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(IJMOE)**www.gaexcellence.com/ijmoe**THE SPA-7 FRAMEWORK: SUSTAINING COURSE
OUTCOME ATTAINMENT THROUGH CONSTRUCTIVE
ALIGNMENT IN MATLAB/SIMULINK LABORATORY
MODULES FOR A LINEAR SYSTEM COURSE**

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Abstract:

Outcome-Based Education (OBE) requires every Course Outcome (CO) to meet a minimum Key Performance Indicator (KPI) threshold each semester. Despite the maturity of these monitoring tools, little attention has been given in the engineering education literature to a fundamental question: do decisions about assessment design lead to stable CO attainment across cohorts and semesters. Most studies do not provide guidance on how to design software-based laboratory assessments to ensure consistency of CO results over time. This paper presents the development and empirical validation of the Seven-Pillar Software-Based Practical Assessment (SPA-7) framework, a constructive-alignment framework that breaks down Biggs and Tang's principle into seven design pillars for software-based laboratory assessments in engineering courses. A retrospective documentary analysis of institutional Continuous Development of Learning (CDL) and Continuous Quality Improvement (CQI) data over four consecutive semesters (October 2022 to August 2024) was performed for two diploma cohorts at Universiti Teknologi MARA Cawangan Pulau

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Pinang to generate eight cohort-semester observations. The seven SPA-7 pillars are based on the official manual Practical Task ESE241, and are aligned with principles in the established learning science literature (constructive alignment, dual coding, cognitive load and formative assessment) and corroborated with empirical performance data for the practical CO (CO2, aligned with Program Outcome PO5). Results show that CO2 results ranged from 82.1% to 95.8% across all eight observations, with a cross-cohort mean of 89.7%, and all observations exceeded the institutional KPI threshold of 65%. The narrow distribution across different cohort characteristics suggests that the framework may support stable and outcome-relevant assessment performance. The SPA-7 framework provides a theoretically sound and empirically substantiated model for maintaining CO performance in software-based laboratory assessments. The framework also supports simultaneous evidence generation for both COs and corresponding POs, improving efficiency in Engineering Accreditation Council (EAC) Standard 2020 accreditation reporting. Furthermore, it is posited to be applicable to other engineering courses where analytical solutions and simulated outputs can be compared.

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Keywords:

Constructive Alignment, Outcome-Based Education, Course Outcome Attainment, Matlab/Simulink, Engineering Laboratory Assessment, Seven-Pillar Software-Based Practical Assessment.



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Introduction

Outcome-Based Education (OBE) has become the dominant pedagogical framework for accredited engineering programs in Malaysia and internationally (IEA et al., 2021; Spady, 1994). Each course defines Course Outcomes (COs) that are mapped to a set of Program Outcomes (POs) reflecting the graduate attributes the engineering accreditation body expects. In this framework, every CO must meet a minimum Key Performance Indicator (KPI), which is typically set by the faculty at between 50% and 65%. The Continuous Quality Improvement (CQI) cycle, operationalized through the Plan-Do-Check-Act (PDCA) loop, is mandated by the Engineering Accreditation Council under the EAC Standard 2020 (Engineering Accreditation Council, 2020). At Universiti Teknologi MARA, CO and PO attainment is monitored through the electronic Result Exam System (eRES), which generates standardized Continuous Development of Learning (CDL) and CQI reports each semester (Engineering Accreditation Council, 2020). Even though these monitoring tools are well-developed, the engineering education literature has paid little attention to a more basic question: do assessment design choices yield stable CO performance across cohorts and across semesters.

A second strand of literature concerns PO5, which mandates the application of "appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations" (Engineering Accreditation Council, 2020; IEA et al., 2021). PO5 is increasingly central to engineering accreditation worldwide, and software-based laboratory assessment is the most common instrument used to generate PO5 evidence (Qadir et al., 2020; Sultana, 2015). The Conceive-Design-Implement-Operate (CDIO) framework (Crawley et al., 2007) explicitly positions hands-on, tool-based engineering work as a core competency that engineering programs must cultivate. The design of a software-based laboratory, beyond the mere assertion that students utilize a certain tool, received insufficient systematic examination, especially at the diploma level.

A third theoretical anchor is constructive alignment, the principle articulated by Biggs (Biggs, 1996) and elaborated by Biggs and Tang (Biggs & Tang, 2011) that Learning Outcomes (LOs), Teaching and Learning Activities (TLAs), and Assessment Tasks (ATs) must be mutually consistent if a course is to produce reliable evidence of student learning. Constructive alignment has been widely adopted in higher-education quality-assurance frameworks but has been operationalized in engineering-laboratory contexts only sporadically. The cognitive-science literature on dual-coding (Paivio, 2010) and multimedia learning (Mayer, 2009), together with cognitive-load theory (Sweller et al., 2019) and formative-assessment research (A. Black, 2019), offers complementary mechanisms by which a constructively aligned laboratory can be expected to produce sustained learning.

ESE241 is a part 4 core course in the Diploma in Electrical Engineering program. The course covers four chapters: (1) introduction to signals; (2) solutions of linear differential equations; (3) Laplace transform and its applications; and (4) trigonometric and exponential Fourier series. Three Course Outcomes are defined: CO1 (cognitive level C5, calculation-intensive, mapped to PO2; Identify and analyze well-defined engineering problems reaching substantiated conclusions using codified methods of analysis specific to their field of activity); CO2 (psychomotor level P3, software implementation, mapped to PO5; Apply appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations); and CO3 (affective level A2, discussion-based, mapped to PO12; recognize the need for, and have the ability to engage in, independent updating in the context of specialized technical knowledge). The course assessment plan comprises Test 1 (10%), Test 2 (15%), four laboratory modules (20% in total, 5% each), an assignment (5%), and the final exam (50%). The four lab modules collectively constitute the CO2 instrument and the empirical focus of this study.

This study makes two contributions to the engineering education literature. First, we propose a Seven-Pillar Software-Based Practical Assessment (SPA-7) framework based on Biggs and Tang's constructive alignment principle (Biggs & Tang, 2011). It is a stepwise application of constructive alignment for software-based laboratory assessments in engineering courses and is outlined in section Theoretical Framework. Secondly, we validate the framework using four semesters of eRES CQI records from Universiti Teknologi MARA Cawangan Pulau Pinang's ESE241 Linear System course. The analysis examines the trajectory of CO2 attainment across cohorts and how well the data fits the mechanism predicted by the framework.

The overall study framework is shown in

Figure 1. Three input streams inform the work: the ESE241 Manual Practical Task as the design document; institutional eRES, CDL and CQI records for four semesters and two diploma

cohorts; and the learning science literature on constructive alignment, dual coding, cognitive load and formative assessment. These inputs are fed into a three-phase process of pillar abstraction, empirical analysis, and framework validation. The outputs are a validated SPA-7 framework, evidence of stable CO2 attainment and notes on the transferability of the framework to other engineering courses.

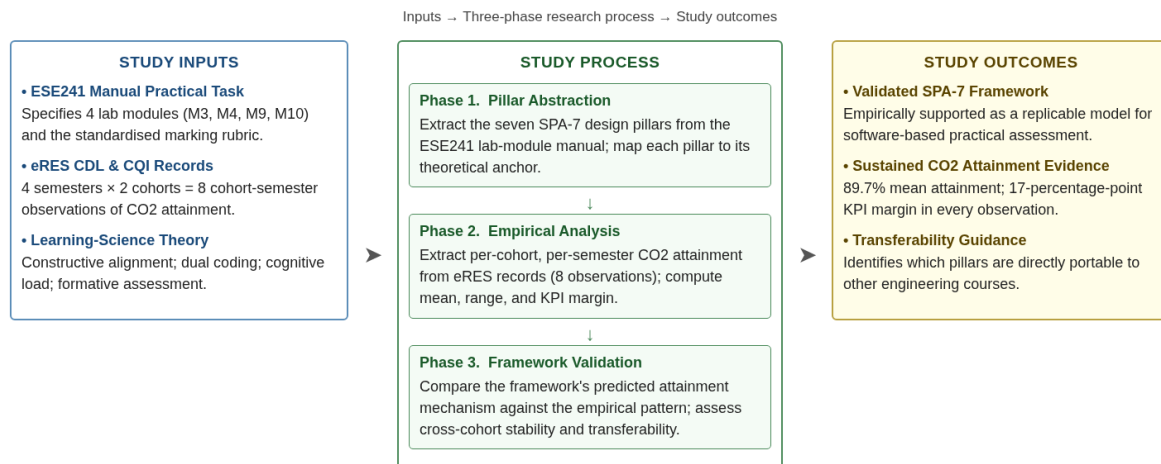


Figure 1: Study Framework: Inputs, Three-Phase Research Process, And Outcomes of the Present Study

The rest of the paper is organized as follows. Section Theoretical Framework elaborates on the SPA-7 framework and substantiates each of its seven pillars with proven learning-science theory. Section Methodology delineates the methods for empirical validation. Section Result and Discussion present the four-semester attainment results and discusses how the SPA-7 pillars account for the observed pattern. Section Conclusion concludes with a discussion of limitations, implications for OBE assessment design, and the transferability of SPA-7 to other engineering courses.

Theoretical Framework

Constructive Alignment as the Foundation

Constructive alignment, articulated by Biggs in 1996 (Biggs, 1996) and elaborated by Biggs and Tang (Biggs & Tang, 2011), holds that the three core elements of any course, the LOs, the TLAs, and the ATs, must be mutually consistent for the course to produce reliable evidence of intended learning. The principle has two parts. First, the constructive part: drawing on constructivist learning theory, learning is what the student does, not what the teacher does; the role of the lecturer is to design activities through which students themselves construct understanding. Second, the alignment part: every TLA must develop the LO's capacity, and every AT must show it. When all three elements align, the course produces clear evidence of learning; when they misalign, extraneous factors contaminate observed performance.

In an OBE context, the LOs of a course align with the COs of the course; the TLAs align with the lectures, tutorials, and laboratory activities through which the COs are pursued; and the ATs align with the assessment instruments through which the CO attainment is measured (Spady, 1994). Hence, constructive alignment is the theoretical basis for the whole OBE-CQI cycle.

The CDL and the CQI reports produced by eRES are longitudinal records of the level of alignment achieved by a course across semesters.

The Seven-Pillar Software-Based Practical Assessment (SPA-7) Framework

The SPA-7 framework breaks down constructive alignment into seven specific design pillars for software-based laboratory assessment in engineering courses.

Figure 2 shows the framework. It places the student at the middle of a Biggs-style triangle whose three vertices are the LOs (the practical CO and its mapped PO), the TLAs (the laboratory procedures supported by industry-standard software), and the ATs (the rubric and the pre-laboratory versus simulation comparison). The triangle is enclosed by the outer accreditation envelope of OBE, EAC Standard 2020, the Washington Accord, and the Malaysian Qualifications Framework (MQF) 2.0. The seven pillars are arrayed around the triangle, each connected to the vertex (or pair of vertices) it primarily supports.

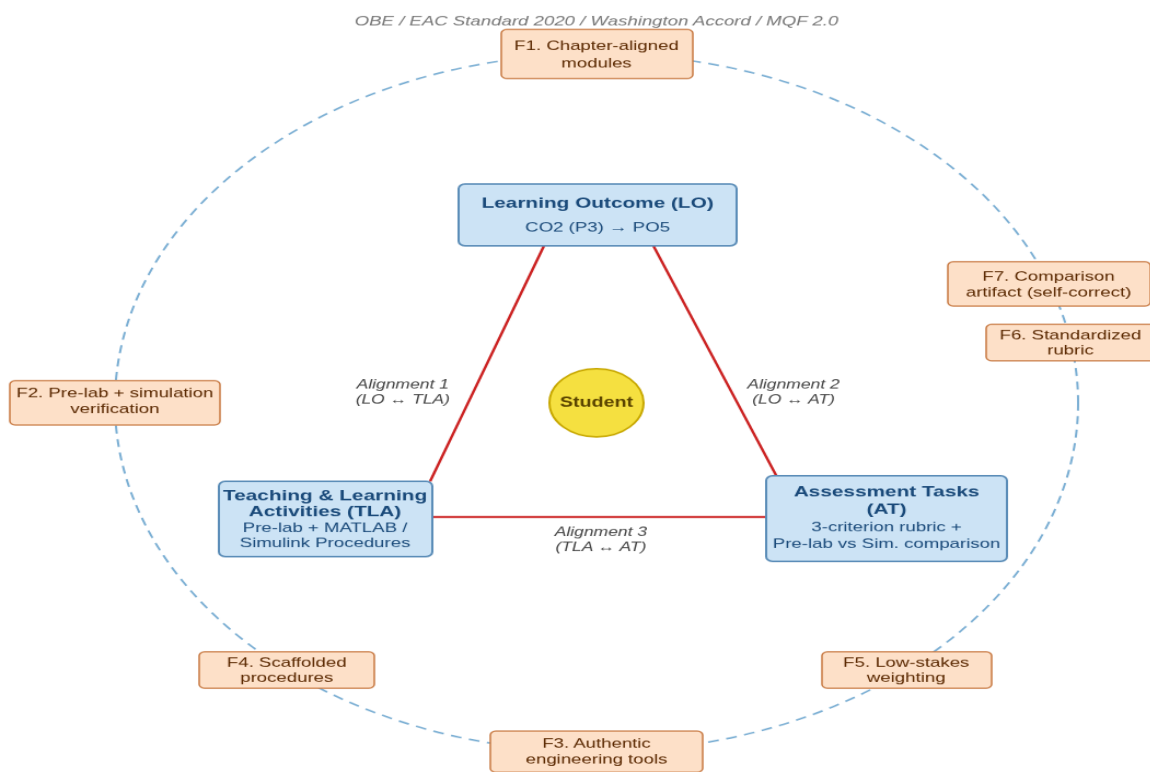


Figure 2: The SPA-7 Framework — A Constructive-Alignment-Based Model for Software-Based Practical Assessment In Engineering Courses (Biggs & Tang, 2011)

Table 1 Description of SPA-7 Framework

Pillar	Name	Description
F1	Chapter-aligned modules	One laboratory module per syllabus chapter ensuring no syllabus chapter is left unmeasured by the practical CO instrument.
F2	Pre-lab simulation verification	+ An analytical paper-based task and the software verification with dual-channel encoding.

F3	Authentic engineering tools	Industry standard software such as MATLAB and Simulink, in support of PO5 graduate attribute attainment.
F4	Scaffolded procedures	Sample code and step-by-step instructions that reduce extraneous cognitive load but keep conceptual decisions.
F5	Low-stakes weighting	Per-module weight that is easy to encourage exploration and self-correction without incurring too much exam pressure penalty.
F6	Standardized rubric	Consistent marking criteria across all modules, cohorts and lecturers, leading to inter-rater reliability and longitudinal comparability.
F7	Comparison artifact (self-correct)	A compulsory comparison table of pre-laboratory versus simulation, which reveals explicit learning objects of analytical-simulation discrepancies.

Table 1 summarizes the SPA-7 based on the defined framework in Figure 2. Each pillar is anchored in established learning-science theory. F1 and F7 instantiate Biggs and Tang's alignment principle directly, the first by ensuring LO-to-AT coverage and the second by closing the AT-to-LO loop through metacognitive reconciliation. F2 instantiates Paivio's (Paivio, 2010) and Mayer's (Mayer, 2009) dual-coding and multimedia-learning theories. F3 instantiates the CDIO authentic-tool principle (Crawley et al., 2007) and the Washington Accord graduate-attribute requirements (IEA et al., 2021). F4 instantiates Sweller's cognitive-load theory (Sweller et al., 2019). F5 instantiates the formative-assessment principles articulated by Black and Wiliam (P. Black & Wiliam, 2009). F6 instantiates Brookhart's (Brookhart, 2018) criteria for effective rubric design.

The SPA-7 Mechanism of Sustained Attainment

The framework's predicted mechanism of sustained CO performance is as follows. Pillars F1, F3, and F6 create structural alignment between LO and AT, ensuring that the assessment instrument is designed to provide proof of the intended outcome rather than ancillary skills. Pillars F2 and F4 design the TLA so that the student's cognitive activity during the lab session matches the cognitive activity required to produce the assessment artifact. Pillars F5 and F7 establish a closed feedback loop by allowing low-stakes experimentation and requiring students to engage in comparison and reconciliation activities together; they convert the assessment from a one-shot judgment into a learning event. When all seven pillars are in place the assessment shows steady evidence of the intended outcome across cohorts. The framework predicts that the practical CO will achieve or exceed its KPI in each semester, provided that the implementation is careful. This prediction is tested directly in Section Result and Discussion.

Methodology

Study Design

This study is a retrospective documentary review of institutional CQI records. The records used are the standardized CDL Report for underperforming CO and CQI Course-Level Report templates which ESE241 lecturers fill out each semester within the eRES system. No primary student data were collected. All data are aggregated and de-identified and generated as part of the routine institutional CQI reporting. Ethical review for retrospective use of aggregate institutional records falls under the current UiTM CQI policy.

Setting and Sample

The research has been carried out in the Diploma in Electrical Engineering at Universiti Teknologi MARA Cawangan Pulau Pinang, Permatang Pauh Campus. ESE241 is offered to two batches of diploma students, CEEE111 (Diploma in Electrical Engineering – Electronic) and CEEE112 (Diploma in Electrical Engineering – Power). The observation period is four consecutive semesters from October 2022 to August 2024. The eight cohort-semester observations generated by this study constitute the unit of analysis. The confirmed enrolment for the last semester (March-August 2024) was 35 students for CEEE111 and 52 students for CEEE112. The institutional COPO archives provide similar data for the last three semesters.

Assessment Instrument

The CO2 instrument consists of four MATLAB/Simulink lab modules: Module 3, Module 4, Module 9, and Module 10 from the official Manual Practical Task ESE241. Each module relates to a particular chapter of the syllabus. A summary of the overall Course Assessment Plan (CAP) is provided in Table 2, and the descriptions for each module are given in Table 3.

Table 2: Course Assessment Plan (CAP) for ESE241

CO	PO	Assessment Instrument	Weight (%)
CO1 (C5)	PO2	Test 1, Test 2, Final Exam	75
CO2 (P3)	PO5	Lab Modules 3, 4, 9, and 10 (5% each)	20
CO3 (A2)	PO12	Assignment	5

Table 3: Description of the Four Laboratory Modules Constituting the CO2 Instrument

Module	Topic	Chapter	Software	Key Artifacts
3	Graphical Method (signal properties)	Ch 1	MATLAB	Pre-lab piecewise function; MATLAB code; signal-property plots; comparison table
4	Solution of Linear Differential Equation	Ch 2	MATLAB (<i>dsolve, ezplot</i>)	Pre-lab analytical solution; RLC circuit MATLAB simulation; output-response comparison
9	Application of Laplace Transform	Ch 3	MATLAB / Simulink	Transfer function derivation; Simulink RLC model; pole-zero stability plot
10	Trigonometric Fourier Series	Ch 4	MATLAB / Simulink	Symmetry identification; Simulink TFS coefficient blocks for $n = 1..7$; Analytical vs. Simulink comparison

Each module is following a common format of six elements: (i) Objectives, (ii) Theory and reference equations, (iii) Pre-Laboratory analytical task, (iv) MATLAB or Simulink procedures

with sample code, (v) Result Sheet, and (vi) Comparison table between Pre-Laboratory and Simulation results. All modules are assessed using the common three-criterion rubric shown in Table 4.

Table 4: Standardized Three-Criterion Marking Rubric Applied to All Four Modules

Criterion	Marks	Evidence Source
Usage of equipment / software	2	Observed in-lab
Circuit / model construction	2	MATLAB code / Simulink model
Data measurement / output verification	1	Result sheet (output plot, comparison)
Total per module	5	4 modules × 5 = 20% of course

Data Sources

Four types of institutional records were used. First, the CDL report on underperforming CO (PDF) for the March– August 2024 semester presents four-semester CO attainment patterns for both cohorts. Second, the same semester CQI course-level report (PDF) includes achievement data in the form of numbers for each cohort, along with the lecturer’s PDCA commentary. Third is the Manual Practical Task ESE241 (March– August 2023 edition), which serves as the design specification document for the four laboratory modules and the source for the SPA-7 pillar definitions. Fourth, per-semester Final Marks Excel files (currently with limited access). All four sources are produced within the eRES framework and bear institutional verification.

Analytical Approach

The analysis proceeds in three stages. Stage 1 develops the SPA-7 framework by abstracting the seven design features from the manual Practical Task and mapping each feature to its theoretical anchor in the established learning-science literature. Stage 2 involves a descriptive empirical examination of the mean and range of CO₂ performance every semester and cohort, compared to the 65% institutional KPI. Stage 3 involves the framework-validation phase: the empirical attainment data are analyzed via the lens of the SPA-7 framework's mechanism, with the seven pillars offering an explanatory account of the observed attainment. A cross-cohort analysis of CEEE111 and CEEE112 assesses the consistency of the evaluation instrument's outcomes, irrespective of the characteristics of the cohort intake, as anticipated by the framework.

Results and Discussion

CO₂ Attainment Across Four Semesters and Two Cohorts

Table 5 displays the CO₂ performance data obtained from the CDL Report for CO and the CQI course-level report for both diploma cohorts for the four consecutive semesters included in the observation period.

Table 5: CO2 Attainment Across Four Semesters and Two Diploma Cohorts

Semester	CEEE111 CO2 (%)	CEEE112 CO2 (%)	KPI (%)
Oct 2022 – Feb 2023	95.8	88.0	65
Mac – Aug 2023	91.6	95.8	65
Oct 2023 – Feb 2024	82.1	87.3	65
Mac – Aug 2024	86.3	90.4	65
Mean	88.95	90.38	65
Range	82.1 – 95.8	87.3 – 95.8	—

Across the eight cohort-semester observations, CO2 attainment ranged from 82.1% (CEEE111, October 2023 – February 2024) to 95.8% (CEEE111, October 2022 – February 2023, and CEEE112, March – August 2023). The mean across cohorts was 89.7%. In each observation, the performance was above the 65% institutional KPI by a minimum of 17 percentage points. No semester or cohort registered a CO2 achievement beneath the KPI threshold.

Cross-Cohort Consistency

The main empirical result is this stability. In ESE241, of the four semesters, only the course outcome CO2 was successful in achieving the KPI in all observations, while the cognitive-calculation outcome (CO1) and the affective-discussion outcome (CO3) exhibited much greater variability in the same observations. The limited range of CO2 readings across different cohort-intake characteristics is exactly what the SPA-7 framework anticipates: when the seven pillars are functioning, the assessment tool should yield consistent proof of the desired outcome regardless of cohort-level differences.

Framework Validation: How the SPA-7 Pillars Account for the Observed Attainment

Table 6 summarizes the seven SPA-7 pillars together with their operational definition in ESE241 and their theoretical anchor in the learning-science literature. Each pillar is then discussed in turn, with reference to how it operates in the four laboratory modules and how it is expected to contribute to the observed CO2 attainment.

Table 6: The Seven Pillars of The SPA-7 Framework as Instantiated in ESE241

#	SPA-7 Pillar	Operational Definition in ESE241	Theoretical Anchor
F1	Chapter-aligned modules	Exactly one lab module per syllabus chapter (Ch. 1–4); every chapter is measured by the CO2 instrument.	Constructive Alignment — LO ↔ AT alignment (Biggs, 1996; Biggs & Tang, 2011)
F2	Pre-lab simulation verification +	Each module requires an analytical pre-lab on paper before MATLAB / Simulink verification, with a mandatory side-by-side comparison.	Dual-coding theory (Paivio, 2010); Multimedia learning (Mayer, 2009)

F3	Authentic engineering tools	MATLAB and Simulink as industry-standard tools; m-file scripts and Simulink models constitute portable evidence.	CDIO framework (Crawley et al., 2007); Washington Accord graduate attributes (IEA et al., 2021)
F4	Scaffolded procedures	Step-by-step instructions with a sample code reduce extraneous loads while preserving the conceptual decisions students must make.	Cognitive Load Theory (Sweller et al., 1998)
F5	Low-stakes weighting	5% per module $\times 4 = 20\%$ of total. Errors during simulation are not heavily penalized, encouraging exploration and self-correction.	Formative assessment theory (P. Black & Wiliam, 2009)
F6	Standardized three-criterion rubric	An identical rubric is used for every module across all cohorts and lecturers, which supports inter-rater reliability and longitudinal comparability.	Effective rubric design (Brookhart, 2018)
F7	Built-in comparison artifact	The mandatory "Pre-Lab vs. MATLAB result" comparison table forces explicit reconciliation of analytical and simulated outputs.	Metacognitive self-regulation: constructive alignment AT \leftrightarrow LO closing the loop (Biggs & Tang, 2011; P. Black & Wiliam, 2009)

Pillar F1 — chapter-aligned modules — creates a direct correlation between syllabus chapters and assessment instances, hence mitigating the possibility that any chapter remains unassessed by the CO2 instrument. This is the notion of constructive alignment concerning LO-to-AT coverage implemented at the within-CO level (Biggs, 1996; Biggs & Tang, 2011). The four ESE241 modules cover signal categorization and properties (Module 3, Chapter 1), the resolution of linear differential equations (Module 4, Chapter 2), applications of the Laplace transform (Module 9, Chapter 3), and trigonometric Fourier series (Module 10, Chapter 4). No chapter is without measurement. The pillar predicts that the CO2 statistic, calculated as a weighted average across modules, will demonstrate more stability than a CO2 statistic derived from a single capstone laboratory exercise — a forecast consistent with the reported range of 82.1%–95.8%.

Pillar F2—pre-laboratory plus simulation verification—instantiates the dual coding principle of Paivio (Paivio, 2010) and the cognitive theory of multimedia learning of Mayer (Mayer, 2009). Each module requires the student to solve the problem analytically on paper before verifying the solution numerically with MATLAB or Simulink. Therefore, students encounter the same conceptual relationship in symbolic form (the analytical pre-laboratory) and again in visual-numerical form (the simulation output). Dual-coding theory predicts that this dual-channel encoding produces stronger and more durable learning than either channel alone, or

the practical effect in ESE241 is that students arrive at the simulation with an analytical expectation against which to interpret the simulated output.

Pillar F3 — authentic engineering tools—addresses the PO5 graduate-attribute requirement of the EAC Standard 2020 (Engineering Accreditation Council, 2020) and the Washington Accord competency profile (International Engineering Alliance, 2013) directly. MATLAB and Simulink are industry-standard tools widely used in the practice of electrical and electronic engineering. The use of these tools means that the artifacts students produce in the laboratory (m-file scripts, Simulink models, pole-zero plots, and transfer-function diagrams) are simultaneously evidence for CO2 and evidence for PO5. The CDIO framework (Crawley et al., 2007) identifies this kind of authentic-tool experience as a core competency that engineering program must cultivate, and this pillar realizes that competency in concrete form. Pillar F4 — scaffolded procedures — operationalizes the cognitive-load-management principle of Sweller, van Merriënboer, and Paas (Sweller et al., 2019). Each module provides step-by-step procedures, sample MATLAB code, and parameter-dialogue screenshots, all of which reduce extraneous cognitive load. The conceptual determinations rest with the learner—which symmetry is applicable to a specific Fourier-series problem? What is the appropriate piecewise function for a specified signal? The handbook alleviates the procedural burden of recalling the syntax for *dsolve* or setting up a Simulink sine-wave block. The pillar predicts that students will not be excluded from CO2 attainment by tool-use difficulties, an effect consistent with the observed cohort-invariance of the CO2 statistic.

Pillar F5 — low-stakes weighting — instantiates the formative-assessment principle articulated by Black and Wiliam (P. Black & Wiliam, 2009) and the broader argument of Chasteen (Chasteen, 2017) that low-stakes formative assessment is essential to the engagement that drives learning. Each module constitutes 5% of the final grade, while the four modules together represent 20% of the total assessment. This differs from the Final Exam (50%), in which errors directly affect the cognitive CO. The minimal weight each module allows students to engage in the simulation, identify discrepancies with the pre-laboratory, and repeat, without the resultant errors significantly impacting their final grade.

Pillar F6 – a standardized rubric with three criteria – enhances inter-rater reliability among lecturers teaching parallel course portions and allows for longitudinal comparability across semesters. The rubric (Equipment usage / 2, Circuit construction / 2, Data measurement / 1) is the same for all modules and cohorts. Good rubrics contain a few explicit criteria and a consistent marking scale (Brookhart, 2018). The SPA-7 rubric satisfies these conditions. If rubrics are not uniform, the heterogeneity between lecturers would increase the variance within a course and the achievement statistic would be less interpretable.

Pillar F7 – built in comparison artifact – where at the end of the result sheet of each module, a comparison table “Pre-Laboratory Answer vs. MATLAB Result” is compulsory. This forces students to reconcile any conflict between their analytical reasoning and the simulation results, and this conflict becomes a learning goal. The artifact makes the implicit verification step an explicit metacognitive activity, thus closing the AT-to-LO loop in terms of constructive alignment (Biggs & Tang, 2011) and enacting the formative assessment principle of feedback-into-action (P. Black & Wiliam, 2009).

The seven pillars combined provide a consistent theoretical account to the observed CO₂ performance. The framework suggests that lab assessment facilitated by software with all seven pillars in place will result in consistent CO performance across cohorts and semesters. This was confirmed by the empirical data for ESE241, which averaged 89.7%, exceeding the KPI by 17 percentage points in each observation.

Mapping CO₂ Evidence to PO5 Graduate-Attribute Attainment

The CO₂ instrument produces evidence for PO5 concurrently within the eRES framework (Engineering Accreditation Council, 2020; IEA et al., 2021). The MATLAB code, Simulink models, output plots and pole-zero diagrams submitted by students in the Result Sheet are portfolio evidence of the use of modern engineering tools and techniques. The collective span of the four modules across the four chapters of the syllabus results in a PO5 evidence base that exceeds what would be generated by a single capstone laboratory exercise. This dual-purpose property, i.e., two forms of accreditation evidence from one assessment tool, is efficient in the context of EAC Standard 2020 reporting mandates and exemplifies a practical benefit of the SPA-7 framework for institutional reporting.

Transferability of the SPA-7 Framework

Of the seven pillars, four (F1, F4, F5, and F6 — chapter-aligned modules, scaffolded procedures, low-stakes weighting, and standardized rubric) are course-agnostic and transferable to any engineering course. Two (F2, F7 — pre-laboratory plus simulation verification and comparison artifact) require a course in which an analytical solution and a simulated output can be compared; this condition is satisfied by signals and systems, control systems, circuit analysis, electromagnetic theory, power electronics, communication systems, and many other engineering courses. One pillar (F3 — authentic tools) requires the course to have an industry-standard software analog; for most electrical and electronic engineering courses, a MATLAB-class tool exists for this purpose. Replication studies in these courses would evaluate the hypothesis that the SPA-7 framework, rather than the selection of MATLAB or Linear System content, is responsible for sustained CO attainment.

Conclusion

This paper has formulated and empirically substantiated the SPA-7 framework—a Seven-Pillar Software-Based Practical Assessment framework based on Biggs and Tang's principle of constructive alignment—for software-based laboratory assessment in engineering courses with a software-implementable practical CO. The framework is illustrated in Figure 2: it places the student at the center of a Biggs-style triangle whose vertices are the LOs, the TLAs, and the ATs, with the seven pillars arrayed around the triangle as the operational instantiation of constructive alignment for software-based practical assessment.

Empirical validation on four consecutive semesters of CQI records for the ESE241 Linear System course at Universiti Teknologi MARA Cawangan Pulau Pinang shows that the practical CO (CO₂, mapped to PO5) was consistently achieved by the institutional 65% KPI in two diploma cohorts and four consecutive semesters with the cross-cohort mean of 89.7% and a range of 82.1% to 95.8%. This achievement, which is consistent across cohorts with different previous mathematical preparedness, is consistent with the assumption of the framework that

a constructively matched software-based assessment produces learning outcomes aligned with the objectives.

The seven pillars are grounded in well-established theories of learning science: constructive alignment (F1, F7), dual-coding and multimedia learning (F2), CDIO authentic tools and Washington Accord graduate attribute competencies (F3), cognitive load theory (F4), formative assessment theory (F5), and effective rubric design theory (F6). The framework provides evidence for the CO and the mapped PO at the same time. This two in one feature increases the efficiency of the framework as per EAC Standard 2020 reporting.

This study has several limitations including the retrospective documentary method and only focusing on two cohorts in one location. No student self-report data were gathered. No causal claims are made except to infer optimal alignment between the predictions of the framework and the observed achievement statistics. Further replication studies in other UiTM campuses and other Malaysian engineering universities would enrich the generalizability of the results. A prospective study evaluating student perception and rubric inter-rater reliability is a logical next step. Running this in at least one other undergraduate course (e.g., Control Systems or Electrical Circuit Analysis) would be a test of the hypothesis that it is the SPA-7 framework that is responsible for the lasting effect, rather than the choice of MATLAB or Linear System content.

In conclusion, this paper adds to the SPA-7 constructiveness alignment framework for the operationalization of the constructive alignment in practical assessment in software-based practice from a theoretical perspective and empirically shows four semesters of evidence that the sustained fulfillment of CO and PO is due to the faithful implementation of the framework. The results show that the SPA-7 framework can support sustainable constructive alignment and improve the effectiveness of software-based practical assessment in engineering education contexts. Overall, SPA-7 gives a robust model, theoretically grounded and empirically verified, for reproducible measurement of CO, intended for program coordinators, engineering educators, and accreditation officers who need reliable accreditation compliant assessments.

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