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Transforming Chemistry Learning through the Development of Higher Order Thinking Based on Revised Bloom's Taxonomy: A Systematic Review

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Abstract
Education is a structured and systematic learning process that aims to improve the knowledge, skills, attitudes and values needed to build a successful career and life. Through education we can produce human resources who are competent and resilient in facing a complex future. The way to produce competent human resources is to improve students' Higher Level Thinking Skills in the learning process. The application of the Revised Bloom's Taxonomy in learning is able to improve students' high-level thinking skills because the revised Bloom's Taxonomy has levels of cognitive abilities starting from low level (LOTS) to high level (HOTS). To find out feedback and student learning outcomes, look at the results of the assessment process after learning. These results can be a reference and even input for teachers to always develop the critical thinking skills learning process. Thus, this article aims to present knowledge information regarding the development of learning high-level thinking skills in chemistry subjects based on the revised Bloom's taxonomy which refers to student assessment.

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PENDAHULUAN

Chemical education is often identified as one of the more challenging subjects due to the complexity of the concepts within it (Armstrong et al., 2018; Hamerská et al., 2024; Ramful & Narod, 2014). The abstract nature of many chemical concepts, such as molecular structure, chemical bonding, and chemical reactions, demands deep understanding and high-level critical thinking skills (Yu et al., 2022). Interactions between subatomic units can affect bonds, molecular structures, and reactions (Caspari et al., 2018). There are many interrelated concepts when examining the essence of chemistry. This phenomenon demands complex and holistic thinking to master chemical concepts more thoroughly and accurately. Traditional chemical education tends to focus on isolated and separate concepts. However, with the increasing complexity of global challenges and problems that chemists need to solve, there is an urgent need to adopt a more holistic approach (Yu et al., 2022). Systems thinking offers a framework that can help chemists understand and manage complex systems (Lehn, 2013; Tiettmeyer et al., 2017). In this context, introducing systems thinking in chemical education becomes very important (Talanquer, 2022).

(Vachliotis et al., 2021) stated that systems thinking is an approach that emphasizes the relationships and interactions between various components within a system. It involves understanding how changes in one part of the system can affect other parts and the system as a whole. In chemistry, this means viewing chemical reactions, materials, and processes not just as separate entities but as interconnected networks (Tümay, 2023). Introducing systems thinking in chemical education is a crucial step to prepare the next generation of chemists to face future challenges. By teaching students to view chemistry as an interconnected system, we can help them become better problem solvers, more adaptive, and more innovative (Hulyadi, Bayani, et al., 2023).

Chemistry is a systemic science that deals with dynamic and complex systems, and systems thinking is an essential aspect of learning chemistry. Therefore, a systems thinking approach is needed in chemical education for meaningful learning about the subject matter (Pappas et al., 2013; Pazicni & Flynn, 2019; Tümay, 2023). Examining and analyzing interconnected concepts within a complex system framework requires high-level thinking skills. An instructional approach that helps students develop higher-order thinking skills is greatly needed in constructing the complexity of chemical concepts (Talanquer, 2022). In an effort to enhance the effectiveness of chemical education, the Revised Bloom's Taxonomy provides a robust framework for developing higher-order thinking skills. The Revised Bloom's Taxonomy offers a systematic framework to achieve this goal (Köksal et al., 2023; Li et al., 2022).

(Li et al., 2022; Sharunova et al., 2022) stated that the Revised Bloom's Taxonomy introduces two main dimensions: the cognitive process dimension and the knowledge dimension. The cognitive process dimension consists of six categories: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. Meanwhile, the knowledge dimension includes Factual Knowledge, Conceptual Knowledge, Procedural Knowledge, and Metacognitive Knowledge. The combination of these two dimensions allows teachers to design more comprehensive and in-depth learning activities (Sudirtha et al., 2022; Widiana et al., 2023). Transforming chemical education through higher-order thinking skills based on the Revised Bloom's Taxonomy not only allows students to understand chemical concepts more deeply but also develops critical and creative thinking skills essential for facing future challenges (Pappas et al., 2013). With the right approach, chemical education can become more engaging and relevant for students.

Every learning objective should be linked to categories in the Revised Bloom's Taxonomy. The integration of Bloom's taxonomy is tailored to the learning objectives or goals (Pappas et al., 2013). Learning activities should be designed to meet various levels of cognitive processes. For example, to develop analytical skills, students can be assigned tasks to compare and contrast redox reactions, acid-base reactions, exothermic and endothermic reactions. For evaluative skills, they can be asked to assess the effectiveness of various purification methods in industrial chemical processes. Interactive learning approaches such as group discussions, laboratory experiments, and computer simulations can help students become more engaged in the learning process (Hulyadi, Muhali, et al., 2023). These activities allow students to apply concepts, analyze results, and create solutions to given problems.

Higher-order thinking skills are part of the 21st-century life skills known as the Seven C's of 21st Century Lifelong Skills, including (1) critical thinking, (2) creativity, (3) communication, (4) collaboration, (5) career and self-directed learning, (6) cross-cultural understanding, and (7) computing/ICT literacy (Bernie, 2005). Bloom's Taxonomy is considered the foundation of higher-order thinking skills. According to Anderson & Krathwohl (2001), the revised Bloom's taxonomy consists of six levels: remembering, understanding, applying, analyzing, evaluating, and creating. This classification includes the cognitive domain, commonly abbreviated as C1 to C6. Higher Order Thinking Skills (HOTS) encompass the highest levels of the revised Bloom's taxonomy, namely analyzing (C4), evaluating (C5), and creating (C6). (Agussuryani et al., 2022; Yusuf et al., 2018) stated that these levels are considered HOTS because they involve complex cognitive processes such as distinguishing, organizing, attributing, making judgments based on criteria, and generating new patterns or structures. The revised taxonomy emphasizes higher-level thinking, which requires mastery of previous knowledge levels and involves metacognitive processes (Febrina, 2019). Students' ability to engage in higher-order thinking is based on their ability to master the lower-order cognitive domains, C1 to C3, in the learning process.

Learning is a system that has interconnected components to achieve enhanced learning objectives. The learning system has outputs from one component that serve as inputs for another. The components include learning objectives, learning methods, learning media, learning strategies, and learning assessment (Pribadi, 2009). To determine the achievement of learning objectives and provide feedback, assessment is necessary. Feedback is essential for revising and correcting the implementation of the learning system. Assessment is an activity carried out by teachers to provide continuous and holistic information about students' achievement of their learning processes and outcomes (Nahadi & Firman, 2019). Assessment is closely related to testing, measurement, and evaluation (Airasian, 2008). Competency assessment based on Bloom's taxonomy cannot be measured only through tests. More comprehensive assessment tools such as portfolios, process skill observation sheets, and other authentic assessments are needed.

Tests are assessment tools that function to measure students' learning outcomes in the cognitive domain. In tests, there are questions that students must answer using their knowledge (Nahadi & Firman, 2019). Information obtained from assessment results can help teachers track the extent of students' learning outcomes, students' competency achievement, and the effectiveness of teaching methods (Nahadi & Firman, 2019). Additionally, it is useful for determining and planning the content to be taught and designing the subsequent learning process to achieve learning objectives (Baird, Andrich, Hopfenbeck, & Stobart, 2017). Assessing students based on the materials discussed with them supports the success of learning by aligning learning and assessment (Erduran, El Masri, Cullinane, & Ng, 2020).

Assessment plays an important role in developing instruction and helping teachers identify learning needs, monitor learning progress, and modify teaching strategies to enhance student skills. Therefore, to develop students' higher-order thinking skills, it is essential to provide HOTS-based learning and assessment. Because the learning process can affect learning outcomes, as stated by Resien et al. (2020), students with creative thinking skills will have better learning outcomes. Well-structured instruments can guide students in developing their cognitive abilities (Hrin et al., 2016; Namestovski & Kovari, 2022).

Research Objectives

To critically analyze existing literature on the transformation of chemical education through the development of higher-order thinking skills based on the revised Bloom's taxonomy. This review aims to synthesize current research findings and practical applications to propose strategic recommendations for integrating Bloom's taxonomy into each chemical learning achievement.

Literature Review

(Akpur, 2020) states that creative thinking is the ability to generate new, original, and useful ideas. It involves thinking beyond existing limitations or patterns to find solutions or approaches that have not been tried before. Creative thinking can be applied in various contexts, including art, science, technology, business, and everyday life. (Birgili, 2015) suggests that creating new works that can change paradigms and habits requires higher-order thinking skills. In the revised Bloom's taxonomy, the ability to create occupies the highest cognitive competence. One of the factors that can support the ability to create is creative thinking. Creative thinking is an essential skill in an ever-changing and challenging world. By developing this ability, individuals can be better prepared to face various situations and create innovations that benefit society (Ardiansah & Zulfiani, 2023; Hatch, 2024). PISA test results show that Indonesian students' creative thinking ability is still relatively low.

The 2022 PISA test conducted by the OECD focused on creative thinking. We will discuss the implications of these results, comparing them with previous PISA test results, which included reading, mathematics, and science, and examining the relevance of creative skills in the current educational context (Hatch, 2024). PISA (Programme for International Student Assessment) is an international evaluation program developed by the OECD to measure the abilities of 15-year-old students in reading, mathematics, and science. However, in 2022, the OECD introduced a new test that assesses students' creative thinking. The purpose of this test is to measure students' ability to think outside the box, a skill increasingly deemed important in a world that is continually changing and full of complex challenges. Creative thinking is an increasingly important skill in the workforce and everyday life. In the digital and globalization era, the ability to think outside the box and find innovative solutions is key to facing complex challenges. This thinking ability is a fundamental 21st-century competency. PISA test results show that Indonesian students' creative thinking ability is still relatively low, as shown in Figure 1.

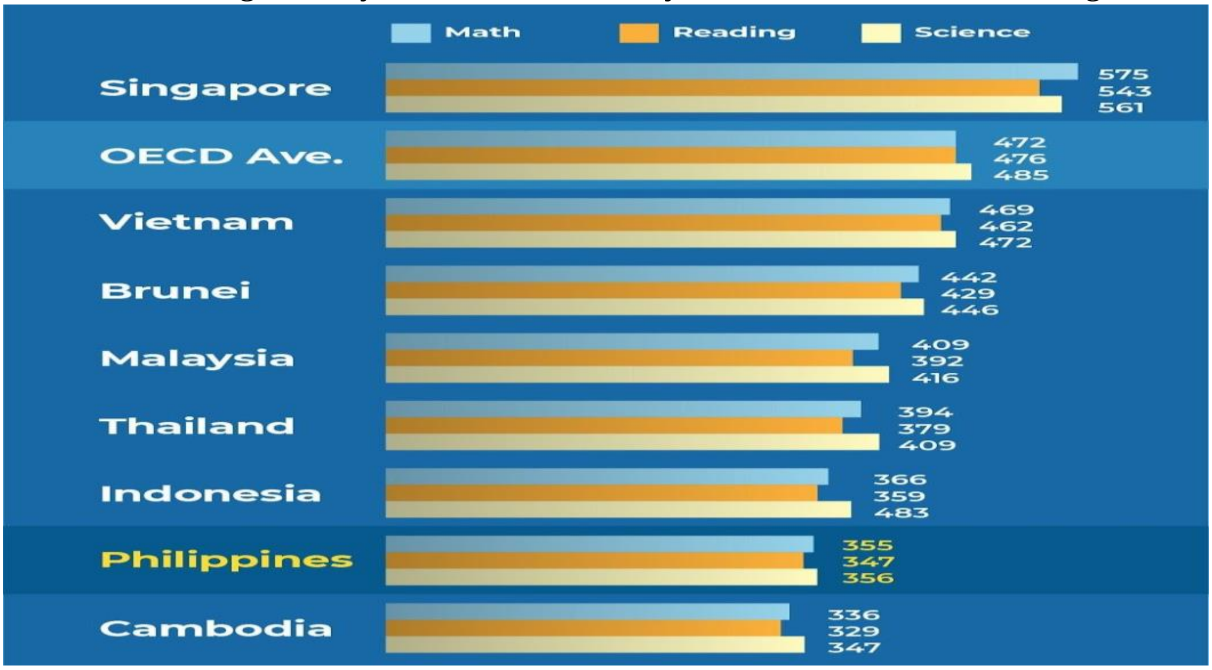

Figure 1. PISA 2022 test results regarding science, mathematics and reading abilities

PISA test results indicate that students' science abilities are still low compared to five other ASEAN countries. This indicator shows that the HOTS (Higher Order Thinking Skills) of Indonesian students need continuous improvement. Teaching using a scientific approach that incorporates contextual issues needs to be continually implemented (Guilfoyle et al., 2023). Previous research has stated that students' higher-order thinking skills are still at a low level in all aspects (Ichsan et al., 2019). Anggraini (2019) also stated that Indonesian students have not yet reached the target of higher-order thinking skills. Based on observations conducted in Banda Aceh, teachers never formulate HOTS questions in daily tests or semester exams. In class evaluations, teachers only provide evaluations with questions in categories C1, C2, and C3, which are the lowest cognitive levels (Sarah et al., 2021). The low level of higher-order thinking skills is also influenced by low learning motivation, as students rely solely on the material explanations given by teachers and are not used to working on HOTS-based questions (Retnawati et al., 2018; Syafryadin et al., 2022).

This issue urgently needs effective and creative solutions to reduce the habit of the Indonesian education system focusing more on content and less on the context of learning. This condition leads to a race to complete learning materials, emphasizing cognitive aspects at levels C1 to C3. The cognitive skills at levels C4 to C6 are still less addressed by most educational institutions (Widiana et al., 2023). Presenting contextual learning is essential for creating meaningful learning experiences and fostering students' learning motivation. Learning from the environment and local issues can enhance students' adaptability in facing problems (Birgili, 2015; Musahal et al., 2024). Environmental issues are fundamental problems that are the center of global attention today. These issues can be utilized as learning resources that need to be studied through various scientific disciplines (Abbass et al., 2022; Adger et al., 2003; Gasper et al., 2011). Environmental problems can be addressed by changing energy usage. Fossil fuels, which still dominate the world's energy sources, must be reduced and replaced with environmentally friendly energy sources (Hunt et al., 2020; Khan, 2012; Schernikau & Smith, 2022). The energy crisis has affected almost all socio-economic aspects of society worldwide, threatening global food stability. Adaptive students with high awareness need to be continuously trained due to the complexity of global issues today. Environmental issues are not the only global problems; health, cyber security, and AI threats to job opportunities are challenges faced worldwide. Higher-order thinking skills are essential amid these global issues (Agussuryani et al., 2022; Yusuf et al., 2018).

Raising students' awareness of the importance of chemistry in life will increase their understanding of chemical concepts. Therefore, it is crucial to develop learning designs and strategies to enhance students' higher-order thinking skills (Santos, 2017). Research conducted by I.G.N. Pujawan et al. (2022) stated that learning activities oriented towards the revised Bloom's taxonomy positively impact students' creative thinking skills and scientific literacy, which are higher-order thinking skills. Teachers have a significant influence on developing learning processes aimed at increasing students' activity and higher-order thinking skills. However, research reveals that teachers' understanding and knowledge of implementing HOTS-based learning in Chemistry subjects in Indonesia are still limited. This knowledge is essential for designing activities to develop teachers' competencies (Nurmawati, 2020). Thus, this review article presents information on developing higher-order thinking skills learning, referring to the results of implementing HOTS assessments for students. The problem statement posed is: How can we develop chemistry learning to enhance higher-order cognitive thinking skills based on Bloom's Taxonomy?

METHOD

The research was conducted using the Systematic Literature Review (SLR) method. According to Xiao and Watson (2019), Systematic Literature Review is a literature review process that adheres to standard guidelines for finding and synthesizing related research papers and evaluating the body of knowledge regarding the problem to be researched. Article searches start from April 16 to May 27, 2024. The keywords used to search for articles are "Bloom-based Cognitive Assessment in Chemistry Learning", "Higher-order thinking skills in Chemistry Assessment", and "Application of Revised Bloom's Taxonomy in the Learning Process Chemistry". After searching for keywords in the database, researchers looked at article titles, abstracts and conclusions that met the inclusion requirements, including discussing 1) The use of higher order thinking skills assessment to assess HOTS-based learning processes; 2) The year of publication is in the last 10 years, starting from 2014 to 2024; 3) The selected articles have Journal rankings Q1 to Q3 detected by Scopus and Sinta 1 to Sinta 3 detected by SINTA. Based on these considerations, we selected 18 articles that passed the inclusion requirements for article analysis. Table 1 shows the articles used in the SLR process.

No	Title	Journal Name	Source Database	Index
1.	Improving Metacognitive Ability and Learning Outcomes with Problem-Based Revised Bloom's Taxonomy Oriented Learning Activities	Emerging Science Journal	Google Scholar	Q1
2.	Probing Internal Assumptions of the Revised Bloom's Taxonomy	CBE—Life Sciences Education	Eric.go	Q1
3.	Higher and Lower-Order Thinking Skills: The Case of Chemistry Revisited	Journal of Baltic Science Education	Google Scholar	Q
4.	A Critical Thinking Assessment Model integrated with Science Process Skills on Chemistry for Senior High School	European Journal of Educational Research	Google Scholar	Q2
5.	The Effectiveness of Using Revised Bloom's Taxonomy-Oriented Learning Activities to Improve Students' Metacognitive Abilities	Journal of Education and e-Learning Research	Google Scholar	Q2

6.	Analysis of 10th Chemistry Curriculum According to Revised Bloom Taxonomy	Journal of Education and e-Learning Research	Eric.go	Q2
7.	Students' Critical Thinking Skills Using HOTS-Based Assessment on pH Calculation	AIP Conf. Proc.	Google Scholar	Q3
8.	Developing an assessment instrument based on HOTS according to Brookhart for thermochemistry materials	AIP Conf. Proc.	Google Scholar	Q3
9.	Acid-base topic materials oriented towards higher-order thinking skills HOTs based instruments	AIP Conf. Proc.	Google Scholar	Q3
10.	Analisis Keterampilan Berpikir Tingkat Tinggi pada Soal Ujian Nasional Kimia	Edusains	Google Scholar	Sinta 2
11.	Pemahaman Guru Kimia Sekolah Menengah Atas tentang Penilaian keterampilan Berpikir Tingkat Tinggi dan Implementasinya	Edusains	Google Scholar	Sinta 2
12.	Pengembangan Instrumen Evaluasi *Higher Order Thinking Skills* Menggunakan Quizizz Pada Materi Termokimia untuk Meningkatkan keterampilan Berpikir Tingkat Tinggi Peserta Didik	Jurnal Pendidikan Sains Indonesia	Google Scholar	Sinta 2
13.	Analisis Soal Ujian Sekolah Mata Pelajaran Kimia Berdasarkan Tingkat Berpikir dan Dimensi Pengetahuan di SMAN 1 Kebumen Tahun 2019 dan 2020	Jurnal Pendidikan Kimia	Google Scholar	Sinta 2

14.	Development of Test Instruments Based on Cognitive Processes and Knowledge Dimensions on Environmental Chemistry	Jurnal Penelitian Pendidikan IPA	Google Scholar	Sinta 2
15.	Analisis keterampilan Kognitif Mahasiswa pada Konsep Asam-Basa Menggunakan Tes Berdasarkan Taksonomi Bloom Revisi	EduChemia (Jurnal Kimia dan Pendidikan)	Google Scholar	Sinta 2
16.	Assessing Students' Higher-Order Thinking Skills: Knowledge And Practices Of Chemistry Teachers In Vocational Senior Secondary Schools	Jurnal Pendidikan Teknologi dan Kejuruan	Google Scholar	Sinta 2
17.	An Analysis Of Chemistry High School End-Of-Year Exams According To Bloom's Cognitive Complexity	Edusains	Google Scholar	Sinta 2
18.	Pengembangan Soal HOTS (High Order Thinking Skills) pada Materi Asam-Basa untuk Kelas XI SMA/MA Sederajat	Jurnal Inovasi Pendidikan Kimia	Google Scholar	Sinta 3
19.	The Development Higher Order Thinking Skill (Hots) As Questions In Chemistry Study (Solubility And Solubility Product Constant)	Jurnal Pendidikan Sains	Google Scholar	Sinta 3

RESULTS AND DISCUSSION

Revised Bloom's Cognitive Based Assessment

Bloom's Taxonomy is a classification of educational objectives initially developed for general educational purposes. This taxonomy was later revised to expand beyond cognitive processes and include types of knowledge as an orthogonal dimension (Larsen et al., 2022). Bloom's cognitive-based assessment approach focuses on developing students' thinking skills at various levels. This approach is based on the revised Bloom's Taxonomy, a framework that classifies thinking skills from lower to higher cognitive levels. Bloom's Taxonomy focuses on the cognitive domain (knowledge, understanding, and development of intellectual attitudes and skills). The goal of this classification is to motivate teachers/educators to focus on various levels of this classification, thus creating a more holistic form of education (Bloom et al., 1956).

To combine the categorization of educational objectives with new knowledge and thinking, Anderson and Krathwohl reformed Bloom's Taxonomy by separating the knowledge dimension from the cognitive process dimension, known as the Revised Bloom's Taxonomy.

The knowledge dimension consists of factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge. Meanwhile, the cognitive process dimension consists of remembering, understanding, applying, analyzing, evaluating, and creating (Agung et al., 2021). Higher Order Thinking Skills (HOTS) encompass the highest levels of the revised Bloom's Taxonomy: analyzing (C4), evaluating (C5), and creating (C6). Students' higher-order thinking skills can be measured using student scores obtained through HOTS-based evaluation instruments (Hirza, 2022). HOTS-based evaluation instruments sharpen thinking and drive higher-order thinking skills so that students can build skills in problem-solving and independently understanding concepts (Kurnia et al., 2022). The assessment is not only carried out during summative assessments but also during daily tests, quizzes, mid-term, and final semester exams. Both LOTS and HOTS level questions need to be tested on students (Tsaparlis, 2020).

The success of improving students' HOTS is influenced by assessment practices. Assessment significantly impacts learning and teaching, such as determining the content to be taught and how the learning process will occur. Students' opportunities to demonstrate their learning outcomes will be higher if there is a connection between learning activities, assessments, and learning targets as written in the curriculum document (Driana et al., 2021).

Research on developing evaluation instruments to measure students' higher-order thinking skills has been conducted by Risdiana et al. (2022) on acid-base material in the 2013 curriculum. In evaluating HOTS, students can be measured through various methods, such as selecting, generalizing, and reasoning. In the research analyzed in our articles, the researchers used the generalizing method with essay-type questions. The level of questions on the critical thinking indicator consists of 2 questions with HOTS indicators, including making judgments, creative thinking consisting of 3 questions with HOTS indicators, flexible thinking and fluent thinking, and problem-solving ability consisting of 3 questions with HOTS indicators, namely planning solutions. The discussion results showed that the development of HOTS questions on acid-base material was declared valid, and the reliability of the questions was very high, with all item discrimination indices being acceptable.

Another study developed HOTS evaluation instruments in thermochemistry material by Kurnia et al. (2022). The researchers used technology-based applications, such as Quizizz, considering it would make students more enthusiastic about learning, as the Quizizz application is tournament-based, encouraging students to work on questions. The discussion results showed that the developed evaluation instruments produced 12 valid HOTS-based evaluation items according to material and media validators. The validation results according to material validators based on aspects of the material had a percentage of 95.83%, construction aspects 94.03%, and language aspects 98.89%. According to media validators, the results were 89.00% for content substance, 90.00% for instructional design, 89.00% for visual communication, and 95.00% for software utilization. The item analysis showed that all 12 items met the valid criteria, had very high reliability, had a "moderate" difficulty level for 5 questions and a "difficult" level for 7 questions, and had good discrimination indices, with all items accepted. User responses showed excellent criteria with an average percentage of 90.67% from teachers and 93.13% from students.

In Indonesia, based on the analysis of our articles, we found three articles related to the implementation of HOTS-based assessment instruments in measuring and enhancing students' higher-order thinking skills. The first article by Masruroh et al. (2022) analyzed the chemistry school exam questions based on thinking levels and knowledge dimensions at SMAN 1 Kebumen in 2019 and 2020. It revealed that, from a thinking level perspective, the school exam questions were quite good as they included a considerable number of HOTS questions.

However, from a cognitive level perspective, the questions were dominated by application (C3) and analysis (C4) levels.

Similarly, the analysis of higher-order thinking skills in national chemistry exam questions by Syahida and Irwandi (2015) showed that higher-order thinking skills in the analyzed national exam questions were only represented by the analysis level (C4), with a percentage of 7.5% in the 2011/2012 academic year and 15% in the 2012/2013 academic year. The subcategories of the analysis level (C4) in the national exam questions only included differentiation and organization processes. In terms of cognitive levels, the multiple-choice questions used in the exams are quite difficult to measure the evaluation (C5) and creation (C6) levels. The questions are considered less varied as they only measure the analysis level (C4), with no questions addressing the metacognitive knowledge dimension. To measure the evaluation (C5) and creation (C6) cognitive levels, questions that assess students' metacognitive skills are needed. One type of question that can be used is essay questions (Masruroh et al., 2022).

Teachers' understanding of cognitive assessment in higher-order thinking skills was shown by Nurmawati (2020). The study revealed that most chemistry teachers in the study were familiar with the HOTS concept. However, few teachers conducted HOTS assessments in daily tests, mid-term tests, or final semester tests. Teachers only implemented it as preparation for students facing the national school exam. This reluctance occurred because teachers were not confident in developing HOTS-based assessments due to certain factors such as the lack of supporting facilities and infrastructure and the lack of training on HOTS assessment.

A study by Zorluoğlu and Kızılaslan (2019) analyzed the 10th-grade chemistry curriculum based on the Revised Bloom's Taxonomy and found that the majority of learning objectives (87%) fell into the knowledge and understanding categories, which are lower cognitive levels. Only 13% of the learning objectives were categorized under application, analysis, evaluation, and creation, which are higher cognitive levels. The conceptual knowledge dimension was most frequently assessed among other knowledge dimensions (factual, procedural, and metacognitive). This indicates that the curriculum design has not yet achieved its goal of designing learning that supports the evaluation and enhancement of higher-order thinking skills in 10th-grade students, as evidenced by only 13% of learning objectives falling under HOTS.

Revised Bloom's Cognitive Domain Based Learning

Activities in the learning process include student participation in lessons, asking questions about unclear topics, taking notes, listening, thinking and analyzing, reading, and other activities that support academic achievement. Harris et al. (2009) identified three forms of science learning activities: activities that build conceptual knowledge, activities that build procedural knowledge, and activities that build expressions of knowledge.

The development of higher-order thinking skills in students can be achieved through various methods, such as designing learning activities that involve the cognitive domain, providing training or mentoring to students to develop critical and creative thinking skills, using innovative learning models, adapting learning to students' characteristics, and enhancing teacher creativity (Eriyanti et al., 2022; Mawardi et al., 2021; Novita et al., 2022; Triastuti, 2021; Zakaria, 2020).

This learning method combines activities like hands-on work, discussion, and concept discovery centered around students (Towns, 2009). Zoller et al. (2007) stated that applying IBL in everyday classroom learning stimulates students with questions before the lesson begins to refresh and encourage their thinking activities. This serves as a stepping stone for students to learn the next material concepts and achieve HOTS.

This problem-solving based learning process involves presenting chemistry problems in the form of questions, requiring students to actively engage and discover new concepts to solve these problems. Research by Udayani (2022) showed that applying a problem-solving model with HOTS-based questions could improve student learning outcomes. This is evidenced by the increase in student scores from cycle 1 to cycle 2. Through problem-solving-based learning, students do not rely solely on memorization but use their critical and creative thinking to solve HOTS questions.

The Relationship between Bloom's Cognitive Based Assessment and the Learning Process to Develop Higher Order Thinking Skills

The assessment of learning outcomes in the cognitive process dimension and knowledge dimension of chemistry education students needs to be analyzed using test instruments that refer to the revised Bloom's taxonomy. The goal is to understand students' cognitive abilities in solving chemistry problems based on their basic concepts and to identify weaknesses early so that they can be addressed without difficulty. Additionally, a learning strategy can be developed to enhance students' cognitive abilities to produce professional future chemistry teachers (Nursa'adah, 2016). One assessment that can be used to measure both the knowledge dimension and the cognitive process dimension is the one based on the revised Bloom's taxonomy. The revised Bloom's taxonomy can measure knowledge and cognitive processes to identify students' abilities from lower to higher levels, as it includes two dimensions: four types of knowledge and six types of cognitive processes (Anderson and Krathwohl, 2010).

Higher-order thinking skills in Bloom's Taxonomy are marked by the ability to think and rationalize critically. One of the higher-order thinking skills is demonstrated through critical thinking skills. Consistently applying critical thinking skills in learning enables students to become competent in managing their learning process. The National Research Council explains that cognitive skills such as critical thinking, problem-solving, and teamwork are competencies that need to be achieved by students. Additionally, students are expected to become creative and up-to-date, and skilled in using information technology. Through critical thinking skills, students can solve problems and make decisions, ultimately leading to metacognition in their learning. These skills can be trained through assignments given to students, such as tests or practice questions. Through practice, it is hoped that thinking methods can be improved, encompassing the development of creativity and innovation (Adji et al., 2023).

Students' higher-order thinking skills can be cultivated by habituating them to solve complex problems. One solution to help sharpen students' higher-order thinking skills is by providing HOTS (Higher Order Thinking Skills) evaluation instruments. Through these instruments, students are expected to answer complex questions that require them to analyze, evaluate, and synthesize based on existing problems (Hirza, 2023).

KESIMPULAN

Higher-order thinking skills (HOTS) are among the essential 21st-century life skills. Bloom's taxonomy forms the foundation for developing higher-order thinking skills in students. The last three levels, namely C4, C5, and C6, represent the categories of achievement for higher-order thinking skills. To successfully develop HOTS, teachers must possess the ability and proficiency to implement HOTS in their teaching. This requires the alignment of supportive teaching tools, such as instructional design, adequate teaching models (such as problem-based learning), teaching materials that include HOTS content, and assessments of higher-order thinking skills.

SARAN

Based on the literature review, discussion, and conclusions presented, researchers suggest that students' procedural and metacognitive knowledge should be deepened to produce competent human resources. The cognitive process dimension of HOTS (analyzing, evaluating, and creating) should be emphasized during the learning process by using teaching models that sharpen higher-order thinking skills and through both formative and summative assessments. It is important for teachers to innovate in teaching by connecting chemistry to its applications in everyday life and various fields.

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