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STEM-Based HOTS Digital Assessment Model in Measuring Higher-Order Thinking Skills of Prospective Teacher Students

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Abstract: This study aims to develop a valid digital assessment model using a STEM-based approach to effectively measure higher-order thinking skills (HOTS) among prospective elementary school teachers. The research employed a Research and Development (R&D) method, adapted from the Borg & Gall model, involving expert validation, preliminary field testing, and main field testing at Universitas Samudra's Elementary Teacher Education program. Instrument validity was examined through the Kaiser-Meyer-Olkin (KMO) test and correlation analysis among indicators. The results showed that the developed model achieved high validity, with strong KMO values and significant indicator correlations, confirming its construct soundness. Additionally, the model enabled real-time feedback, enhancing students' conceptual understanding and application of HOTS in STEM-related tasks. The discussion highlights how integrating technology and STEM principles into assessment design supports more interactive and reflective learning. The model also addressed challenges in traditional HOTS assessment, such as lack of immediacy and contextual relevance. In conclusion, the STEM-based HOTS digital assessment model provides an effective and practical tool for evaluating prospective teachers' higher-order thinking, offering significant implications for improving teacher education and elementary classroom practices.

Keywords: Digital Assessment; HOTS; Prospective Teacher Education; STEM; Teacher Education.

Introduction

Twenty-first-century education requires students to not only acquire basic knowledge but also the ability to think critically, creatively, and solve complex problems (Arwin et al., 2024; Haryati et al., 2024; Kenedi et al., 2019, 2025; Mat et al., 2024; Padernal & Tupas, 2024; Ramadhani et al., 2022; Zainil & Kenedi, 2022). For this reason, Higher Order Thinking Skills (HOTS) are very important for the younger generation to master (Ahmad et al., 2018; Boliver et al., 2021; Gading & Rohaeti, 2024; Haryati et al., 2024; Hasruddin et al., 2024; Kim et al., 2020; Pantiwati et al., 2024; Putri & Umah, 2020). HOTS includes critical and analytical thinking skills, as well as the ability to solve problems in a more in-depth and applicable manner (Eliyasni et al., 2019; Lyon et al., 2020; Pragholapati, 2021; Tanudjaya & Doorman, 2020).

At the elementary education level, these skills are essential for students to face increasingly complex challenges in an ever-evolving world. One way to support the development of HOTS in students is by integrating the STEM (Science, Technology, Engineering, and Mathematics) approach, which

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combines knowledge and skills from various disciplines and emphasizes problem solving and creativity (Anggaryani et al., 2022; Arwin et al., 2024; Baran et al., 2021; Rahman et al., 2023; Ramadhani et al., 2023; Trevallion & Trevallion, 2020; Triana et al., 2020). STEM education provides opportunities to develop higher-order thinking skills through project-based learning, the use of technology, and collaboration between various interrelated disciplines (Bowen et al., 2022; Dare et al., 2021; Gading & Rohaeti, 2024; Hasan, 2024; Hasruddin et al., 2024; Jumanto et al., 2024; Li & Oon, 2024; Maryanti & Sartono, 2024; Muskhir et al., 2024; Setyani et al., 2024; Zainil et al., 2023; Zainil et al., 2024). However, despite the growing recognition of the importance of HOTS in basic education, assessing these skills among prospective teachers, especially in basic education, still faces various challenges. Observations conducted at several educational institutions in Indonesia show that most prospective teachers are still accustomed to assessment methods that focus more on testing factual knowledge and basic understanding. Assessments are often in the form of theoretical tests that emphasize memorization and basic skills, which cannot fully describe students' abilities in critical thinking and solving more complex problems. In interviews with several education administrators and lecturers in elementary school teacher education programs, they revealed that although the application of STEM in the teacher education curriculum has begun to be implemented, the evaluation and assessment of students' HOTS in the context of STEM is still very limited. Much of the teaching focuses on knowledge alone, without providing sufficient space for developing higher-order thinking skills. This fact shows that the current assessment system is inadequate for measuring HOTS in the context of STEM-based learning, and there is still a significant need to develop more effective assessment models.

One of the main issues faced in HOTS assessment is the limitation of existing assessment tools. Traditional HOTS assessments, such as multiple-choice or essay exams, cannot optimally assess the critical thinking and problem-solving skills required in STEM. Many existing assessment instruments are still simple and focus more on basic knowledge aspects, rather than the ability to apply knowledge in more complex situations. This case is a major problem, especially in preparing prospective teachers who can measure and develop their students' HOTS. In addition, many assessments are done manually, which is time-consuming and often not objective. With the development of digital technology, there is great potential to develop more efficient, objective assessment models that can provide more in-depth feedback. However, even though technology can offer solutions in terms of efficiency and reliability, implementing digital assessments to measure HOTS in the STEM framework for prospective elementary school teachers is still rare. Many existing digital assessment models focus more on testing basic knowledge than higher-order thinking skills.

Several previous studies have explored the use of digital assessment models in education; however, most of them have been limited to higher levels of education or focused on specific subject areas. For instance, Colley (2020) developed a digital assessment tool to measure HOTS among high school students within a STEM context. Their findings demonstrated that digital assessments could enhance the effectiveness of evaluating higher-order thinking skills. However, their study did not focus on teacher education—particularly not on prospective elementary school teachers—and did not fully integrate the STEM approach into the assessment design. Meanwhile, Harris & Jones (2019) designed a technology-based assessment model within teacher education. While their research contributed to the application of digital tools in educational assessment, it did not specifically address the measurement of HOTS, nor did it connect the assessment design with STEM-based learning in elementary education. These studies suggest that, although there has been considerable work on digital assessments and HOTS, no prior research has specifically developed a digital assessment model that integrates the STEM approach and directly targets the measurement of HOTS in prospective elementary school teachers.

The novelty of this study lies in the development of a digital assessment model specifically designed to measure higher-order thinking skills (HOTS) within a STEM learning framework for prospective elementary school teachers. The model uniquely combines HOTS indicators with interdisciplinary STEM content and leverages interactive digital technology to deliver real-time feedback—features not found in prior models. This research is crucial because assessment plays a central role in shaping the learning process, particularly in fostering and measuring HOTS, which are emphasized in 21st-century learning and in curriculum reforms such as Indonesia's Merdeka Curriculum. The lack of valid, relevant, and contextually appropriate assessment tools for elementary teacher education poses a risk of disconnect between curriculum objectives and classroom practices. Moreover, the integration of digital technology in assessment is essential to address demands for efficiency, objectivity, and timely feedback in modern teacher education.

The assessment model developed in this study aims to solve the problems prospective teachers face in

assessing HOTS. This digital assessment is designed not only to measure students' basic knowledge and their ability to think critically, solve problems, and apply knowledge in real-world contexts. Thus, this research has a significant contribution in preparing prospective elementary school teachers who not only master theory but are also able to assess and develop higher-order thinking skills in their students using the right technology. This research aims to present a valid and effective model that can be applied in teacher education, improving the overall quality of basic education.

Through this research, an assessment model can be created that is relevant to current needs and innovative in supporting the development of HOTS for prospective elementary school teachers. This research is expected to make a real contribution to advancing basic education by equipping prospective teachers with the tools and skills necessary to produce a future generation that not only master's knowledge but also has the thinking skills needed to face the challenges of an increasingly complex world.

Method

This research uses the R&D method to develop a digital assessment model that measures Higher Order Thinking Skills (HOTS) in STEM-based learning for prospective elementary school teachers. The stages of the development process are illustrated in the following figure.

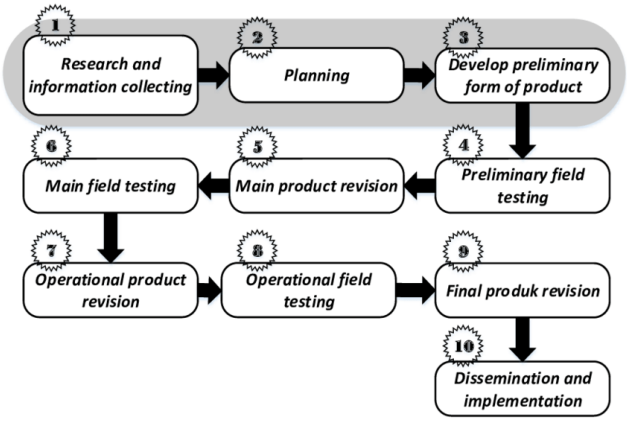

Figure 1. The stages of the development process

The process involves ten stages: first, research and information gathering to identify problems in the field through observation and interviews, and second, planning the design of assessment instruments that focus on HOTS skills. Third, developing an initial product in the form of a digital assessment model prototype. Fourth, an initial field trial to identify shortcomings. Fifth, the main product should be revised based on the trial results. Sixth, a main field trial on a larger sample to test the model's effectiveness. Seventh, the operational product will be revised after the main trial is evaluated. Eighth, operational field trials will be conducted to assess the feasibility and effectiveness of the model in the real field. Ninth, the final product will be revised based on the results of the operational trial. Finally, the refined assessment model will be disseminated and implemented to relevant parties for wider use.

Place and Time of Research

This research was conducted at Samudra University's Primary School Teacher Education Study Program (PGSD), located in Langsa City, Aceh. It will last six months, with the stages divided as follows: three months for model development, two months for initial field testing, and one month for main field testing and model revision.

Research Sample

The sample in this study consisted of prospective elementary school teachers studying at the PGSD program at Samudra University. The sample was selected using purposive sampling, namely the selection of students directly involved in the STEM learning process and HOTS assessment. This sample was selected because they would be the main users of the assessment model developed and could provide the necessary feedback to refine the model. The number of samples in the initial field test was 30 students, while in the main field test, the number would increase to 100 students.

Data Collection and Analysis Techniques

The data collection technique in this study involved using a questionnaire to be filled out by prospective teacher students after using the digital assessment model. This questionnaire contained questions related to the assessment model's effectiveness and ease of use, as well as the suitability of the model in measuring HOTS in the context of STEM. The data obtained from this questionnaire will be analyzed using descriptive statistics to describe the responses and feedback from users regarding the developed assessment model. In addition, data from interviews with experts and users will also be analyzed qualitatively to gain deeper insights into aspects that need to be improved in the assessment model.

Research Instruments

The instruments used in this study include a digital assessment rubric designed to assess HOTS in prospective teachers and a validation questionnaire used to collect data from experts and users. Two experts in education and learning technology validated these instruments to ensure that the measuring tools used are

valid and reliable. Based on the validation results, the assessment instruments are confirmed to have high validity, with a reliability coefficient value of more than 0.85, which indicates a good level of reliability.

Result and Discussion

Result

The research results are presented based on the main stages of the research, namely:

Research and Information Collection

In the information gathering stage, the researcher identified problems through interviews with lecturers and administrators of the PGSD study program at Samudra University. These interviews aimed to determine the HOTS assessment practices that had been implemented in the learning process in the study program. From the interview results, it was found that although there was teaching about STEM and HOTS, there was no structured and well-integrated assessment model that effectively measured higher-order thinking skills. In addition, classroom observations showed that HOTS evaluations were still more oriented towards knowledge-based assessment, with little or no monitoring of the application of critical thinking or problem-solving skills.

The researchers also collected documents related to learning planning and semester program plans (RPS) that refer to curriculum standards. The results of the document analysis showed that although STEM is an important part of the curriculum, HOTS assessment in these courses has not been fully integrated with technology that can provide direct and detailed assessment.

Planning

Based on the results of this information gathering, the researchers carried out planning by designing a digital assessment model that measures HOTS in the context of STEM learning. The design of this model prioritizes the measurement of higher-order thinking skills through digital-based assessment instruments that can provide real-time feedback. In this stage, the researcher used literature on HOTS and STEM assessment to develop assessment concepts and indicators relevant to the needs of prospective elementary school teachers.

The digital assessment model developed includes several main components:

Assessment Rubric

This rubric measures higher-order thinking skills through various STEM-related tasks, such as science-based problem solving, technological experiments, and engineering tasks that require in-depth analysis and creativity.

Project-Based Tasks

This model is designed to integrate STEM-based projects that allow prospective teachers to collaborate in solving real-world problems. These tasks are designed to measure their ability to plan, develop, and evaluate innovative solutions.

Technology-Based Digital Assessment

An application- or platform-based assessment system that allows students to collect data and complete assignments online. This technology also provides real-time automatic feedback and can provide in-depth analysis of students' HOTS skill development. These components will be developed during the model development stage.

Develop preliminary form of product

At this stage, researchers developed a digital assessment model designed to measure Higher Order Thinking Skills (HOTS) in the context of STEM-based learning for prospective elementary school teachers. This assessment model aims to provide a more efficient, objective, and technology-integrated measurement tool to assess higher-order thinking skills, such as critical thinking, creativity, and problem-solving abilities. To develop appropriate assessment indicators, researchers conducted a series of Focus Group Discussions (FGDs) involving PGSD lecturers from Samudra University, STEM education experts, and other teaching staff with experience in HOTS assessment. The first FGD produced 18 HOTS indicators relevant to STEM-based assessment, such as problem solving, data analysis, teamwork, and creativity in the context of science and technology.

The validation of the STEM-based digital HOTS assessment model was conducted in two stages involving three experts Dr. Asnawi, M.Pd [1], Dr. Melva Zainil, M.Pd [2] and Prof. Syafri Ahmad, Ph.D [3]. The results are as follows Table 1.

Based on Table 1, the results of the first stage of validation show that most components of the STEM-based HOTS digital assessment model are still in the moderately valid (C) category, with several aspects that need improvement, such as STEM-based Project Assignments, HOTS Assessment Rubrics, and HOTS Test Instruments. Based on input from experts, revisions were made to these elements, such as adding team collaboration elements to the project, clarifying the assessment rubric descriptors, and ensuring that the HOTS test instruments covered all relevant aspects. After the revision, the results of the second stage of validation showed an improvement in the quality of the model, with all components reaching the B (Valid) category and two components, namely the HOTS Digital

Assessment Model and the Digital Assessment Platform, successfully moving up to the A (Highly Valid) category. Thus, this model was declared valid and ready for further testing.

Table 1. Results of Validation Stages 1 and 2

Validated Components	Validation Score for Stage 1	Validation Score for Stage 2	Validation Category	Dominant Validator
HOTS Digital Assessment Model	75	85	A (Highly valid)	[1]
STEM-Based Project Assignment	38	48	B (Valid)	[2]
HOTS Assessment Rubric	27	35	B (Valid)	[3]
Digital Assessment Platform	33	42	A (Highly valid)	[1]
Student Observation Sheet	29	33	B (Valid)	[2]
HOTS Test Instrument	40	50	B (Valid)	[3]
Implementation Guide	30	40	B (Valid)	[1]

Preliminary Field Testing and Main Product Revision

The results of the initial field trial for the STEM-based HOTS digital assessment model were conducted at PGSD Universitas Samudra, involving 30 prospective elementary school teachers. This trial aimed to identify the effectiveness of the model in measuring higher-order thinking skills (HOTS) in the context of STEM-based learning. Based on the results of factor analysis, the following are the results of the initial field trial.

Table 2. Initial Field Test Results

Validated Components	KMO Value	Effective Variance	Correlation Coefficient	Description
Digital HOTS assessment Model	0.84	75	0.84	Significant
STEM-Based project Assignments	0.79	70	0.76	Significant
HOTS Assessment rubric	0.78	65	0.73	Significant
digital Assessment platform	0.81	80	0.81	Significant
student Observation sheet	0.76	72	0.74	Significant
HOTS test instrument	0.81	78	0.79	Significant
Implementation guide	0.77	74	0.78	Significant

Based on Table 2, the test results show that the KMO values for all assessment components are at a significant level, indicating that the use of factor analysis is very appropriate for measuring indicator suitability. Each assessment component contributes effectively to the model, with the Digital Assessment Platform and HOTS Test Instrument showing strong contributions. The correlation coefficients between indicators also show positive and significant relationships, meaning that these indicators support each other in effectively measuring higher-order thinking skills.

Based on the test results, several revisions were made to improve the quality and effectiveness of the developed assessment model. First, team collaboration elements were added to the STEM-based project tasks, and the level of task complexity was increased to better reflect real-world problem-solving scenarios. Second, the level descriptors in the HOTS assessment rubric were clarified to ensure more accurate and consistent evaluation of student performance. Third, the HOTS test instrument was enriched with more comprehensive and challenging questions to enhance its ability to measure higher-order thinking skills effectively. Lastly, the implementation guide was refined by providing clearer instructions on the use of technology within the digital assessment platform, ensuring that users can navigate and apply the model with ease.

Main Field Testing

The results of the main field trial for the STEM-based HOTS digital assessment model were conducted in the Primary School Teacher Education Study Program at Samudra University. This trial aimed to test the effectiveness of the assessment model in a real-world context, involving testing on a larger and more representative group. Based on the results of factor analysis, the following are the results of the main field trial showing the KMO value, effective contribution, and correlation coefficient between indicators used in the HOTS digital assessment model.

Based on Table 3, the main field test results show that the KMO values for all components are in the significant category, indicating that the indicators in the HOTS digital assessment model are highly relevant and contribute strongly to the measured factors. Each component shows a high effective contribution, and the correlation coefficient between indicators shows a strong and significant relationship with one another.

This indicates that the indicators in the model support each other in measuring higher-order thinking skills.

Table 3. Main Field Trial Results

Validated Components	KMO Value	Effective Contribution	Correlation Coefficient	Description
Digital HOTS assessment Model	0.73	75	0.81	Significant
STEM-Based project Assignments	0.73	76	0.81	Significant
HOTS Assessment rubric	0.79	79	0.83	Significant
digital Assessment platform	0.80	80	0.83	Significant
student Observation sheet	0.78	78	0.82	Significant
HOTS test instrument	0.78	75	0.81	Significant
Implementation guide	0.78	74	0.80	Significant

The results of the main field test for the STEM-based HOTS digital assessment model conducted in the Primary School Teacher Education Study Program at Samudra University indicate that this model is very effective in measuring higher-order thinking skills in prospective primary school teachers. Based on the factor analysis used to measure the effectiveness of the model, several main components show significant results. The KMO values for all assessment components were in the significant category, indicating that the factor analysis used to measure the suitability of the indicators in this model was very appropriate. Components with high KMO values, such as the Digital Assessment Platform and HOTS Assessment Rubric, with values of 0.809 and 0.790, respectively, show a very strong contribution to the overall assessment model.

Meanwhile, the effective contribution of each component shows that all elements of the model contribute significantly to the HOTS assessment variable. Components such as the Digital Assessment Platform and HOTS Assessment Rubric have a very significant contribution, with scores of 80% and 79% respectively. These figures show that these components are very effective in measuring HOTS, while other components such as the HOTS Test Instrument and STEM-Based Project Assignments also make a significant contribution with a contribution of around 75%-78%. In addition, the correlation coefficients between indicators in each assessment component show a strong and significant relationship. For example, the Digital Assessment Platform has a correlation coefficient of 0.836, while the HOTS Assessment Rubric shows a correlation coefficient of 0.830. These values indicate that the indicators in these components support each other well and are relevant in measuring higher-order thinking skills.

Overall, the main field test results show that this STEM-based HOTS digital assessment model is highly effective in measuring HOTS skills in prospective elementary school teachers. With these results, the model is declared highly effective and ready to proceed to the next stage of implementation.

Discussion

The main field test results show that the developed STEM-based HOTS digital assessment model is effective in measuring the higher-order thinking skills of prospective elementary school teachers. Factor analysis shows significant KMO values for all components, with the highest values in the Digital Assessment Platform (0.809) and the HOTS Assessment Rubric (0.790). The effective contribution of each component was also high, reaching 80% and 79%, and the correlation coefficient between indicators was above 0.8, indicating a strong relationship between indicators in this model. These findings show that the developed model is not only efficient but also provides excellent results in measuring HOTS skills in prospective elementary school teachers.

This study contributes to the development of a technology-based assessment model that measures HOTS, which has not been widely done at the higher education level for prospective teachers. Previous studies, show that digital literacy affects teachers' ability to develop HOTS-based assessments, which is in line with these findings (Llamas-Nistal et al., 2013). This study expands on this concept by developing a digital platform that can improve the effectiveness of HOTS assessment in prospective teacher students. In addition, research by Mariana & Kristanto (2023), which developed a HOTS and STEM-based assessment model, also provides a strong basis for this study, but differs in that this study focuses on the education of prospective elementary school teachers and the integration of platform-based digital assessment.

Parmiti et al. (2022) also examined teachers' perceptions of the application of HOTS in science education. This study adds a new dimension by developing a digital assessment model that can be practically implemented in the context of higher education for prospective teachers. Similarly, the study by Hamzah et al. (2022), which emphasizes the importance of HOTS assessment in science education, adds a new element by developing a model that can be used in higher education for prospective teachers. Kim et al. (2020), who researched the use of computer-based

scaffolding to improve higher-order thinking skills through problem-based learning, also supports the technology-based approach in this study, although it adapts it for HOTS assessment in the context of prospective teachers (Kwangmuang et al., 2021).

A comparison with previous studies shows that although previous approaches also developed HOTS assessment models, none specifically integrated STEM with digital assessment that could be used by prospective elementary school teachers. This study fills that gap by developing an assessment model that not only assesses higher-order thinking skills but also prepares prospective teachers to teach those skills using technology in the future.

A key strength of this study is the use of a digital platform that allows HOTS assessment to be conducted efficiently and provides real-time feedback, which is particularly important in the context of teacher education. In addition, this model integrates a STEM approach into assessment, which is not only relevant to science-based learning but also provides more holistic skills for 21st-century education. Unlike previous studies, this model focuses on prospective elementary school teachers and supports more advanced technology-based teaching and assessment.

The implication of this study for elementary school teacher education is that the assessment model developed can be an effective tool for measuring HOTS skills in prospective teacher students. By using a digital platform, students can obtain faster and more accurate feedback, which in turn helps them to develop higher-order thinking skills that will be applied in their teaching in elementary schools (Asnawi et al., 2025; Lam et al., 2024; Nassereddine & Nassreddine, 2024; Padernal & Tupas, 2024; Sumarlin et al., 2024; Veven et al., 2024). This model can also be used to improve the quality of assessment in higher education, particularly in teacher education, by integrating technology and STEM in the evaluation of HOTS skills. More importantly, this model prepares prospective teachers to teach higher-order thinking skills to their students in a more structured and technology-based manner

Conclusion

This study successfully developed and validated a STEM-based digital assessment model to measure higher-order thinking skills (HOTS) among prospective elementary school teachers. The model demonstrated high validity, as indicated by KMO values above 0.80 and strong correlation coefficients between indicators. Key components, such as the HOTS assessment rubric and the digital assessment platform, contributed significantly to the model's effectiveness in evaluating critical thinking, creativity, and problem-solving skills. Compared to previous studies, this research presents a unique contribution by integrating interdisciplinary STEM content with real-time digital feedback, specifically designed for teacher education. This integration not only enhances the objectivity and efficiency of assessment but also aligns with 21st-century learning demands and the implementation of the Merdeka Curriculum in Indonesia.

The findings can be generalized to similar educational contexts where digital tools and STEM-based learning are being adopted, particularly in teacher training programs. As a practical implication, the model can serve as a reliable tool for teacher educators to assess and improve prospective teachers' ability to foster HOTS in their future students. Furthermore, schools and teacher education institutions may adopt this model to strengthen the quality of assessment practices and better prepare teachers to face the complexities of modern classrooms.

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Author Contributions

Conceptualization, D.R. and A.K.K.; methodology, A.K.K.; software, M.F.R.; validation, D.R., A.K.K., and H.H.; formal analysis, M.F.R.; investigation, D.R.; resources, A.K.K.; data curation, H.H.; writing—original draft preparation, D.R.; writing—review and editing, A.K.K.; visualization, A.M.; supervision, A.K.K.; project administration, A.K.K.; funding acquisition, A.M. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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