinking skills. As learners advance through these levels, they engage in increasingly complex cognitive processes, culminating in critical evaluation and synthesis. The levels of the cognitive domain are depicted in Figure 3. At the Knowledge level, students recall and recognize fundamental facts and information. In the comprehension level, learners not only grasp the material but also interpret and explain it in diverse ways, developing skills such as summarization, explanation, and comparison. The application level requires students to utilize acquired knowledge in real-world contexts, fostering problem-solving abilities and the capacity to adapt concepts to new situations. The analysis level involves a deeper examination of information, enabling students to understand relationships and structures within the material. This stage hones skills such as dissecting information, identifying connections, and analyzing cause-and-effect dynamics. At the synthesis level, learners integrate disparate pieces of information to create something novel. This level emphasizes the generation of new ideas, the combination of concepts, and the creation of innovative projects. The evaluation level demands critical assessment of information to form well-reasoned conclusions. At this stage, students develop skills in argumentation, comparing alternatives, and making informed decisions. Each level builds upon the preceding one, guiding students toward a comprehensive and sophisticated understanding of subject matter.

Bloom's Taxonomy provides a structured framework for educators to define learning objectives, evaluate student achievements, and design effective instructional strategies. In Ming's study, the taxonomy was applied to assess intended learning outcomes in both the cognitive and psychomotor domains [26, 27]. The cognitive domain pertains to mental processes such as thinking, understanding, information processing, and intelligence. It encompasses how individuals acquire, store, process, and apply knowledge. Skills within this domain include problem-solving, decision-making, memory, language, perception, attention, and learning. Cognitive psychology, a subfield dedicated to studying these processes, explores how individuals think and process information. The term psychomotor combines elements of psychology and physiology, referring to the interplay between cognitive thought and physical movement. Psychomotor skills involve muscle control, hand-eye coordination, and fine motor abilities, such as writing, drawing, or performing tasks that require precision. These skills are especially vital in fields such as education and sports, where physical performance is integrated with cognitive understanding. Psychomotor activities also include gross motor functions and coordination required in various physical tasks. Understanding the interplay between the cognitive domain and psychomotor skills is crucial for analyzing how individuals learn, think, and perform across diverse activities [28, 29, 30]. Leveraging these concepts, a closed-loop control system can be implemented to achieve targeted levels of success based on assessments of course learning outcomes. Such systems enable continuous monitoring and adjustments, ensuring the system's behavior remains aligned with desired reference points despite dynamic changes. This approach is particularly effective for optimizing learning processes and maintaining consistent performance standards.

2.4. Closed Loop Control System

A closed-loop control system is a robust approach used to manage and regulate processes or systems. It achieves this by receiving feedback from the system's output and using that information to adjust its behavior, aiming to approach or maintain a desired target, also known as the setpoint. This type of control is widely employed to achieve stable, precise, and accurate results. The components of a closed-loop control system, as illustrated in Figure 4, include the process (or system), setpoint, sensors, controller, disturbance, and feedback loop. The process refers to the real-world system or operation being controlled, such as temperature regulation, speed control, pressure adjustment, or water level management. The setpoint is the target value the control system strives to achieve, representing a specific desired value of a measurable variable. Sensors are critical elements that monitor the current state of the process, capturing real-world data and converting it into a format usable by the control system. This data is then processed by the controller, which compares the measured state to the setpoint. Based on this comparison, the controller calculates the required adjustments and generates an output signal to correct any deviations. The controller employs a specific control strategy or algorithm to determine these corrective actions. In real-world applications, external factors, known as disturbances, can introduce variability and challenge the system's ability to maintain the desired output. Disturbances include environmental factors such as temperature fluctuations, humidity, wind, or noise; mechanical issues such as vibrations or wear and tear; and even large-scale disruptions such as the COVID-19 pandemic, which severely impacted systems worldwide, particularly in education. The presence of disturbances significantly influences the reliability, sensitivity, and performance of control systems. Thus, robust control strategies must account for such disturbances, enabling the system to detect and correct for them effectively. The feedback loop is the mechanism through which the system continuously evaluates its performance. Data from sensors is transmitted back to the controller, providing real-time information about the system's current state. This iterative process allows the system to make continuous adjustments, ensuring it converges toward and maintains the target value. By integrating these components, closed-loop control systems ensure adaptive and reliable performance, even in the presence of external disturbances, making them indispensable in various engineering and real-world applications.

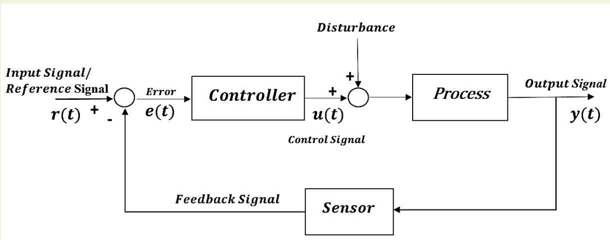

Figure 4. Closed loop control system

The working principle of a closed-loop control system typically involves the following steps: sensors measure the current state of the process and convey this information to the controller. The controller calculates the difference (error signal) between the setpoint and the current state and produces an output signal to reduce or approach this difference to zero. The actuator uses the controller's output to perform a physical action designed to bring the current state of the process closer to the setpoint. Sensors again measure the current state, and this information is sent back to the controller through the feedback loop. This loop continues continuously; the controller continuously monitors the current state and adjusts its output as needed. Closed-loop control systems are widely used in various industrial applications, automation, machine control, temperature regulation, and automation of industrial processes. These systems offer an effective approach to reach target values more quickly, accurately, and stably, and to correct variations.

2.5. Design of a Closed-Loop Control System for Evaluating Learning Outcome Gains

The closed loop control system design can be used to evaluate Learning Outcomes Gains. The design structure showing this usage is shown in Figure 5. A detailed description of the adaptive design in question is given below.

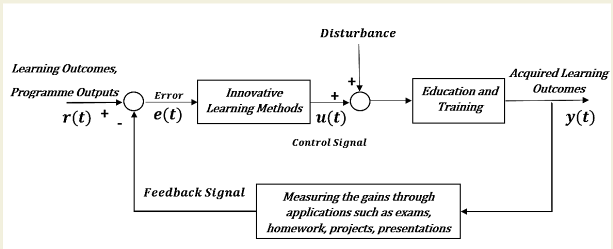

Figure 5. Closed loop control system design for Learning Outcomes

2.5.1. Input: Design of Learning Outcomes

Every closed-loop control system requires an initial input, and in education, this input determines the design of learning or program outcomes. Learning outcomes reflect the fundamental objectives and goals of the educational program. This stage is crucial in determining what knowledge, skills, and competencies students should acquire. These determinations should be based on factors such as industry needs, post-graduation goals, and student requirements. External factors like industry, society, stakeholders, and accreditation bodies play a significant role in defining program learning outcomes [31]. For example, in determining the learning outcomes for a circuit analysis course in an electrical engineering department, collaboration with industry representatives and stakeholders can be essential. Through this collaboration, the learning outcomes for the circuit analysis course can be shaped to align with industry needs and societal expectations, ensuring that graduates possess up-to-date knowledge and skills. Additionally, student requirements should be taken into account. Students' interests, learning styles, and career goals contribute to the determination of learning outcomes. For instance, if an electrical engineering

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program aims for its graduates to specialize in power electronics, the learning outcomes may need to include a deep understanding of power electronics topics and the ability to solve problems in this field [32]. In conclusion, like any closed-loop control system, educational programs also require inputs, and these inputs shape the determination of learning outcomes. These outcomes should be designed to align with industry needs, post-graduation goals, and student requirements. This process forms the foundation of the program and ensures that graduates are well-equipped for success.

2.5.2. Controller: Design of Teaching Methods

The controller in a closed-loop control system represents teaching methods. Specific teaching methods, materials, or courses are provided to students to help them achieve learning outcomes. This stage is crucial in determining the teaching process, developing the curriculum, and delivering the necessary knowledge to students. In engineering education, the teaching methods provided to students enable the successful attainment of learning outcomes. However, these teaching methods should not only facilitate knowledge transfer but also encourage active student participation, enhance problem-solving skills, and focus on real-world applications. Consider wanting to impart the ability to understand electrical circuits to a student. Traditional textbooks and classroom lectures can teach this subject, but without being supported by practical experiences, students' abilities to solve real-world problems may be limited. Therefore, teaching methods such as laboratory work, simulations, and project-based learning are crucial in developing students' abilities to analyze and design electrical circuits [32].

2.5.3. Process: Education Process

The process represents the education process itself. Students encounter a specific teaching method or curriculum during this process. In this stage, students attend classes, complete assignments, and take exams over a certain period to reach the learning outcomes. Students will experience how to learn through the delivery of lectures, completion of projects, laboratory work, and other learning activities. The education process utilizes measurement and assessment tools to determine how close students are to achieving learning outcomes. Tools such as exams, project evaluations, assignments, and projects are used to monitor student performance. This data helps identify students' strengths and weaknesses. This stage is crucial for assessing how close students are to achieving learning outcomes. This stage also includes the process of providing feedback to students. The feedback given to students helps them more effectively reach the learning outcomes. It contributes to improving their weaknesses and reinforcing their strengths. For example, consider a laboratory experiment in an electrical engineering course. This laboratory work provides students with an opportunity to apply their circuit analysis skills. The results of the laboratory work can be used to identify which areas students struggled with and what they understood better. This information provides an opportunity for students to engage in additional study or receive guidance [33].

2.5.4. Feedback Student Performance and Program Improvement

The feedback signal is a fundamental component of the closed-loop control system. It provides information about how close students are to achieving performance and learning outcomes. This feedback helps identify students' strengths and weaknesses and assesses the effectiveness of teaching methods in reaching program goals. These measurements are determined based on the assessment of student performance using tools such as exams, experiments, assignments, and other instruments. Providing feedback to students helps them more effectively reach the learning outcomes, improving their weaknesses and reinforcing their strengths. The effectiveness of teaching methods can be enhanced, and better results can be achieved through feedback. Additionally, these feedback mechanisms offer valuable insights for program managers on how the education program can be improved. Information about the successes and challenges of the program allows for making the program more effective. For instance, if an engineering program identifies that students are weak in a specific area, this feedback can be used to enhance the relevant course or provide additional support [34].

3. Implementation of The Proposed System

Case Study: Implementing a Closed-Loop Control System Design to Achieve Learning Outcomes in a Circuit Analysis Course

The "Circuit Analysis Course" is typically offered in engineering disciplines such as electrical and electronic engineering, aiming to equip students with the skills to analyze and design electrical circuits. The learning outcomes and achievements of this course specify what students are taught regarding circuit analysis and the skills they should acquire. In a study conducted by Ming (2012), the learning outcomes for the Circuit Analysis Course are outlined as follows: *i*) Analyzing and understanding DC and AC electrical circuits. *ii*) Performing and interpreting circuit simulations. *iii*) Solving and interpreting transient responses of first and second-order electrical circuits [27]. These learning outcomes and achievements should demonstrate that students possess the necessary knowledge and skills in circuit analysis, enabling them to successfully solve engineering problems. This course helps students enhance their understanding, analysis, and design skills for electrical circuits, preparing them for engineering applications. Additionally, these outcomes are utilized to assess and improve the quality of the engineering program.

To achieve these specified learning outcomes, each sub-assessment element should be clearly aligned with a specific learning outcome. This includes methods such as midterm and final exams, quizzes, lab work, assignments, projects, and presentations. Each question in exams, each lecture, and each application should be aligned to assess one of the specified learning outcomes. The scores derived from these alignments will be used to evaluate the attainment of learning outcomes. Subsequently, an analysis of program outcomes attainment based on the achievements of course learning outcomes will be conducted. The numerical quantification of course learning outcomes can be considered a crucial step. Elsheikh et al. (2017) proposed a procedure for the quantification of learning outcomes, involving listing course topics, assigning appropriate Bloom's Taxonomy cognitive levels, integrating topics, formulating learning outcome statements, matching course learning outcomes with program outcomes, aligning assessment assets with course learning outcomes, and finally, balancing and fine-tuning processes [35]. In this study, some of these methods have been employed. According to the Bologna quality process, university courses span one semester with a planning of 14 weeks, typically comprising 8 weeks of midterms and 16 weeks of final exams. The weekly course activities and assessment methods are detailed and shared with students at the beginning of the semester, and this information is uploaded into the Bologna quality system in the course information system. This course information is accessible to students and other users.

3.1. Procedure for Developing Course Learning Outcomes

3.1.1. Listing Course Topics

In this step, the topics are listed, and each topic is assigned a percentage representing its weight compared to other topics. The weighting assignment is subjective. A simple way to determine the percentage weight is to consider the time spent on the topic.

3.1.2. Assigning the Appropriate Bloom's Taxonomy (BT) Cognitive Level

In the second step, each topic is assigned a level in Bloom's Taxonomy, indicating the learning level that the student should achieve. Steps 1 and 2 are shown in Table 1. The table presents a possible topic list for the Circuit Analysis course, along with the weight assigned to each topic based on the number of weeks devoted to teaching these topics [36]. Additionally, a Bloom's Taxonomy level (cognitive domain) is assigned for each topic.

3.1.3. Integration of Topics

Closely related topics can be grouped together. During grouping, considerations include suitability, applied teaching and learning methods, assessment techniques, and the desired Bloom's Taxonomy level to be achieved. The number of groups is limited to be equal to or greater than the assigned Program Outcome number. The number of course learning outcomes should not be excessive; for example, in a 3-credit hour course, 3-5

Table 1. List of topics with assigned weight and IT cognitive level

#	Topic	Weeks	Weight (%)	Bloom's Taxonomy Level (Cognitive)
1	Basic Concepts	1	5	2
2	Circuit Laws	2 and 3	15	5
3	Node Voltage Method & Mesh Current Method	4 and 5	15	5
4	Fundamental Theorems	6 and 7	15	5
5	Capacitor and Inductor	8 and 9	5	2
6	RL and RC Circuits	10 and 11	15	5
7	Alternating Current	12 and 13	15	5
8	Analysis of AC Circuits & Power Calculations	14 (=1)	15	5

course learning outcomes will suffice [34].

Program Outcome Number ≤ Course Learning Outcome Number = Number of Groups (3)

Note that weights are now assigned to groups instead of individual topics. The group weight is simply the sum of the weights assigned to the topic titles. On the other hand, the Bloom's Taxonomy level for the group is the highest among all the topics within the group.

3.1.4. Writing Course Learning Outcome Statements

A course learning outcome statement is crafted for each group of topics. The first part of the statement, beginning with "At the end of the semester, the student should be able to," is common for all course learning outcomes. The second part of the statement is unique to each group. This second part starts with an action verb and represents the topics covered in the group. The choice of action verbs should be deliberate, as the verb indicates the level of learning the student is expected to achieve [35]. Table 3 lists three course learning outcomes for the Circuit Analysis course. The course learning outcomes draw their weights from the groups in Table 2. Additionally, note the removal of the Bloom's Taxonomy (BT) level column in Table 3, as it is now represented by the action verb at the beginning of the second part of the course learning outcome [35]. Course learning outcome 1 and course learning outcome 3 indicate a BT level of 6 for the action verb "design," while course learning outcome 2 indicates a BT level of 4 for the action verb "evaluate."

3.1.5. Matching Course Learning Outcomes with Program Outcomes

After the Course Learning Outcomes are established, they can be easily matched with Program Outcomes. It is crucial to ensure the following: 1. Each assigned

Program Outcome is matched with at least one course learning outcome. 2. A course learning outcome is matched with one and only one Program Outcome. Table 4 illustrates how Course Learning Outcomes are matched with Program Outcomes. The weights of Course Learning Outcomes should be appropriately assigned. In Table 4, the values assigned to Program Outcomes for Circuit Analysis Course are seen with their corresponding percentage weights.

3.1.6. Matching Assessment Artifacts with Course Learning Outcomes

An example assessment plan for the Circuit Analysis course is listed in Table 5. Each assessment artifact is

Table 2. Grouping of topics (Step 3)

Group No.	Topics in the Group	Weight (%)	Bloom's Taxonomy Level
1	*Basic Concepts, Circuit Laws, Node Voltage Method and Mesh Current Method, Fundamental Theorems	40	6
2	*Capacitor and Inductor, RL and RC Circuits	30	5
3	*Alternating Current, Analysis of AC Circuit and Power Calculations	30	5

Table 3. Developed course learning outcomes

No.	Course Learning Outcome	Weight (%)	Bloom's Taxonomy Level
	By the end of the semester, the student is expected to:		
1	*Analyze circuits using methods employed in the solution of direct current circuits	40	6
2	*Articulate the functions, operating principles, and types of capacitors and inductors	10	4
3	*Perform analysis using methods applied in the solution of alternating current circuits and calculate various power expression types	50	6

Table 4. Matching course learning outcomes to program outcomes (Step 5)

	Program Outcome 1: Possesses sufficient knowledge in mathematics, natural sciences, and electrical-electronics engineering topics	Program Outcome 2: Identifies, defines, models, and solves engineering problems, selecting and applying appropriate analytical methods and modeling techniques for this purpose	Program Outcome 3: Develops, selects, and utilizes modern techniques and tools necessary for engineering applications
Course Learning Outcome 1	20%	15%	---
Course Learning Outcome 2	---	---	30%
Course Learning Outcome 3	20%	15%	---
Total	40%	30%	30%

Table 5. Mapping assessment to course learning outcomes (Step 6)

		Quiz 1 Questions		Midterm Exam Qustions				HW	Lab	Quiz 2 Questions		Final Exam Questions			
Course Learning Outcomes	Weight of Course Learning Outcomes in the 14-Week Course	1	2	1	2	3	4	1	1	1	2	1	2	3	4
1. Can analyze using the methods used in direct current circuit solution	40%	5%	5%	15%	15%	---	---	15%	15%	---	---	15%	15%	---	---
2. Can express the function, operating principle, and types of capacitor and inductor	10%	---	---	---	---	20%	---	40%	40%	---	---	---	---	---	---
3. Can analyze using the methods used in alternating current circuit solution and can make calculations for various power expression types	50%	---	---	---	---	---	20%	15%	15%	5%	5%	---	---	20%	20%

assigned to the appropriate Course Learning Outcome. Similar conditions to Step 5 apply: 1. Each assigned Course Learning Outcome is matched with at least one assessment artifact. 2. An assessment sub-element is matched with one and only one Course Learning Outcome. The weight of each assessment assigned to a Course Learning Outcome can be easily calculated. The matching done in Step 5 is crucial to ensure accurate and transparent matching required for accreditation. Finally, the course design is evaluated by comparing the Course Learning Outcome weight in Table 3 (derived from the distribution of weights on topics) with the Course Learning Outcome weight in Table 5 (derived from the distribution of assessment grades). If the numbers in both tables match, the procedure is concluded.

4. A Case Study for a Circuit Analysis Course

The Circuit Analysis I course accommodates 47 students. This study is conducted based on the assessment dataset comprising 47 student evaluations. These data rely on previously obtained information from the recommended method. Periodic evaluations will be conducted according to the percentage weights provided in detail in Table 5, based on the measurement methods. However, certain assumptions need to be made for the assessment of the achievement levels. To determine that sufficient proficiency is achieved in each Learning Outcome of the Circuit Analysis Course, let the success threshold be ≥ 60% [27]. The condition for being considered successful should be set as ≥ 60% after each evaluation given in Table 5. However, it is not necessary for each assessment tool to be ≥ 60%; it may be wise to establish a ratio associated with their percentage weights. Additionally, for each learning outcome to probabilistically reach the ≥ 60% success threshold at the end of the year, a ratio associated with the percentage weights of assessment tools stands out. A case study example regarding these ratios is provided below:

- For Quiz 1, a minimum success rate of ≥ 50% is accepted, and if it is not achieved, additional measures such as extra study sessions, additional explanations, additional assignments, and solving questions together with the student are incorporated into the system as an On/Off control.

- For the Midterm Exam, a minimum success rate of ≥ 55% is accepted, and if it is not attained, additional measures are implemented using an On/Off control for extra study sessions.

- For the assignment, a minimum success rate of ≥ 80% is accepted, and if it is not achieved, additional measures are implemented using an On/Off controller for extra study sessions.

- For the Laboratory, a minimum success rate of ≥ 80% is accepted, and if it is not attained, additional practical exercises are incorporated using an On/Off control.

- After Quiz 2, the overall success is calculated, and if it does not reach ≥ 60%, collaborative efforts are initiated to assist in achieving the desired success in the Final Exam.

- After the Final Exam, the overall success is calculated, and if it does not reach ≥ 60%, collaborative efforts are provided to assist in achieving the required success for either the makeup exam or summer school.

- For the achievement level of Learning Outcomes and Program Outcomes, a success rate of ≥ 60% will be considered as passing.

To facilitate easier comparison and evaluation of the success scores of assessment elements, normalized values will be used. In this study, the Rescaling (min-max normalization) method has been employed.

4.1. Rescaling (min-max normalization)

Also known as min-max scaling or min-max normalization, rescaling is the simplest method and consists in rescaling the range of features to scale the range in [0, 1] or [−1, 1]. Selecting the target range depends on the nature of the data. The general formula for a min-max of [0, 1] is given as:

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{1}$$

where $\boldsymbol{x}$ is an original value, $\boldsymbol{x'}$ is the normalized value. If this formula is applied to the success grades in the exam, $\boldsymbol{x'}$ = Normalized exam score, $\boldsymbol{x}$ = Student exam score, $\mathbf{max}(\boldsymbol{x})$ = highest score in the exam, $\mathbf{min}(\boldsymbol{x})$ = lowest score in the exam [37]. The normalized result values obtained from the dataset of 47 students for Quiz 1, according to the percentage weights given in Table 5, are presented in Table 6 to encompass the level of achievement.

According to the results shown in Table 6 for Quiz 1, the normalized average value for Quiz 1 is 0.47. Regarding the condition ≥ 0.50, indicating the success status of Quiz 1, the number of students surpassing this level is 24, and the Achievement Level is calculated as 24/47=51.06.

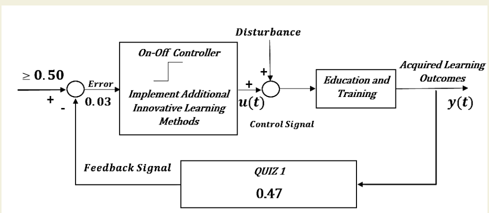

Figure 6. On-Off closed loop control system structure for post-quiz gains.

However, elevating the Quiz 1 average value from 0.47 to ≥ 0.50 can be a crucial step in meeting the desired conditions for learning outcomes. To achieve this step, the closed-loop control system structure provided in Figure 6 will be utilized. Within this structure, the use of On-Off controller is deemed appropriate. The foundation of the On-Off control is to provide full power to the system until the desired setpoint is reached. When the setpoint is reached and exceeded in feedback, the power is completely turned off.

The activities carried out for Quiz 1 examination are performed separately for the Midterm Exam, Assignment, Laboratory, Quiz 2, and the Final Exam. After each new assessment and the inclusion of additional learning techniques into the system, the results are evaluated. Additionally, disruptive events such as COVID-19 or similar significant incidents will be introduced into the system. A design is provided in the system modeling to incorporate the effects of this in the design.

The assessment tools obtained based on the 47-student evaluation dataset, derived from the method proposed earlier, are presented in Table 7 with the normalized values for Learning Outcomes. In Table 8, the achievement levels based on Learning Outcomes are displayed. For the Learning Outcome: "Can perform analysis using the methods employed in alternating current circuit analysis and calculate various power expressions," the average is 0.591, and the success rate remains at 57.44%. It is necessary to raise this success level above ≥60%. For this purpose, the proposed method can be utilized.

In Table 9, the alignment of Course Learning Outcomes with Program Outcomes and their corresponding success levels is presented. Program Outcome 1 and Program Outcome 2 exhibit a success level of only 57.44%. It is necessary to elevate this success level to ≥ 60%. The inadequacies in the success levels obtained through the evaluation tools in the current systems are not addressed by incorporating different training methods into the system until the next assessment tool. The proposed method can be used to implement these educational interventions with the aim of achieving the desired improvement in success levels.

5. Conclusion

This article emphasizes how closed-loop control systems can enhance learning outcomes in engineering education and contribute to students' more effective learning. This approach, which is addressed through the design of program outcomes, teaching methods, the training process, and assessment processes, has the potential to make engineering education more effective and student-centered. The example of electrical-electronic engineering is used to demonstrate the applicability of this approach, but similar methods can be applied in other engineering disciplines as well. This approach

Table 6. Achievement level based on course learning outcomes for Quiz 1

	Quiz 1 Questions		Quiz 1 (mean)	Minumum success for Quiz 1	Objectives	Achievement Levek
Course Learning Outcomes	1	2				
1. Can analyze using the methods used in direct current circuit solution	0.452	0.487	0.470	? 0.50	Could not be reached, Do additional study	51.06
2. Can express the function, operating principle, and types of capacitor and inductor	Non	Non	---	---	---	---
3. Can analyze using the methods used in alternating current circuit solution and can make calculations for various power expression types	Non	Non	---	---	---	---

Table 7. Numerical matching of evaluation with course learning outcomes

	Quiz 1 Questions		Midterm Exam Qustions				HW	Lab	Quiz 2 Questions		Final Exam Questions			
Course Learning Outcomes	1	2	1	2	3	4	1	1	1	2	1	2	3	4
1. Can analyze using the methods used in direct current circuit solution	0.452 5%	0.487 5%	0.55 15%	0.50 15%			S1 0.90 15%	L1 0.82 15%			0.40 15%	0.60 15%		
2. Can express the function, operating principle, and types of capacitor and inductor					0.65 20%		S2 0.82 40%	L2 0.85 40%						
3. Can analyze using the methods used in alternating current circuit solution and can make calculations for various power expression types						0.48 20%	S3 0.87 15%	L3 0.75 15%	0.52 5%	0.55	5%		0.53 20%	0.46 20%

Table 8. Achievement levels based on course learning outcomes

Course Learning Outcomes	Weight of Course Learning Outcomes in the 14-Week Course	Normalized Average Term Evaluation Score	Achievement Level
1. Can analyze using the methods used in direct current circuit solution	40%	0.635	70.21
2. Can express the function, operating principle, and types of capacitor and inductor	10%	0.798	93.61
3. Can analyze using the methods used in alternating current circuit solution and can make calculations for various power expression types	50%	0.591	57.44

Table 9. Matching course learning outcomes with program outcomes based on data set

	Program Outcome 1	Program Outcome 2	Program Outcome 3
Course Learning Outcome 1	(0.635) × 20%	(0.635) × 15%	
Course Learning Outcome 2	---	---	(0.798) × 30%
Course Learning Outcome 3	(0.591) × 20%	(0.591) × 15%	---
Program Output Average Values	0.613	0.613	0.798
Normalized Program Outcome Evaluation Score	40% = 0.2425	30% = 0.1839	30% = 0.2394
Normalized Average Program Outcome Evaluation Score		0.2425 + 0.1839 + 0.2394 = 0.6658	
Achievement Level	57.44	57.44	93.61

may contribute to improving the quality of engineering education and better aligning graduates with industry requirements. In this study, a case study is presented with a digitized example model for the course learning outcomes of Circuit Analysis I, developed and introduced to the literature based on the implementation of a closed-loop control system. The presented model structure is explained step by step and analyzed in detail for the accessibility of course learning outcomes. The presented system has a dynamic structure, suitable for the addition of new training techniques and methods.

In the current education system, the results of exams and other assessment tools are considered separate components that do not influence each other. However, the proposed method offers the opportunity to include additional study and different learning methods into the system based on the results students achieved in previous assessments, potentially impacting the results of subsequent assessment tools. This approach allows for adaptive management of the education system. When the proposed method is used, students' progress can be observed, and personalized learning materials can be provided by analyzing their learning speeds. This way, each student's educational experience can be made more effective and personalized. This approach enables the education system to operate in a more flexible and student-centered manner, providing the opportunity to maximize each student's potential. Closed-loop control systems in education can offer a new perspective. Monitoring how close students are to achieving learning outcomes, evaluating teaching methods, and continuously improving the program can lead to more effective learning and efficient education programs. The use of closed-loop control systems in education could be a powerful tool to increase student success and enhance the quality of educational institutions. Additionally, this study may serve as a valuable guide for universities in the assessment of courses in the Bologna Quality processes. Furthermore, as education continues to embrace digital transformation, integrating feedback-driven systems can bridge traditional instruction with AI-powered adaptive learning. Future work should explore the application of this framework across multidisciplinary programs and investigate its long-term impact on student success metrics.

Research Ethics

Not applicable.

Artificial Intelligence Use

The author states that generative AI tools (e.g., ChatGPT) were used only for language editing during manuscript preparation. No AI-generated content was used for analysis or interpretation. The authors take full responsibility for the integrity and accuracy of the content.

Author Contributions

The author solely conducted all stages of this research.

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6. References

[1] Makhoul, S. A. (2019). Higher education accreditation, quality assurance and their impact to teaching and learning enhancement. Journal of Economic and Administrative Sciences, 35(4), 235–250. https://doi.org/10.1108/JEAS-08-2018-0092

[2] Dill, D. D., & Beerkens, M. (2013). Designing the framework conditions for assuring academic standards: Lessons learned about professional, market, and government regulation of academic quality. Higher Education, 65(3), 341–357. https://doi.org/10.1007/s10734-012-9548-x

[3] de Paor, C. (2016). The contribution of professional accreditation to quality assurance in higher education. Quality in Higher Education, 22(3), 228–241. https://doi.org/10.1080/13538322.2016.1263925

[4] Kaliannan, M., & Chandran, S. D. (2012). Empowering students through outcome-based education (OBE). Research in Education, 87(1), 50–63. https://doi.org/10.7227/RIE.87.1.4

[5] Syeed, M. M., Shihavuddin, A., 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

[6] Khanna, R., & Mehrotra, D. (2019). The roadmap for quality improvement from traditional through competency based (CBE) towards outcome based education (OBE) in dentistry. Journal of Oral Biology and Craniofacial Research, 9(2), 139–142. https://doi.org/10.1016/j.jobcr.2019.02.004

[7] Zamir, M. Z., Abid, M. I., Fazal, M. R., Qazi, M. A. A. R., & Kamran, M. (2022). Switching to outcome-based education (OBE) system, a paradigm shift in engineering education. IEEE Transactions on Education, 65(4), 695–702. https://doi.org/10.1109/TE.2022.3169184.

[8] Rao, N. J. (2020). Outcome-based education: An outline. Higher Education for the Future, 7(1), 5–21. https://doi.org/10.1177/2347631119886418

[9] McKendree, B., & Washburn, S. G. (2021). Secondary teachers' implementation of metacognition and interpretation of student metacognitive knowledge and regulation. Journal of Agricultural Education, 62(3).

[10] Wu, Y., Xu, L., & Philbin, S. P. (2023). Evaluating the role of the communication skills of engineering students on employability according to the outcome-based education (OBE) theory. Sustainability, 15(9), 9711. https://doi.org/10.3390/su15129711

[11] Abdul Karim, N. A. H., & Yin, K. Y. (2018). Outcome-based education: An approach for teaching and learning development. Journal of Research, Policy & Practice of Teachers and Teacher Education, 3(1), 26–35.

[12] Xu, Z., Ge, L., He, W., Song, G., Liu, J., Hou, L., ... Li, X. (2024). Developing a BOPPPS (bridge-in, objectives, pre-assessment, participatory learning, post-assessment and summary) model combined with the OBE (outcome based education) concept to improve the teaching outcomes of higher education. Humanities and Social Sciences Communications, 11(1), 1–13.

[13] Guggari, S., Okoye, K., & Abraham, A. (2023). Review of challenges and best practices for outcome based education: An exploratory outlook on main contributions and research topics. In A. Abraham, A. Bajaj, N. Gandhi, A. M. Madureira, & C. Kahraman (Eds.), Innovations in Bio-Inspired Computing and Applications. IBICA 2022. Lecture Notes in Networks and Systems (Vol. 649). Springer. https://doi.org/10.1007/978-3-031-27499-2_58

[14] Akir, O., Eng, T. H., & Malie, S. (2012). Teaching and learning enhancement through outcome-based education structure and technology e-learning support. Procedia - Social and Behavioral Sciences, 62, 87–92. https://doi.org/10.1016/j.sbspro.2012.09.015

[15] Li, M., & Rohayati, M. I. (2024). The relationship between learning outcomes and graduate competences: The chain-mediating roles of project-based learning and assessment strategies. Sustainability, 16(14), 6080.

[16] Garnjost, P., & Lawter, L. (2019). Undergraduates' satisfaction and perceptions of learning outcomes across teacher- and learner-focused pedagogies. The International Journal of Management Education, 17(2), 267–275. https://doi.org/10.1016/j.ijme.2019.03.004

[17] Logan, R. M., Johnson, C. E., & Worsham, J. W. (2021). Development of an e-learning module to facilitate student learning and outcomes. Teaching and Learning in Nursing, 16(2), 139–142.

[18] Yamarik, S. (2007). Does cooperative learning improve student learning outcomes? The Journal of Economic Education, 38(3), 259–277.

[19] Isusi-Fagoaga, R., García-Aracil, A., & Navarro-Milla, I. (2023). Impact of teaching-learning approaches on graduates' learning outcomes: Evidence in Belarus. Higher Education, Skills and Work-Based Learning.

[20] Clark, N., & Hsu, J. L. (2023). Insight from biology program learning outcomes: Implications for teaching, learning, and assessment. CBE—Life Sciences Education, 22(1), Article ar5.

[21] Marín-Vinuesa, L. M., & Rojas-García, P. (2023). E-learning web-apps use acceptance: A way to guide perceived learning outcomes in blended learning. Sustainability, 15(3), 2136.

[22] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives, the classification of educational goals. Handbook I: Cognitive domain. David McKay Company.

[23] Yan, L., Echeverria, V., Jin, Y., Fernandez-Nieto, G., Zhao, L., Li, X., ... Martinez-Maldonado, R. (2024). Evidence-based multimodal learning analytics for feedback and reflection in collaborative learning. British Journal of Educational Technology, 55(5), 1900–1925.

[24] Huba, M. E., & Freed, J. E. (2000). Learner-centered assessment on college campuses: Shifting the focus from teaching to learning. Allyn & Bacon.

[25] Kirkavak, N., Özaktaş, H., & Ertem, M. A. (2019). Müdek report card: An alternative model for assessment of program outcomes. Journal of Industrial Engineering, 30(1), 32–48.

[26] Kirschner, P. A. (2012). Epistemology or pedagogy, that is the question. Advances in Cognitive Psychology, 8(2), 205–215.

[27] Ming, L. S. (2012). Alignment of learning outcomes and assessment. In 2012 International Conference on Information Technology Based Higher Education and Training (ITHET) (pp. 1–3). IEEE

[28] Linkon, S. L. (2024). What it means to transform teaching and learning: A summary of recent literature on progressive education. Retrieved February 1, 2024, from http://www.teachingforchange.org/wp-content/uploads/2013/01/ProgressiveEdSummary.pdf

[29] National Governors Association. (2007). Compete to complete: Increasing postsecondary attainment through common standards. Retrieved February 1, 2024, from https://www.ccsso.org/sites/default/files/2017-07/CompeteToComplete

[30] Rexeisen, R. J., & Garrison, M. E. (2013). A model for international students' sense of belonging: The role of international student affairs professionals. Journal of Studies in International Education, 17(5), 606–622.

[31] ABET (Accreditation Board for Engineering and Technology). (2017). Criteria for accrediting engineering programs: 2017-2018. Baltimore, MD: Author.

[32] Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231.

[33] Suskie, L. (2018). Assessing student learning: A common sense guide. John Wiley & Sons.

[34] Angelo, T. A., & Cross, K. P. (1993). Classroom assessment techniques: A handbook for college teachers. Jossey-Bass.

[35] Elsheikh, E. M. A., Sarudin, I., & Gunawan, T. S. (2017). A systematic approach for developing course learning outcomes to fulfil accreditation requirements in Malaysia. In 2017 7th World Engineering Education Forum (WEEF) (pp. 428–433). IEEE

[36] Anadolu University Official Web Site. (n.d.). Devre analizi ders içerik. Retrieved February 1, 2024, from https://www.anadolu.edu.tr/akademik/fakulteler/ders/13586/devre-analizi/ders-icerik

[37] Bostan, A., & Karakaya, M. (2016). A case study on impact of student course-attendance on exam grades. Mersin University Journal of the Faculty of Education, 12(1).

 https://doi.org/10.26701/ems.1733766