

Teaching and Assessments Practices in Engineering Education for Effective Students Engagement and Learning

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Received 29 June 2025, Received in revised form 14 December 2025

Accepted 14 January 2026, Available online 30 March 2026

ABSTRACT

Effective student engagement and learning in engineering education depend on the alignment of teaching and assessment practices with Course Objectives and Course Learning Outcomes (CLOs). This study examines the implementation of various pedagogical and evaluative approaches in engineering modules, with particular emphasis on project-based and research-based learning. These approaches engage students in solving Complex Engineering Problems (CEPs) and participating in Complex Engineering Activities (CEAs), providing authentic exposure to real-world engineering challenges. Through these activities, students develop critical thinking, problem-solving, creativity, and innovation skills, alongside improved communication and teamwork competencies essential for professional practice. The study employs two case studies: an undergraduate module in Highway and Traffic Engineering (CE4623) involving 36 final year bachelor's students, and a graduate module in Drainage and Irrigation Engineering (CE5153) course involving 10 master's students, both implemented during the 2022-2023 academic year. In the undergraduate case study, rubric-based project assessments were employed to quantitatively evaluate student attainment of CLOs related to problem analysis and engineering design. In contrast, the postgraduate case study adopted a qualitative evaluation approach based on instructor observations, project presentations, and the overall quality of technical reports, reflecting the research-oriented nature of the course. The findings indicate that explicit alignment between project structure, CLOs, and assessment mechanisms enhances student engagement, analytical thinking, and communication skills. The use of rubrics further supports continuous improvement by clarifying performance expectations and facilitating constructive feedback. Overall, the results suggest that these teaching and assessment practices contribute to the development of lifelong learning skills and better prepare students to address evolving engineering challenges.

Keywords: Complex engineering problems; problem-based learning; research-oriented; case studies

INTRODUCTION

Teaching practices play an essential role in fostering student engagement and enhancing learning outcomes within higher education institutions. The teaching methods, strategies, and pedagogical approaches educators employ are critical to ensuring that students achieve the Course Objectives and Course Learning Outcomes (CLOs) established by the curriculum. It is widely acknowledged that the effective alignment of teaching and assessment activities with the intended learning outcomes is fundamental to achieving the educational aims of modules

and academic programs (Aada 2020; Biggs 1996; Biggs 2022). Such alignment ensures that instructional delivery, learning activities, and assessment tasks operate cohesively to support student development in both theoretical understanding and practical application.

Clear alignment also provides students with a coherent learning structure, enabling them to better understand the expectations of the course and the competencies they are required to demonstrate. When learning activities and assessments are intentionally mapped to CLOs, students are more likely to develop the knowledge, skills, and professional attributes needed for success in their academic journey and future careers. Furthermore, well-aligned

teaching practices promote deeper learning by encouraging students to actively engage with course materials, apply concepts to real-world problems, and reflect on their performance through structured feedback mechanisms. In engineering education, this alignment is particularly crucial due to the complexity and multidisciplinary nature of the competencies expected of engineering graduates.

In engineering education, this alignment is especially critical, as students must not only acquire theoretical knowledge but also develop practical skills to address complex engineering problems. The teaching methodologies employed significantly influence the learning environment and develop students' interests in the module. For instance, exposing the students to research activities requires embedding research-oriented activities in the teaching and learning materials. Additionally, the engineering modules require critical thinking and the development of innovative solutions to address real-world problems. This practice engages students in research activities and exposes them to research aspects of learning materials. As students explore new methods, technologies, and techniques in real-world engineering contexts, they are better prepared to think critically and solve complex problems (Noguez & Neri, 2019).

The engineering modules may include research-informed content and practical case studies grounded in real-world engineering practice to enrich students' learning experiences and enhance their critical thinking through authentic examples (Mahdi et al., 2020). In addition, the systematic integration of Complex Engineering Problems (CEPs), as defined by the Washington Accord (IEA, 2021), alongside problem-based learning (PBL) activities, is crucial in contemporary engineering education.

CEPs are characterised by problems that require in-depth engineering knowledge across multiple disciplines (WP1) and involve a wide range of potentially conflicting technical, economic, environmental, and societal requirements (WP2). Such problems demand substantial analytical depth and professional judgement, often without a clear or straightforward solution pathway (WP3) and are typically non-routine or unfamiliar, extending beyond standard engineering practice (WP4). Furthermore, CEPs require innovative and creative solutions that are not fully addressed by existing codes or standards (WP5), while also incorporating critical considerations of sustainability, ethics, safety, and societal impact (WP6). Finally, these problems are often characterised by significant uncertainty, incomplete information, and risk, requiring informed decision-making under constraints (WP7). Embedding CEP-oriented PBL activities within engineering modules, therefore, plays a vital role in developing students' practical

competencies, professional judgement, and lifelong learning capabilities in alignment with international accreditation standards.

Table 1 lists the seven characteristics of CEPs outlined in the Washington Accord (IEA, 2021), providing a structured overview of the depth of knowledge, analytical demands, novelty, sustainability considerations, and uncertainties typically associated with CEPs.

TABLE 1. Characteristics of Complex Engineering Problems (CEPs) Based on the Washington Accord (IEA, 2021)

Code	CEP Characteristic	Description
WP1	Depth of Knowledge Required	Requires in-depth technical knowledge across multiple engineering principles and concepts; cannot be solved with routine or basic methods.
WP2	Range of Conflicting Requirements	Involves wide-ranging, potentially conflicting constraints such as technical, economic, environmental, social, and regulatory considerations.
WP3	Depth of Analysis Required	Requires complex analysis, interpretation, and judgement; solutions are not obvious and demand detailed evaluation of alternatives.
WP4	Familiarity of Issues	The problem context is non-routine, novel, or unfamiliar, extending beyond typical professional practice.
WP5	Breadth and Uniqueness of Solutions	Solutions require originality, creativity, or innovation; not completely addressed by established standards or codified procedures.
WP6	Sustainability and Societal Impact Considerations	Must account for ethical, safety, sustainability, societal, cultural, and environmental impacts in the design and decision-making process.
WP7	Level of Uncertainty and Risks	Characterised by uncertainty, incomplete information, or significant risk, requiring informed decision-making under constraints and ambiguity.

The CEPs and PBL are characterized by their level of complexity, engineering knowledge, and innovation involved (Tan & Jin 2023). This complexity encompasses problem contexts that require integrating advanced engineering principles, multidisciplinary reasoning, and evaluating competing technical and non-technical constraints. Within PBL environments, students are

frequently exposed to ill-defined or ambiguous scenarios that demand rigorous analysis, systematic decision-making, and the ability to synthesise information from diverse sources. Addressing CEPs further involves exercising engineering judgement under conditions of uncertainty and incomplete information, requiring students to justify design choices while considering safety, ethics, sustainability, and societal implications. The innovative element arises from the need to generate solutions that are not fully prescribed by existing standards or guidelines, thereby encouraging creativity and the development of novel engineering approaches. These characteristics closely align with the Washington Accord's definition of Complex Engineering Problems, reinforcing the role of CEP-driven PBL in cultivating higher-order cognitive skills, professional competencies, and lifelong learning attributes essential to modern engineering practice.

The choice of assessment methods and the quality of feedback provided to students play a critical role in shaping learning effectiveness in higher education. Well-designed assessment strategies for both formative and summative serve not only as measurement tools but also as mechanisms that guide and reinforce student learning. When assessments are explicitly aligned with course objectives, intended learning outcomes, and the pedagogical approaches employed, they create meaningful opportunities for students to monitor their progress, identify gaps in understanding, and refine their learning strategies (Heitink et al., 2016; Van Der Steen et al., 2023). Formative assessments provide timely, actionable feedback that supports continuous improvement, while summative assessments evaluate students' cumulative mastery of competencies at key points in the course.

In engineering education, the use of rubric-based assessment has become increasingly important due to the diverse set of competencies required of engineering graduates. Rubrics enable instructors to evaluate not only technical proficiency but also transversal skills such as problem-solving, teamwork, communication, ethical reasoning, and the ability to apply engineering knowledge in complex or unfamiliar contexts (Nayak et al., 2017; Tobajas et al., 2019). By making assessment criteria explicit and transparent, rubrics promote fairness, consistency, and clarity in evaluation while helping students better understand performance expectations. Moreover, rubrics support the development of higher-order thinking and professional skills by encouraging students to reflect on their work relative to clearly articulated standards. As a result, rubric-based assessment plays a central role in fostering student development across multiple dimensions of engineering practice.

The real challenge in engineering education is to develop modules that effectively foster critical thinking,

technical proficiency, and professional skills by integrating well-designed teaching and assessment methods. As engineering problems become increasingly complex and multidisciplinary, educators must adopt pedagogical approaches that not only transmit foundational knowledge but also cultivate students' ability to analyse, design, and innovate in real-world contexts. This includes aligning instructional strategies with intended learning outcomes, accreditation requirements, and industry expectations to ensure that graduates are prepared to solve contemporary engineering problems with sound judgement and creativity.

The objective of this paper is to present practical examples of diverse teaching methodologies that are systematically aligned with course objectives and curricular requirements, thereby promoting effective student engagement and deeper learning in engineering disciplines. By demonstrating how approaches such as problem-based learning, project-based activities, case-based instruction, and the integration of CEPs can be embedded into engineering modules, this paper highlights how carefully structured pedagogical designs can enhance students' cognitive development, strengthen their technical competencies, and support the development of lifelong learning skills. These examples serve as a reference framework for educators seeking to enhance the quality and effectiveness of engineering education in line with global accreditation standards.

To achieve these objectives, the course projects were deliberately structured to align with the intended CLOs across both undergraduate and postgraduate programs. Each project was designed to target specific competencies, including problem analysis, engineering design, data interpretation, and technical communication. In the undergraduate module, these competencies were assessed using structured rubrics that translated CLOs into measurable performance indicators. The rubric criteria provided direct and transparent evidence of student learning and engagement by evaluating technical accuracy, analytical depth, solution feasibility, teamwork, and clarity of presentation.

In contrast, the postgraduate module adopted a research-oriented assessment approach, evaluating CLO attainment qualitatively through instructor observations, project presentations, and the overall quality of technical reports and research outputs. This approach emphasised higher-order cognitive skills, originality of solutions, and depth of critical analysis expected at the Master's level. Overall, this constructive alignment ensured coherence between learning activities, assessment tasks, and expected outcomes, consistent with outcome-based education principles.

METHODOLOGY

This study examines the efficacy of diverse pedagogical and evaluative methods in promoting student engagement and enhancing learning within engineering education. The methodological approach is centred on two detailed case studies that illustrate how selected teaching and assessment strategies are implemented within specific engineering modules. These case studies serve as practical demonstrations of how instructional activities can be aligned with course objectives, learning outcomes, and accreditation requirements, particularly those related to critical thinking, problem-solving, and technical competency development.

In designing the study, emphasis was placed on analysing how real-world engineering issues, research-informed content, and complex engineering problem (CEP) elements are embedded within the curriculum. The study also evaluates the effectiveness of both formative and summative assessment approaches in supporting students' reflective learning, performance improvement, and mastery of higher-order engineering skills. Through this dual focus on pedagogy and assessment, the methodology aims to provide a comprehensive understanding of how structured teaching interventions influence student learning behaviours and academic outcomes.

CASE STUDY DESIGN

Two case studies were selected to demonstrate the application of effective, research-supported teaching methodologies in engineering education. Case Study 1 focuses on the Highway and Traffic Engineering (CE4623) module, an upper-level undergraduate course that integrates analytical tasks, modelling exercises, and real-world transportation engineering challenges. The module incorporates CEPs, data-driven case studies, and collaborative project work that require students to apply engineering judgement in realistic scenarios.

Case Study 2 examines the Drainage and Irrigation Engineering (CE5153) module at the graduate level, which emphasises hydrological analysis, design of water management systems, and research-based learning activities. This module was chosen due to its strong integration of field-based problems, simulation tools, and research-oriented assignments that encourage students to investigate advanced engineering concepts and propose innovative solutions.

Both modules, offered within a Civil Engineering programme, were deliberately selected because they exemplify pedagogical approaches that promote active

learning, multidisciplinary reasoning, and practical skill development. The case studies offer students opportunities to confront authentic engineering challenges through group discussions, hands-on projects, technical simulations, and structured research tasks. By analysing these modules, the study aims to highlight how thoughtfully designed instructional and assessment practices can strengthen engineering students' engagement, motivation, and overall competency development.

CASE STUDY 1: HIGHWAY AND TRAFFIC ENGINEERING (CE4623)

The Highway and Traffic Engineering (CE4623) module, offered within the Civil Engineering program, is structured to immerse students in the process of solving a CEP as defined by the Washington Accord. The module incorporates real-world engineering challenges that align directly with the Wks and CEAs specified by the International Engineering Alliance (IEA, 2021). These frameworks emphasise competencies such as analytical reasoning, engineering judgement, innovation, and the ability to address multifaceted global issues, particularly those related to transportation infrastructure, safety, and mobility management.

To operationalise these goals, students engaged in two major project assignments designed to simulate authentic professional engineering environments. The first project focused on field-based traffic data collection and analysis, requiring students to interpret existing traffic conditions, assess network performance, and identify critical issues affecting road users. The second project involved traffic modelling and the design of traffic management solutions, where students utilised software tools and engineering methodologies to develop and evaluate alternative design scenarios.

These projects required students to integrate theoretical concepts with practical application, encouraging them to navigate challenges involving data limitations, conflicting constraints, and the need for innovative yet feasible design strategies, hallmarks of CEP engagement. The instructional design promoted collaborative learning, where students worked in teams to analyse problems, justify engineering decisions, and communicate their findings. Student performance in this module was assessed using a rubric-based evaluation system to ensure fairness, consistency, and transparency. The rubric measured diverse dimensions of student capability, including technical competency, analytical depth, problem-solving skills, teamwork, oral presentation quality, and overall communication effectiveness. This structured assessment approach supported constructive feedback and enabled students to

reflect on their strengths and areas for improvement, aligning with outcome-based education (OBE) and Washington Accord accreditation expectations.

CASE STUDY 2: DRAINAGE AND IRRIGATION ENGINEERING (CE5153)

The Drainage and Irrigation Engineering (CE5153) module is an upper-level undergraduate course designed to promote research-based learning and critical analytical skills within the civil engineering discipline. The module adopts a curriculum structure that integrates research-focused activities, including lectures on contemporary research publications, the preparation of scholarly review articles, and the completion of semester-long research projects. These activities aim to familiarize students with advanced concepts in drainage and irrigation system design while strengthening their competencies in research methodology, data modelling, and engineering problem-solving.

The instructional approach employed in this module emphasises integrating research-oriented learning with practical case studies that reflect real-world challenges in hydrological engineering. Students were introduced to industry-relevant design and simulation tools commonly used for planning and evaluating irrigation and drainage systems. Working in collaborative teams, students analysed field-based issues such as water distribution efficiency, drainage network performance, and soil–water interactions. They were required to propose technically sound, sustainable design solutions and to communicate their findings through structured presentations and reports.

These pedagogical strategies were intended to cultivate higher order thinking skills, including critical reasoning, synthesis of technical information, evaluation of alternative solutions, and professional communication. The inclusion of team-based research assignments also supported the development of collaborative competencies essential to modern engineering practice, particularly when addressing multifaceted, complex engineering activities that involve hydrological, environmental, and socio-technical considerations. Student evaluation in this module was based on multiple performance indicators, including participation in research seminars, the quality and depth of their review articles, and the rigor and innovation demonstrated in their semester-long research projects. This multidimensional assessment approach enabled a comprehensive evaluation of students' technical proficiency, research capabilities, and engagement with complex engineering problems, consistent with outcome-based education (OBE) and Washington Accord expectations.

STUDY CONTEXT AND PARTICIPANTS

The study was conducted during the 2022–2023 academic year across two consecutive semesters using a face-to-face delivery mode. Case Study 1 involved 36 final-year undergraduate students enrolled in the Bachelor of Civil Engineering programme during Semester 1 (Fall 2022–2023). Case Study 2 involved 10 postgraduate students enrolled in a Master's-level Civil Engineering programme during Semester 2 (Spring 2022–2023). The undergraduate project-based activities spanned approximately eight weeks, while the postgraduate research-based project extended across the entire semester. These cohorts were selected to demonstrate the application of aligned teaching and assessment strategies across different academic levels and learning contexts.

RESULTS AND DISCUSSION

This section presents illustrative examples of the implementation of various teaching and assessment practices across the selected case studies and discusses their observed influence on student engagement and learning. Given the exploratory nature of this study, the results are primarily descriptive and qualitative, focusing on instructional alignment, student participation, and observed learning outcomes.

CASE STUDY 1

The *Highway and Traffic Engineering (CE4623)* module requires students to address a CEP as an integral component of both learning and assessment. The CEP was explicitly aligned with the Washington Accord Wks, including WK2, WK4, WK5, and WK6 (IEA, 2021), as well as relevant CEAs and selected United Nations Sustainable Development Goals (SDG9 and SDG11). The CEP was structured into two project-based assignments, as summarised in Table 2, to ensure progressive engagement with real-world transportation engineering challenges.

TABLE 2. Alignment of CEP with WK and CEAs

	Marks	CLO	PLO	Wks	CEAs
Project-1	10	2	3	2,5	2,4
Project-2	10	4	5	4,6	2,4

Through these projects, students were exposed to authentic field problems that required identifying traffic-

related issues, analysing data, and formulating appropriate engineering solutions. The project activities encouraged students to apply theoretical knowledge in practical contexts, thereby supporting the development of higher-order cognitive skills. Student performance was assessed

using rubric-based evaluation criteria tailored to different learning skills, as presented in Table 3. The use of rubrics provided a structured and transparent mechanism for assessing technical proficiency, analytical reasoning, and communication effectiveness.

TABLE 3. Assessment Rubrics of CEP assessment

	Unsatisfactory	Satisfactory	Good	Very Good	Excellent
Identification and Preparation of Basic Data	Inability to identify and present the basic design data	Limited ability to identify and present the basic design data	Have identified and presented most of the require data	The required basic data have adequately identified and presented	Complete require data set is identified and presented for design
Steps involved in the design	Cannot follow all steps involved in design in specific context	Follow a few steps involved in the design in specific context	Follow few steps involved in the process in specific design context	Follow all steps involved in the specific design context	Follow all steps comprehensively involved in the specific design context
Design of elements and propose solution	Incomplete design without incorporating all parameters and inappropriate solution	Proposed design with few complete sets of elements and solution	Have designed most of the required elements and propose a reasonable solution	Propose one or more complete design and solution with all design elements	Propose one or more comprehensive design and solution to problem with complete data and drawings
Evaluate and Report outcomes	Does not evaluate the results in relevance to identified data and design elements	Have presented limited evaluation of results in relevance to identified data and design elements	Have evaluated and presented the results in relevance to identified data and design elements	Have evaluated and presented results in good relevance to identified data and design elements	A thorough evaluation of results is presented in relevance to identified data and design elements

Table 4 summarises student performance in Case Study 1, which was evaluated using rubric-based assessments aligned with CLO-2 and CLO-4. Each project consisted of four assessment criteria, with a maximum score of 10 marks per project and 20 marks in total. Analysis of the rubric scores for the 36 students indicates

a mean total score of 15.11 (SD = 1.51), with scores ranging from 12.0 to 18.5. The results suggest that most students achieved moderate to high performance levels across both projects, indicating satisfactory attainment of problem analysis and engineering design competencies.

TABLE 4. Summary rubric scores of Case Study 1: Highway and Traffic Engineering (Undergraduate)

Statistic	Total Project Score
Mean	15.11
Standard Deviation	1.54
Minimum	12.00
Maximum	18.50

Assessment type: Rubric-based (CLO-2 and CLO-4)
 Sample size: n = 36 students
 Maximum score: 20 marks (two projects)
 Descriptive Statistics

The distribution of scores suggests that most students demonstrate satisfactory to high levels of competency in problem analysis, engineering design, and technical communication. The rubric scores provide quantitative

evidence of student engagement and learning, particularly in technical analysis, application of engineering principles, and communication of solutions. Instructor observations further indicated that students demonstrated improved

confidence in interpreting real traffic data, justifying engineering decisions, and proposing feasible traffic management interventions.

CASE STUDY 2

The integration of research-oriented activities within the Drainage and Irrigation Engineering (CE5153) module demonstrated positive indications of enhanced student engagement and conceptual understanding. Students actively participated in research seminars that analysed and discussed scholarly publications on irrigation and drainage design. These activities improved students' comprehension of advanced engineering concepts and exposed them to current research practices within the discipline.

In addition, students were required to prepare review articles, which strengthened their research skills and critical evaluation of existing literature. The module also incorporated real-world case studies in drainage and

irrigation engineering, providing context and fostering analytical thinking. Student assessment comprised seminar participation, evaluation of review articles, and a semester-long research project focused on data modelling for irrigation design.

Throughout the research project, students worked collaboratively in teams and employed design and simulation tools to propose solutions to practical field-based challenges. Observations from the instructional process indicated a high level of student involvement, particularly during discussions and collaborative tasks. The team-based approach facilitated knowledge sharing and peer learning, while the requirement to present findings enhanced students' communication and presentation skills.

Unlike Case Study 1, formal assessment rubrics were not employed in Case Study 2. Student learning was evaluated qualitatively based on instructor observations during presentations and the overall quality of technical reports and research papers. Assessment focused on depth analysis, originality of proposed solutions, technical coherence, and clarity of communication.

TABLE 5. Summary of Case Study 2: Drainage and Irrigation Engineering (Postgraduate)

Assessment Component	Max Marks	Mean	SD	Min	Max
Project 1 – Report	10	8.45	0.86	7.0	9.5
Project 2 – Report	5	4.30	0.26	4.0	4.5
Project 2 – Presentation	5	4.40	0.21	4.0	4.5

Assessment type: Observation-based (reports & presentations)

Sample size: n = 10 students

Note: No formal rubrics used

Descriptive Statistics by Assessment Component

In Case Study 2, student performance was evaluated using instructor observations supported by report and presentation scores. For Project 1, report scores ranged from 7.0 to 9.5, with a mean of 8.45 (SD = 0.86), indicating strong engagement with research-based learning activities. For Project 2, report and presentation scores showed consistently high performance, with mean scores of 4.30 (SD = 0.26) and 4.40 (SD = 0.21), respectively. The limited variation in scores suggests a uniformly high level of competency among postgraduate students, particularly in technical writing, critical analysis, and oral communication.

Instructor observations indicated that student engagement in CEP- and CEA-based activities contributed positively to the development of critical thinking, report writing, presentation, and communication skills. Although the findings are qualitative, the alignment between project activities, learning outcomes, and assessment criteria suggests that the instructional design effectively supported the intended educational objectives and accreditation-related competencies.

Project evaluation outcomes indicate consistent performance across report writing and presentations, reflecting strong engagement with research-based learning activities. Instructor observations highlighted students' ability to synthesise literature, apply advanced engineering concepts, and communicate effectively at the postgraduate level. These qualitative findings suggest that research-oriented, observation-based assessment can effectively support higher-order learning outcomes in advanced engineering courses. Overall, the combination of research-based learning and practical case studies contributed to a more interactive and participatory learning environment. While the results are based on limited qualitative evidence, the observed outcomes suggest that such pedagogical approaches can effectively support student engagement, technical skill development, and professional competencies in engineering education.

CONCLUSION

This study presented practical examples of teaching and assessment approaches commonly applied in engineering education, with a focus on their implementation within two selected modules. Both case studies incorporated project-based learning elements, supported by research activities and real-world case studies, and integrated CEPs and CEAs. These pedagogical strategies were observed to enhance students' exposure to authentic engineering challenges and support the development of critical thinking, analytical skills, and engineering judgment.

The activities also improved communication skills and encouraged students to adopt a more reflective, self-directed approach to learning, aligning with the broader goals of lifelong learning in the engineering profession. The use of rubric-based assessments provided structured, transparent, and constructive feedback, enabling students to better understand performance expectations and monitor their learning progress. While the findings of this study are exploratory and based on limited qualitative evidence, the examples presented suggest that incorporating problem-based, research-oriented, and CEP-driven learning activities can strengthen the quality and relevance of engineering modules. Such approaches are particularly important in preparing future engineers to address evolving technological and infrastructure challenges. Further research involving larger cohorts and more comprehensive data collection is recommended to validate and expand upon these initial observations.

Although the findings are exploratory and based on limited cohorts, this study contributes practical insights into how different assessment approaches can be strategically applied across academic levels to support outcome-based education and Washington Accord expectations. Future studies involving larger samples and multi-institutional data are recommended to further validate these findings.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support from Sohar University and Universiti Kebangsaan Malaysia.

DECLARATION OF COMPETING INTEREST

None.

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