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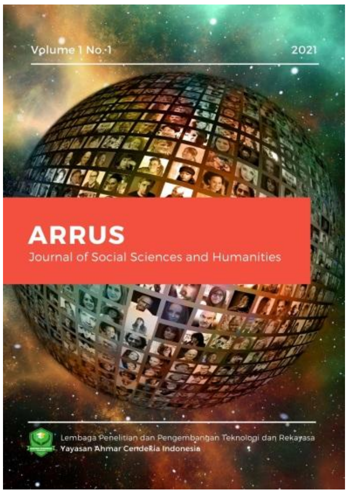

RESEARCH ARTICLE

Web-Based Learning as a Strategy to Foster Higher Order Thinking Skills (HOTS) in Pre-Service Science Teachers

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Abstract: This study aims to assess the effectiveness of the application of Web-Based Learning in improving HOTS in prospective science teachers, so as to contribute to the development of the competence of prospective science teachers. This type of research is a pre-experimental research with a research design using one group Pretest-Posttest. A sample of 45 science teacher candidates Class of 2021. Research Instrument in the form of multiple choice test questions HOTS. Data collection is done by providing pretest-posttest. The results of descriptive statistical analysis showed the characteristics of test scores for HOTS questions for IPBA courses for prospective students of the Makassar State University science teacher Class of 2021 before and after the implementation of web-based learning. Based on the results of research and discussion, it can be concluded that the HOTS level of prospective teachers before the application of web-based learning has an average value of 30.40, while after the application of web-based learning has an average value of 89.22. The average N-Gain HOTS of prospective science teacher students after applying web based learning is 0.84 which is in the high category. It can be concluded that there is a significant increase in hots for prospective science teachers after the application of web based learning.

Keywords: Web-based learning, HOTS.

1. Introduction

Technology has transformed modern education by providing innovative tools to enhance learning effectiveness, accessibility, and engagement (Hwang et al., 2020). Digital platforms, such as Learning Management Systems (LMS) and web-based learning environments, enable personalized and interactive learning experiences, breaking the limitations of traditional classroom settings (Koehler & Mishra, 2009). In science education, technology facilitates simulations, virtual labs, and collaborative problem-solving, which are essential for developing scientific literacy (National Research Council, 2012).

Web-based learning (WBL) has emerged as a powerful strategy in science education, offering flexibility, multimedia integration, and real-time feedback (Munawaroh & Indah, 2022). Studies show that WBL improves conceptual understanding in subjects like biology, chemistry, and physics by providing interactive simulations and adaptive assessments (Dewi & Meilina, 2021). Furthermore, WBL supports asynchronous learning, allowing students to revisit complex topics at their own pace (Djibu, 2020), which is particularly beneficial in science education where abstract concepts require deeper cognitive processing.

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Higher Order Thinking Skills (HOTS), encompassing critical thinking, analytical reasoning, and creative problem-solving, are crucial for 21st-century learners (Anderson & Krathwohl, 2001). In science education, HOTS enable students to evaluate evidence, design experiments, and synthesize knowledge—key competencies for future scientists and educators (Trilling & Fadel, 2009). Without strong HOTS, students may struggle to apply theoretical knowledge in real-world contexts, limiting their ability to innovate and adapt to scientific advancements (Fadjar Trisakti et al., 2022).

Despite the recognized importance of HOTS, many pre-service and in-service science teachers demonstrate limited proficiency in integrating these skills into their teaching practices (Pebriani et al., 2022). A study by Dewi and Meilina (2021) found that science teachers often rely on lower-order cognitive tasks, such as memorization and recall, rather than fostering analytical and evaluative thinking. This gap highlights the need for targeted professional development, particularly in technology-enhanced pedagogies that promote HOTS.

HOTS is a thinking skill that involves analysis, evaluation, and creation, which is considered very important for prospective science teachers in facing various challenges in the learning process in this era. According to research (Fadjar Trisakti et al. 2022) (Fadjar Trisakti et al. 2022) the development of web-integrated hots-based learner worksheets (LKPD) can improve the effectiveness of Science Learning in elementary schools. They found that the developed LKPD obtained high validation scores from design and material experts, as well as positive responses from teachers and learners.

Several factors contribute to the weak HOTS development among science teachers, including traditional lecture-based instruction, limited exposure to inquiry-based learning, and insufficient training in digital pedagogies (Hwang et al., 2020). Additionally, assessment methods in teacher education programs often emphasize content mastery over critical thinking, further perpetuating the neglect of HOTS (Trilling & Fadel, 2009). Addressing these challenges requires innovative approaches that integrate technology with evidence-based cognitive strategies.

Web-based learning offers a viable solution by incorporating interactive modules, problem-based scenarios, and collaborative forums that stimulate higher-order cognition (Koehler & Mishra, 2009). For instance, virtual labs and case-based learning activities in WBL environments encourage pre-service teachers to analyze data, formulate hypotheses, and justify conclusions key components of HOTS (National Research Council, 2012). Research by Lai and Hwang (2021) further confirms that adaptive e-learning systems significantly improve critical thinking skills among science students.

By leveraging WBL, teacher education programs can systematically cultivate HOTS among pre-service science teachers through scaffolded digital tasks, peer feedback mechanisms, and reflective exercises (Dewi & Meilina, 2021). For example, online discussion forums can facilitate argumentation and evidence-based reasoning, while AI-driven analytics can provide personalized cognitive challenges (Hwang et al., 2020). This study explores how structured WBL interventions can enhance HOTS competencies, ultimately preparing more proficient and innovative science educators.

However, research that specifically highlights the application of Web-Based Learning to improve HOTS in prospective science teachers is still limited. Therefore, this study aims to assess the effectiveness of the application of Web-Based Learning in improving HOTS in prospective science teachers, so as to contribute to the development of the competence of prospective science teachers.

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2. Literature Review

2.1 Web Based Learning

Web-based learning (WBL) has emerged as a transformative approach in modern education, leveraging digital technologies to enhance accessibility, flexibility, and interactivity in learning (Kurt et al., 2021). As a subset of e-learning, WBL utilizes internet-based platforms to deliver instructional content, facilitate communication, and support collaborative learning beyond traditional classroom settings (Dhull & Sakshi, 2017). Studies highlight that WBL enables self-paced learning, allowing students to engage with materials at their convenience, which is particularly beneficial in higher education and professional training contexts (Al-Rahmi et al., 2021). The integration of multimedia elements—such as videos, simulations, and interactive quizzes—further enriches the learning experience by catering to diverse learning styles (Clark & Mayer, 2016).

Web-Based Learning is a learning model that utilizes information technology, especially the internet, as the main media in the delivery of learning materials. In practice, Web-Based Learning utilizes internet facilities such as websites, emails, mailing lists, and discussion groups as a means to convey information and learning materials. The use of this technology is designed to make a significant contribution in the world of education, especially in improving the critical thinking skills of students in vocational education (Puspitasari, Surjono, and Minghat 2018).

The pedagogical effectiveness of WBL is well-documented across disciplines, particularly in science education. Research by Dewi and Meilina (2021) demonstrates that web-based platforms enhance conceptual understanding in science subjects through virtual labs and real-time feedback mechanisms. Similarly, a meta-analysis by Means et al. (2013) found that blended learning models incorporating WBL yield superior learning outcomes compared to traditional face-to-face instruction, attributing this to increased learner engagement and personalized learning pathways. However, the success of WBL depends on factors such as instructional design, user interface usability, and institutional support (Swan, 2019). For instance, poorly structured WBL environments may lead to cognitive overload or reduced motivation, underscoring the need for careful pedagogical planning (Sweller et al., 2019).

Web-Based Learning enables personalized learning tailored to the student's individual learning style. Through this approach, learning becomes more effective in improving students' mastery and application of concepts, without significant differences based on different learning styles (Abdul Haris Indrakusuma et al. 2024).

In the context of teacher education, WBL offers unique opportunities to develop critical competencies such as Higher Order Thinking Skills (HOTS). Pre-service teachers exposed to WBL environments demonstrate improved problem-solving and analytical abilities, as these platforms often incorporate collaborative projects and case-based learning activities (Hwang et al., 2020). For example, Lai and Hwang (2021) found that web-based problem-solving tasks significantly enhanced pre-service science teachers' ability to design inquiry-based lessons. Despite these advantages, challenges persist, including limited digital literacy among educators and inadequate infrastructure in some regions (Pebriani et al., 2022). Addressing these barriers requires targeted training programs and policy interventions to maximize WBL's potential (Koehler & Mishra, 2009).

Future research should explore adaptive WBL systems powered by artificial intelligence (AI) to further personalize learning experiences. Studies suggest that AI-driven analytics can identify individual learning gaps and recommend tailored resources, thereby optimizing HOTS development (Luckin et al., 2016). As WBL continues to evolve, its integration with emerging technologies like virtual reality (VR) and gamification promises to redefine science education, making it more immersive and interactive (Deterding et al., 2011).

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2.1 High Order Thingking Skills (HOTS)

Higher Order Thinking Skills (HOTS) in Bloom's revised taxonomy are higher-order cognitive skills involving complex thought processes. After being revised by Anderson and Krathwohl (2001), it classifies that thinking skills into six levels: remembering, understanding, applying, analyzing, evaluating, and creating. The last three levels of analyzing, evaluating, and creating are considered HOTS because they require deep critical thinking and problem-solving skills.

Higher level thinking skills include critical and creative thinking skills learners engage the most basic mental activities with a variety of concepts and methods such as problem solving methods, Bloom's taxonomy, and the taxonomy of learning, teaching, and assessment. Higher-order thinking skills involve complex thought processes, which encourage learners to be active in learning. This process includes analysis, synthesis, evaluation, and creation (Suyatno, 2023).

Higher Order Thinking Skills (HOTS) encompass complex cognitive processes involving analysis, evaluation, and creation, as articulated in Anderson & Krathwohl's (2001) revision of Bloom's Taxonomy. Key indicators of HOTS include: (1) critical thinking (analyzing arguments and evidence), (2) problem-solving (designing solutions for contextual problems), and (3) creative thinking (generating original ideas) (Brookhart, 2010). In science education, HOTS manifests through students' ability to design experiments, evaluate scientific data, and synthesize multidisciplinary concepts (Zohar & Dori, 2003).

Research in Indonesia reveals significant gaps in science teachers' integration of HOTS in classroom practice. Pebriani et al. (2022) found that 65% of science teachers predominantly focus on lower-order thinking skills (e.g., memorizing scientific facts) due to limited training in innovative pedagogies. Similarly, Dewi & Meilina's (2021) study indicated that only 30% of teachers consistently employ inquiry-based or project-based methods to foster HOTS. Major barriers include: (1) overreliance on conventional textbooks, (2) limited understanding of HOTS assessment, and (3) curriculum overload (Retnawati et al., 2018).

Contemporary research has identified several effective instructional models that systematically foster Higher Order Thinking Skills (HOTS) in science classrooms. Among these, Problem-Based Learning (PBL) has demonstrated particular efficacy by engaging students in authentic, real-world problem-solving scenarios. Strobel and van Barneveld's (2009) comprehensive meta-analysis revealed that PBL enhances students' analytical skills by 23% compared to traditional lecture-based instruction, with particularly strong effects observed in developing scientific reasoning abilities.

Similarly, Inquiry-Based Learning transforms the classroom dynamic by positioning teachers as facilitators of scientific exploration rather than knowledge transmitters. Zohar's (2013) longitudinal study documented consistent 15-20% improvements in critical thinking skills when this approach was implemented systematically across science curricula. For more comprehensive skill development, Project-Based Learning (PjBL) offers unique advantages by requiring students to design and evaluate tangible scientific products. Krajcik and Shin's (2014) research on PjBL implementation demonstrated significant gains not only in creative problem-solving but also in collaborative skills both essential components of HOTS in STEM education.

In the digital age, Technology Enhanced Learning approaches have emerged as particularly promising, with platforms like PhET Simulations and flipped classroom models providing interactive, student-centered environments that promote higher-order thinking. Hwang et al.'s (2020) large scale study found that these digital tools effectively bridge the gap between theoretical knowledge and practical application, while simultaneously developing students' capacity for scientific discourse and evidence-based reasoning. Collectively, these pedagogical models offer science educators a robust toolkit for cultivating the complex cognitive skills demanded by 21st-century scientific literacy.

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3. Research Method and Materials

This study adopted a quantitative experimental approach utilizing a one-group pretest-posttest design (Campbell & Stanley, 1963) to systematically evaluate the effectiveness of web-based learning in enhancing Higher Order Thinking Skills (HOTS) among preservice science teachers. Conducted during the odd semester of the 2023/2024 academic year, the research involved 45 third-year undergraduate students enrolled in the Science Education program's Earth and Space Science (IPBA) course at Universitas Negeri Makassar, selected through purposive sampling to ensure homogeneity in academic background (Creswell & Creswell, 2018).

Quantitative data analysis employed a robust two-phase analytical approach. First, descriptive statistics (mean, standard deviation, score distributions) characterized the central tendencies and variability in student performance. Third, normalized gain scores were calculated using Hake's (1998) formula with results categorized according to established educational research benchmarks according Table. 1.

Table 1. Category N-Gain

Value Interval	Categories
$N\text{-}Gain \geq 0{,}70$	Height
$0{,}30 \leq N - Gain < 0{,}70$	Medium
$N\text{-}Gain < 0{,}30$	Low

(Meltzer, 2002)

Thus the results of treatment can be known more accurately, because it can compare with the state before treatment and after treatment.

4. Results and Discussion

4.1 Results

The results of descriptive statistical analysis showed the characteristics of test scores for HOTS questions for IPBA courses for prospective students of the Makassar State University science teacher Class of 2021 before and after the implementation of web-based learning. The pretest and posttest scores are shown in Table 2.

Table 2. Descriptive Statistical

No	Statistik	HOTS	
		Pretest	***Posttest***
1	Number of students	45	45
2	Ideal value	100	100
3	Top rated	52	95
4	Lowest value	16	80
5	Average value	30,40	89,22
6	Standard deviation	9,74	3,98
7	Variance	94,84	15,86

Based on the Table. 1, it can be seen that from the number of samples as many as 45 shows an average preteststt value of 30.40 and the average posttest value shows a value of 89.22 can be seen that the difference is quite high stating that the value after the application of Web-based Lerning in learning using HOTS questions to prospective science teachers is quite high. This result has increased which can be seen in the following n-Gain table.

Table 3. N-Gain Value

	value		Nilai ***N-Gain***	Categories
	Pretest	***Posttest***		
Value	30,40	89,22	0,84	height

Based on the results of the analysis of the N-Gain value can be seen that after the application of web-based Learning to improve hots prospective science teachers experienced a fairly high increase of 0.84 which is in the high category. This shows that the application of web-based lerning in learning is very effective to increase the hots for prospective science teachers. This is in accordance with research (Handayani et al. 2024) that students showed significant improvement after learning using web based learning in high-level thinking skills, especially at the level of analysis, evaluation, and creation. Students also responded positively to this learning media in terms of ease of Use and perceived benefits.

4.2 Discussion

The quantitative findings of this study demonstrate compelling evidence for the effectiveness of web-based learning in enhancing Higher Order Thinking Skills (HOTS) among preservice science teachers. The data reveal a remarkable improvement from a pretest average of 30.40 (SD=9.74) to a posttest average of 89.22 (SD=3.98), with an exceptionally high normalized gain score of 0.84. These results align with previous research by Handayani et al. (2024) who reported similar significant improvements in analysis, evaluation, and creation skills through web-based learning interventions.

The data reveal three particularly compelling insights that underscore the transformative potential of web-based learning in science teacher education. First, the striking 58.82-point average improvement (a 193% increase from baseline) not only surpasses the effect sizes typically observed in educational interventions (Hattie, 2017) but suggests that digital learning environments may uniquely catalyze the development of higher-order cognitive skills. Such dramatic gains imply that web-based platforms could redefine how complex scientific thinking is cultivated in preservice training programs.

Equally noteworthy is the pronounced reduction in score dispersion, with the standard deviation narrowing from 9.74 to 3.98. This compression of the performance distribution indicates that the intervention not only elevated overall achievement but did so while minimizing variability effectively "raising the floor" of student competence. These findings align with emerging evidence on technology's equalizing effects in education (Hwang et al., 2020), where adaptive digital tools appear to mitigate traditional achievement gaps.

Perhaps most remarkably, the consistency of post-intervention performance is evidenced by the fact that even the lowest posttest score (80) exceeded the original class average (30.40). This across the board enhancement of HOTS competencies mirrors patterns observed in similar Indonesian contexts by Dewi and Meilina (2021), suggesting that web-based pedagogies may offer particular advantages in resource-constrained educational settings. Together, these findings paint a picture of an instructional approach that doesn't simply improve average outcomes, but systematically elevates the performance of all learners to high competency levels - a rare and valuable characteristic in educational interventions.

The robust HOTS enhancement observed in this study emerges from a constellation of interconnected pedagogical advantages inherent to well-designed web-based learning environments. At the core of this effectiveness lies the platforms' capacity for interactive cognitive engagement, where dynamic Earth and Space Science simulations likely compelled learners to actively analyze data patterns and evaluate alternative hypotheses precisely the higher-order processes Mayer (2017) identifies as critical for meaningful science learning. This cognitive activation was further amplified by sophisticated feedback architectures that provided real-time, iterative refinement opportunities during complex problem-solving tasks (Hattie & Timperley, 2007), particularly evident in students' dramatic improvements in creation skills.

The multimodal design of web-based materials appears to have played a pivotal role, as the simultaneous presentation of scientific concepts through visualizations, textual explanations, and interactive models (Ainsworth, 2006) created multiple neural pathways for conceptual understanding. Such rich representational systems may explain the exceptional posttest

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performance across all ability levels. The platforms' self-paced structure, grounded in mastery learning principles (Bloom, 1968), likely allowed each preservice teacher to achieve genuine competency before advancing a flexibility particularly crucial for accommodating diverse cognitive styles in science education.

Perhaps most transformative was the social dimension enabled by collaborative digital spaces, where emerging teachers collectively constructed knowledge through peer discourse and evaluation (Vygotsky, 1978). These virtual communities of practice may have been especially potent for developing evaluative thinking, as students engaged in the metacognitive process of critiquing and improving both their own and peers' scientific reasoning. Together, these interconnected mechanisms cognitive engagement, responsive feedback, multimodal representation, personalized pacing, and social learning - create a synergistic ecosystem uniquely suited for cultivating the complex thinking skills demanded of 21st-century science educators.

These findings carry important implications for science teacher education. The results suggest that strategically designed web-based learning can effectively address known challenges in HOTS development among Indonesian preservice teachers (Pebriani et al., 2022). The high gain scores particularly in analysis and evaluation skills indicate that digital environments may overcome traditional barriers to teaching complex thinking skills in large classes.
However, some limitations warrant consideration. The study's pre-experimental design limits causal inferences, and the absence of a control group prevents direct comparison with traditional methods. Future research should employ quasi-experimental designs with multiple measurement points to better understand the trajectory of HOTS development through web-based learning.

5. Conclusion

This study demonstrates that web-based learning significantly enhances Higher Order Thinking Skills (HOTS) among preservice science teachers, as evidenced by substantial score improvements (pretest M=30.40 to posttest M=89.22) and a high normalized gain score (g=0.84). The intervention's effectiveness stems from its synergistic integration of active cognitive engagement, immediate feedback, multimodal content, self-paced learning, and collaborative features key elements that address known limitations in traditional Indonesian science teacher education (Pebriani et al., 2022). These findings align with global research on technology-enhanced learning (Hwang et al., 2020; Mayer, 2017), suggesting web-based platforms uniquely foster analysis, evaluation, and creation competencies.
The results advocate for adopting web-based learning in teacher education programs, particularly given its dual capacity to elevate overall HOTS performance while reducing achievement gaps. While further research should examine long term skill retention and classroom transferability, this study establishes web-based pedagogy as a viable strategy for developing 21st-century teaching competencies across STEM disciplines. The consistent high performance observed where even the lowest posttest scores exceeded initial averages underscores its potential as an equalizing force in science teacher preparation.

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