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Standardized Higher Order Thinking Skills' Assessment in Engineering Mechanics: A Traditional Literature Review and Future Research Directions

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ABSTRACT

Purpose – This study aims to examine the need to develop assessment instruments for higher-order thinking skills in teaching Engineering Mechanics in Vocational High Schools under the Construction and Property Technology Expertise Program and explore directions for future research.

Methodology – This study employs a Traditional Literature Review approach to summarize, analyze, and synthesize over 100 scholarly sources from Google Scholar and Scopus databases from 2016 to 2025. The analysis uses keywords such as higher-order thinking skills (HOTS), assessment, Engineering Mechanics, vocational high schools (SMK), and test theory.

Findings – The review findings indicate that the teaching of Engineering Mechanics in vocational high schools (SMK) has not yet optimally incorporated higher-order thinking skills (HOTS). Teachers tend to use test items based on classical test theory, which are limited in accurately measuring students' analytical and problem-solving skills. The assessment approaches employed have yet to consider the alignment of test items with students' characteristics.

Contribution – This study contributes to the development of more accurate HOTS-based Engineering Mechanics assessment instruments through the application of modern test theory, while also enhancing the quality of teaching and assessment in Vocational High Schools specializing in Construction and Property Technology to better align with industry demands.

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INTRODUCTION

Industrial Revolution 4.0 has transformed the industrial landscape through technological advancements such as automation, artificial intelligence, and digitalization (Attaran, 2023; Cabanová, 2019; Ikenga & Sijde, 2024). These changes demand a workforce that not only possesses technical skills (hard skills) but also demonstrates complex higher-order thinking skills (HOTS), including analysis, evaluation, and solution creation (Jaedun et al., 2024; Nizaruddin et al., 2022). Such skills distinguish human competencies from machines and serve as a foundation for competitiveness in the digital industrial era. Vocational education, particularly at the Vocational High Schools (SMK) level, plays a pivotal role in preparing graduates to thrive in this context. Integrating HOTS into the learning process is essential to cultivate adaptive and solution-oriented students. Unfortunately, according to the PISA report (OECD, 2022), Indonesian students exhibit low literacy and reasoning skills, which are key indicators of underdeveloped higher-order thinking capabilities, including among SMK students. This is particularly concerning given that sectors such as the construction industry require workers who can analyse complex situations and make precise technical decisions (Alfiyah et al., 2021).

One of the subjects that plays a strategic role in developing such capabilities is Engineering Mechanics. This subject is a foundation for analyzing forces, understanding structural equilibrium, and designing technical solutions in dynamic field situations (Pangastuti et al., 2024). These competencies are critically important in the construction industry, where analytical errors can lead to severe consequences. However, Engineering Mechanics is often perceived as difficult and reduced to mere computational exercises, depriving students of broader and deeper cognitive engagement (Wardoyo & Ma'arif, 2015). This is the primary rationale for selecting Engineering Mechanics as the focus of this study. Moreover, there is a critical issue concerning teachers' assessment systems in Engineering Mechanics classrooms. Assessments are still predominantly composed of items targeting Lower Order Thinking Skills (LOTS), relying on classical test theory approaches that are insensitive to the diverse abilities of students (Narasati et al., 2021; Wang et al., 2022). Many teachers remain unfamiliar with modern approaches such as Item Response Theory (IRT) or the Rasch Model (Sumintono & Widhiarso, 2015a), despite these methods offering more objective and equitable means of evaluating students' higher-order thinking skills.

A literature mapping was conducted using VOSviewer on 100 scholarly articles related to HOTS in vocational education during the 2015–2025 period to strengthen the identification of research direction and urgency. The visualization results reveal that HOTS is a dominant topic closely associated with terms such as learning, student, and skills. However, topics such as engineering mechanics, construction, and assessment remain on the periphery, represented by smaller nodes and weaker linkages. This indicates that integrating HOTS, technical learning, and assessment instrument development remains an underexplored area of research. The visualization highlights the potential and the necessity for further studies in this field.

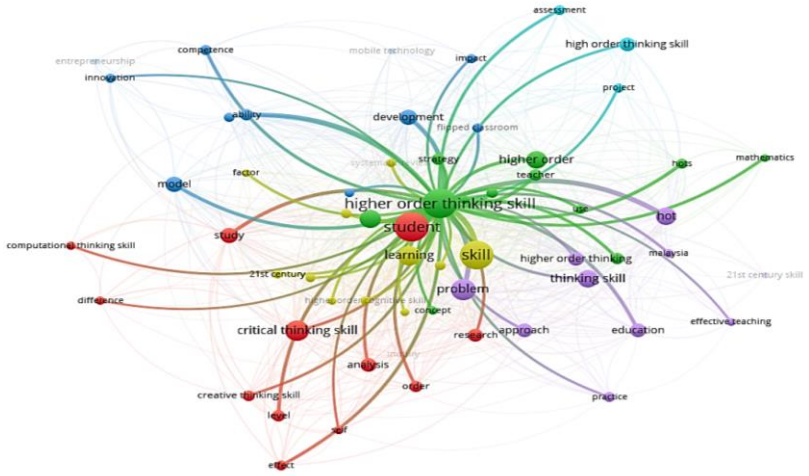

Figure 1. Bibliometric Mapping of the HOTS Topic Using VOSviewer (2015–2025)

The identified research gap lies in the absence of a standardized HOTS assessment instrument grounded in modern measurement theory and contextualized within the teaching of Engineering Mechanics in vocational high schools (SMK). Most existing literature focuses on developing HOTS assessments in a general context, without adequately addressing the specific characteristics of vocational technical content. This study aims to address that gap. In response to this issue, the present research is designed to answer two key questions: (1) What is the current state of HOTS assessment research in the context of Engineering Mechanics instruction in vocational schools? Moreover, (2) What are the findings and gaps in the existing literature that can inform the development of a relevant and standardized assessment instrument? The objectives of this study are to identify the challenges and needs in assessing HOTS within the teaching of Engineering Mechanics in SMK, to analyze the literature in order to map trends, gaps, and opportunities for assessment development, and to construct a conceptual framework for the development of HOTS assessment instruments based on modern measurement theory. Theoretically, this study contributes to formulating a HOTS assessment development framework rooted in the Revised Bloom's Taxonomy and constructivist principles, where learning is viewed as an active process of constructing meaning through contextual experience. Practically, it offers recommendations for designing HOTS assessment instruments that vocational teachers can utilize to conduct more meaningful evaluations aligned with industrial demands.

The scope of this research is limited to a literature review on HOTS assessment within the subject of Engineering Mechanics in SMK, particularly under the Construction and Property Technology expertise program. The focus is on the content, context, and measurement approaches used in HOTS assessment. To guide a systematic development process, this study constructs a conceptual framework that connects three main components: (1) HOTS as the target cognitive abilities (C4–C6), (2) Engineering Mechanics as the core content of construction technology education, and (3) assessment as a standardized measurement tool utilizing modern approaches (IRT/Rasch) that align with the characteristics of vocational students.

METHODOLOGY

Research Design

This study employs a qualitative approach using the Traditional Literature Review method. This method was selected for its suitability for the exploratory and reflective nature of the research. It aims to investigate the need to develop HOTS assessment instruments in Engineering Mechanics at vocational high schools (SMK). Although it does not follow a strict systematic protocol as in a Systematic Literature Review (SLR), the Traditional Literature Review nonetheless adheres to principles of validity and traceability through a structured literature selection and analysis (Rozas & Klein, 2010). To strengthen the findings, a bibliometric analysis was also conducted using the VOSviewer software, which facilitates mapping topic relationships within scientific publications and visually identifies potential research gaps.

Stages of Literature Review

To ensure a more structured Traditional Literature Review process, this study follows five main stages of literature analysis as outlined below:

Identification of Topic and Scope

The topic focuses on assessing Higher Order Thinking Skills (HOTS) in the subject of Engineering Mechanics within the Vocational High School (SMK) Construction and Property Technology Expertise Program. The scope includes articles that discuss higher-order cognitive assessment, modern measurement approaches, and the context of vocational technical education.

Literature Search and Selection

Literature was gathered from academic databases such as Google Scholar and Scopus, covering publications from 2015 to 2025. Keywords used included: Higher Order Thinking Skills (HOTS), Engineering Mechanics, Vocational Education, Assessment, Classical Test Theory, Item Response Theory, and Rasch

Model. Inclusion criteria consisted of articles relevant to the context of vocational education, HOTS assessment, or technical education measurement. Exclusion criteria included non-peer-reviewed publications or articles unrelated to the vocational education domain.

Analysis and Synthesis of Information

Selected literature was analyzed thematically and narratively, encompassing research trends, measurement methods, technical learning content, and challenges in assessing HOTS at the SMK level. The literature was also mapped according to key concepts and its theoretical contributions.

Bibliometric Visualization

Metadata from the 100 selected articles was analyzed using VOSviewer to map inter-topic relationships. The visualization results revealed the dominance of HOTS as a topic and the weak connections to vocational technical and assessment themes, further emphasizing the identified research gap.

Interpretation and Framework Formulation

The results of the synthesis and mapping were used to develop a conceptual framework for constructing HOTS assessment instruments in Engineering Mechanics. This framework integrates the cognitive dimensions of the Revised Bloom's Taxonomy, constructivist learning principles, and modern measurement approaches (IRT/Rasch).

Instrument

The primary instrument used in this study is a conceptual framework designed to evaluate the relevance and contribution of the literature across three main dimensions: HOTS assessment (C4–C6), the context of Engineering Mechanics in vocational high schools (SMK), and measurement models applicable to SMK settings. In addition, an analytical checklist was employed to identify whether an article presents a valid, measurable approach that aligns with the needs of vocational technical education.

FINDINGS

This study finds that HOTS-based assessment in teaching Engineering Mechanics at vocational high schools (SMK) still faces significant challenges regarding instrument design, measurement approaches, and implementation within the vocational education context. Based on a synthesis of over 100 sources of literature, the findings are categorized into the following three main areas:

Limited Integration of HOTS in Engineering Mechanics Instruction

Implementing Higher Order Thinking Skills (HOTS) in the teaching of Engineering Mechanics has not been carried out systematically. Many teachers continue to deliver material procedurally, focusing primarily on formulas and calculations, without encouraging students to think analytically or creatively. Students are often guided toward memorizing formulas rather than understanding underlying concepts or solving contextual problems. For example, Narasati et al (2021) reported that although teachers are familiar with HOTS, their ability to construct items requiring analysis or evaluation remains limited. Similarly, Wardoyo & Ma'arif (2015) emphasized that lacking HOTS integration hinders students from connecting mechanics concepts with real-life situations in construction fields. This condition indicates that HOTS has yet to become an inherent component of technical teaching approaches in vocational schools. Higher-order thinking skills are critically needed in the construction industry, which is dynamic and uncertain. This highlights the importance of integrating technical content, industrial context, and cognitive demands at higher levels.

Weak Quality and Validity of Assessment Instruments

The following finding reveals that the assessment instruments currently used in vocational schools to measure HOTS lack adequate psychometric quality. Many instruments rely solely on expert judgment or limited pilot testing, without undergoing rigorous statistical validation processes such as construct validity,

internal reliability, or person–item fit analysis. Iskandar (2013) and Kamilati (2018) noted that teachers often use direct, convergent-type questions that do not allow students to explain reasoning, analyze alternatives, or design solutions. In contrast, HOTS-based items should be open-ended, require reasoning, and potentially have more than one correct answer. Unfortunately, such approaches are rarely applied in Engineering Mechanics assessments. Furthermore, most studies still rely on Classical Test Theory (CTT), which, while commonly used, has limitations, such as failing to account for individual student characteristics and being unable to distinguish abilities when items are not equivalent accurately. More objective and adaptive approaches, such as Item Response Theory (IRT) and the Rasch Model, are still underutilized by both educators and researchers in this field (Jumini & Retnawati, 2022; Sumintono & Widhiarso, 2015b)

The Need for Contextualized and Standardized HOTS Instruments

Several studies have attempted to develop HOTS instruments for technical fields; however, findings show that the approaches used vary widely and often do not meet standard measurement criteria. Some instruments assess only a single dimension of HOTS (e.g., analysis) and lack comprehensive validity and reliability testing. Below is a summary of the synthesis from five key studies related to the development of HOTS assessment in the context of vocational education:

Table 1. The summary of the synthesis from five key studies related to the development of HOTS assessment

No	Writers	Methodology	Focus of The Study	Key Findings	Gap
1	Rouf et al (2021)	R&D dan CFA	Development of a HOTS-Based Scientific Literacy Instrument in Engineering Mechanics.	Scientific literacy can promote students' HOTS in Engineering Mechanics within vocational high schools (SMK) for building construction.	No analysis of item difficulty level or reliability has been conducted.
2	Arthur et al (2023)	R&D dan CFA	Development of HOTS-Based Structural Moment Test Items.	HOTS constructs are reflected in Engineering Mechanics test items.	The IRT/Rasch approach has not yet been applied.
3	Narasati et al (2021)	R&D	HOTS Assessment in Engineering Mechanics Using Quizizz.	Digital platforms can support HOTS assessment in Engineering Mechanics.	Validity was examined only descriptively (Aiken's V).
4	Putri & Saparji (2014)	Case Study	Application of the SOLO Taxonomy to Identify Students' Thinking Errors.	Produces a profile of students' thinking errors in Engineering Mechanics problems.	Has not been developed into a quantitative measurement tool.
5	Jumini & Retnawati (2022)	Descriptive Quantitative	Implementation of the Rasch Model in HOTS Assessment.	The Rasch model is effective for mapping HOTS proficiency.	Has not been implemented in the vocational technical context (SMK).

Thematic Synthesis and Directions for Future Research

From the synthesis presented in the table above, a general pattern emerges indicating that existing Engineering Mechanics instruments have not yet comprehensively and systematically measured Higher Order Thinking Skills (HOTS). Instrument validation is still primarily conducted using classical approaches, and modern statistical methods such as Item Response Theory (IRT) or the Rasch Model have not been implemented in the design of HOTS-based Engineering Mechanics test items. This suggests that current instruments lack a specific focus on HOTS and are not sufficiently contextualized for practical use. This gap is particularly concerning given the high demand for such instruments in response to the complex and rapidly evolving nature of fieldwork in the construction industry.

DISCUSSION

Referring to the bibliometric analysis using VOSviewer presented in the introduction, the theme of Higher Order Thinking Skills (HOTS) is closely related to various research aspects associated with soft skills, such as critical, analytical, and creative thinking, as well as other essential 21st-century competencies (Friyatmi et al., 2020). These skills extend beyond basic literacies like reading and arithmetic and encompass broader literacies, including the ability to process information and solve problems systematically and logically (Arthur et al., 2023). Higher-order thinking skills are especially crucial in vocational education, particularly for students in Vocational High Schools (SMK) enrolled in specialized programs that lead to employment in high-risk and critical sectors (Mufit & Wrahatnolo, 2020). One such program is the Construction and Property Technology Expertise Program. To ensure students' readiness for the workforce, they must be equipped with relevant competencies, including a sound understanding of Engineering Mechanics as a core foundation in the construction and property domain (Jaya, 2023).

Despite its significance, Engineering Mechanics remains among the most challenging and intimidating subjects for many students (Asmanullah et al., 2019). Understanding core concepts often challenges teachers in creating engaging and conducive learning environments (Narassati, 2021). Consequently, evaluation processes become suboptimal, particularly in assessing whether students' competencies align with established standards. This issue is further compounded by the limited capacity of teachers to design and integrate assessments that reflect HOTS principles (Herawati, 2021; Ningsi & Shaleh, 2024). Current assessment instruments still fail to accommodate higher-order thinking skills adequately, often neglecting a balanced integration of conceptual, contextual, and procedural dimensions (Putri & Suparji, 2014; Thornhill-Miller et al., 2023). However, evaluation remains a crucial final stage in measuring student competence in the classroom (Friyatmi et al., 2020). Therefore, systematic efforts are required to improve assessment quality, including developing HOTS-based evaluation instruments and enhancing teachers' capacity to implement them effectively in instruction.

In the study by Rouf et al (2021) 's Prototype of Science Literacy Instruments on the Competence of Construction and Property Technology Expertise, literacy is a crucial form of accountability for progress in various vocational domains (Arthur et al., 2023). Literacy is also inherently linked to HOTS-based assessment items. An OECD survey revealed the low capacity of SMK students to engage with complex problem scenarios, prompting the development of a scientific literacy instrument based on Engineering Mechanics content as an essential domain competency (OECD, 2023). The study also identified a significant challenge: the disconnect between theoretical instruction and real-world construction problems. Therefore, HOTS-based assessment development must consider the relevance of instructional content to practical industry demands.

Furthermore, Arthur et al (2023), in their study Development of HOTS-Based Assessment Instruments in Calculating Building Structures Moment for Vocational High School (VHS), emphasized that HOTS-oriented assessments can support students in better understanding structural concepts accommodated by Engineering Mechanics. However, the effectiveness of such assessments depends on instructional approaches that foster deep learning; otherwise, HOTS assessments risk becoming mere measurement tools with little impact on

students' competence development. This highlights the need for an integrated approach between assessment and instructional methods that stimulate student exploration and critical thinking.

Research on developing Engineering Mechanics instruments and their urgency has taken various forms. Narasati et al (2021), in their study on HOTS instrument development for SMK building programs, presented their instrument via the Quizizz application as a solution to students' misconceptions about the subject's complexity. Online quizzes enabled better student engagement and understanding, especially as the digital platform aligns with the technological affinity of today's learners (Hagare & Rahman, 2019). However, such digital assessments must still ensure the validity and reliability of HOTS measurement.

Putri & Suparji (2014) found that students often make mistakes in Engineering Mechanics problems due to a lack of conceptual understanding. A precise mapping of students' comprehension is essential to reach higher cognitive levels effectively. Their study applied the SOLO Taxonomy, focusing on students' learning outcomes. Although this taxonomy differs from that used in HOTS frameworks, it offers valuable insights for teachers and stakeholders in developing effective assessment instruments for a subject often perceived as difficult. The studies summarized in the table represent relevant contributions to developing Engineering Mechanics assessment tools and provide a foundational reference for this research.

Across the reviewed studies, the most prominent challenge in developing standardized instruments lies in teachers' capacity to adapt them to students' characteristics, learning needs, and classroom realities. The limited teacher competence in designing HOTS-based assessments, particularly within the Engineering Mechanics content area in the Construction and Property Technology program, highlights the need for targeted teacher training. Adequate professional development can be critical in supporting the effective implementation of HOTS assessments in vocational schools.

Based on the VOSviewer mapping and literature review results, future research should adopt a holistic approach to HOTS assessment development, starting from the preparation stage, through the design process, to the output and its alignment with other instructional components. This includes the appropriateness of learning methods, teacher training (as previously discussed), and instrument validation under various classroom conditions. Finally, to explore the long-term impact of HOTS assessments in Engineering Mechanics, their contribution must be demonstrated in bridging the gap between theoretical classroom practices and the real needs of the construction industry. This also ties into achieving effective link and match strategies, a hallmark of vocational education. Considering increasing competition in the skilled labor market and rapid technological advancements that automate critical processes in the construction sector, future studies should examine how HOTS competencies support SMK graduates in remaining competitive and work-ready in an ever-evolving industrial landscape.

CONCLUSION

Based on the explanation above, it can be concluded that the measurement of student competencies in Vocational High Schools (SMK) under the Construction and Property Technology Expertise Program remains suboptimal. This is particularly evident in students' mastery of core competencies required for employment in the construction industry, which demands more complex analytical abilities, such as those in Engineering Mechanics. Higher-level cognitive abilities are recognized as Higher Order Thinking Skills (HOTS). According to the VOSviewer mapping results, HOTS is strongly connected to several other themes, with "assessment" emerging as one of the most prominent. The literature indicates that HOTS assessment in Engineering Mechanics still requires greater attention, not merely in item development, but also in enabling teachers to design proper measurement standards aligned with students' learning outcomes. These standards must consider appropriate approaches, methods, frameworks, and other relevant elements that reflect current technological and industrial developments, particularly those aligned with the demands of the construction sector. A more holistic approach appears necessary to develop practical HOTS assessments within the Construction and Property Technology program in SMK. Such an approach is essential for preparing

graduates who are both adaptive and technically skilled and ready to meet the evolving challenges of the modern workforce.

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