



ANALYZING PRE-SERVICE BIOLOGY TEACHERS' QUESTIONS ON EVOLUTION CONCEPTS BASED ON BLOOM AND SOLO TAXONOMIES

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ABSTRACT. *This study aims to analyze the integration between the cognitive process dimensions of Revised Bloom's Taxonomy and the structural complexity of the SOLO Taxonomy in questions constructed by pre-service biology teachers, as well as its correlation with students' cognitive learning outcomes. A descriptive-quantitative approach with co-relational analysis was employed, evaluating a total sample of 420 question sentences generated by students during their field teaching program (PPL). Data collection was conducted using double-coding observation rubrics and statistically processed via Spearman's rho non-parametric correlation test. The results indicated a stark gradation phenomenon, with question distribution heavily accumulating within lower-order thinking skills (LOTS), predominantly spanning the Remembering (C1) and Understanding (C2) levels with Unistructural and Multistructural reasoning profiles. Conversely, higher-order thinking skills (HOTS) were strictly concentrated at the Analyzing (C4) and Evaluating (C5) levels, aligning with Relational and Extended Abstract structures. Statistical analysis revealed a positive and significant correlation coefficient ($p = 0.707$, $p < 0.001$), indicating a very strong linear relationship where higher cognitive demands inherently correspond to greater structural reasoning maturity. In conclusion, while pre-service teachers possess a solid foundation in factual knowledge, their capacity to formulate higher-order questions remains limited. Therefore, transforming classroom communication through constructivist learning strategies and gradual conceptual scaffolding is highly recommended to foster integrative thinking and bridge the cognitive transition toward deep conceptual understanding.*

Keywords: Questioning Skills, Bloom Taxonomy, SOLO Taxonomy.

ABSTRAK. Penelitian ini bertujuan untuk menganalisis integrasi antara dimensi proses kognitif dari Taksonomi Bloom Terrevisi dan kompleksitas struktural dari Taksonomi SOLO pada pertanyaan yang dikonstruksi oleh mahasiswa calon guru biologi, serta korelasinya dengan hasil belajar kognitif siswa. Pendekatan deskriptif-kuantitatif dengan analisis korelasional digunakan dalam penelitian ini, dengan mengevaluasi total sampel sebanyak 420 kalimat pertanyaan yang dihasilkan oleh mahasiswa selama program Praktik Pengalaman Lapangan (PPL). Pengumpulan data dilakukan menggunakan rubrik observasi pengodean ganda (*double-coding*) dan diproses secara statistik melalui uji korelasi non-parametrik Spearman's rho. Hasil penelitian menunjukkan adanya fenomena gradasi yang timpang, di mana distribusi pertanyaan menumpuk secara masif pada keterampilan berpikir tingkat rendah (*Lower-Order Thinking Skills*/LOTS), yang didominasi oleh level Mengingat (C1) dan Memahami (C2) dengan profil penalaran *Unistructural* dan *Multistructural*. Sebaliknya, keterampilan berpikir tingkat tinggi (*Higher-Order Thinking Skills*/HOTS) terkonsentrasi secara ketat pada level Menganalisis (C4) dan Mengevaluasi (C5), yang selaras dengan struktur *Relational* dan *Extended Abstract*. Analisis statistik mengungkapkan nilai koefisien korelasi yang positif dan signifikan ($p = 0,707$, $p < 0,001$), yang menunjukkan adanya hubungan linear yang sangat kuat di mana tuntutan kognitif yang lebih tinggi secara inheren sejalan dengan kematangan penalaran struktural yang lebih besar. Kesimpulannya, meskipun mahasiswa calon guru memiliki fondasi pengetahuan faktual yang kuat, kapasitas mereka dalam merumuskan pertanyaan tingkat tinggi masih terbatas. Oleh karena itu, transformasi komunikasi di kelas melalui strategi pembelajaran konstruktivis dan pemberian perancahan (*scaffolding*) konseptual secara bertahap sangat direkomendasikan untuk menumbuhkan pemikiran integratif dan menjembatani transisi kognitif menuju pemahaman konseptual yang mendalam.

Kata Kunci: Keterampilan Bertanya, Taksonomi Bloom, Taksonomi SOLO

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INTRODUCTION

Higher education in biology plays a vital role in cultivating critical, analytical, and reflective thinking skills among prospective science teachers (Mahanal et al., 2019). A primary indicator of students' cognitive structure maturity and the quality of their thinking processes is their questioning skills. Rather than serving merely as a classroom communication tool, questioning functions as a cognitive window reflecting how students process complex biological information, identify knowledge gaps, and construct logical reasoning (Chin & Osborne, 2015; Kusuma et al., 2023). For prospective biology teachers, high-level questioning skills reflect mature pedagogical readiness, serving as a core asset to subsequently design essential questions capable of stimulating higher-order thinking skills (HOTS) among students in schools (Chin & Osborne, 2015; Graesser & Person, 1994). However, empirical findings reveal that the questioning skills of pre-service biology and science teachers remain largely dominated by lower-order thinking skills (LOTS), underscoring the urgent necessity to explicitly foster and empower these skills within teacher education curricula (Graesser & Person, 1994; Mamu, 2024; Yanto et al., 2022).

Animal evolution serves as a critical and highly strategic context for examining questioning skills because it demands an integrated, multi-scalar understanding, bridging micro-level population genetics, anatomical adaptations, and reproductive isolation with macro-level phylogenetic reconstruction (Erwinsyah, 2025; Zohar & Nemet, 2002). The inherently abstract and systemic nature of evolutionary phenomena requires learners to operate at higher cognitive tiers, specifically at the Relational and Extended Abstract levels of the SOLO taxonomy, as well as the Analytical and Evaluative dimensions of Bloom's Revised Taxonomy. However, complex evolutionary concepts frequently trigger persistent misconceptions and fragmented mental models among prospective biology teachers (Erwinsyah, 2025; Yanto et al., 2022; Zohar & Nemet, 2002). Consequently, rather than formulating deep-reasoning inquiries about dynamic natural selection mechanisms, prospective teachers' questions often remain superficial, unistructural, and strictly focused on lower-order factual recall regarding historical evolution (Kusuma et al., 2023; Mamu, 2024; Yanto et al., 2022).



To date, evaluations of the quality of student questioning skills have predominantly relied on a single perspective, most notably the Revised Bloom's Taxonomy (Chin & Osborne, 2015; Krathwohl, 2002; Kusuma et al., 2023). The revised framework transformed the original unidimensional structure into a two-dimensional taxonomy, intersecting the Knowledge Dimension (factual, conceptual, procedural, and metacognitive) with the Cognitive Process Dimension spanning from remembering (C1) to creating (C6) (Krathwohl, 2002). While Bloom's Taxonomy is exceptionally effective in mapping the intended hierarchy of mental operations demanded by a question, it primarily classifies instructional objectives and task categories rather than capturing the structural coherence of a learner's cognitive architecture (Biggs & Collis, 1982; Erwinsyah, 2025; Suryanda et al., 2023). To address these analytical boundaries, the Structure of Observed Learning Outcomes (SOLO) Taxonomy provides a distinct, complementary lens by evaluating the increasing structural complexity of observed cognitive performances (Erwinsyah, 2025; Nabila et al., 2026). Operating across five hierarchical tiers from Unistructural (isolated single-aspect thinking) and Multistructural (unintegrated multiple aspects) to Relational (conceptually integrated systems) and Extended Abstract (deduction of generalized principles) (Biggs & Collis, 1982). The SOLO Taxonomy assesses how effectively learners weave disparate information into a coherent whole (Nabila et al., 2026). Integrating Bloom's Cognitive Process Dimension with SOLO's Structural Complexity creates a robust, dual-lens theoretical framework capable of diagnosing both the mental depth and the conceptual integration embedded in prospective biology teachers' questions (Erwinsyah, 2025).

Previous empirical research evaluating student questioning skills in biology education has overwhelmingly relied on single-perspective frameworks, predominantly the Revised Bloom's Taxonomy (Chin & Osborne, 2015; Kusuma et al., 2023). Studies investigating pre-service science and biology teachers consistently report a heavy skew toward Lower-Order Thinking Skills (LOTS), with factual recall and basic comprehension questions accounting for up to 88% to 100% of generated inquiries (Yanto et al., 2022). While Bloom's Taxonomy effectively categorizes the intended cognitive process dimension of an interrogative sentence (from C1 remembering to C6 creating), it inherently lacks the diagnostic capacity to evaluate the underlying structural complexity and systemic coherence of the biological concepts being related (Suryanda et al., 2023). Conversely, while the SOLO Taxonomy has been successfully utilized to assess observed learning outcomes and conceptual integration in



various biological topics, its application to evaluate student-generated questions remains scarce, particularly within highly abstract and multi-scalar topics such as animal evolution (Erwinsyah, 2025).

To bridge this empirical and methodological gap, the novelty of this study lies in introducing a simultaneous dual-lens cross-analysis framework that intersects Bloom's Cognitive Process Dimensions with SOLO's Structural Complexity Tiers (Krathwohl, 2002). Through this integrated matrix, this study moves beyond merely scoring the surface-level action verbs of student questions (Kusuma et al., 2023; Suryanda et al., 2023). Instead, it precisely diagnoses potential cognitive misalignments, identifying instances where prospective biology teachers formulate questions that superficially demand analytical reasoning (Bloom C4), yet reflect fragmented, unistructural, or multistructural conceptual frameworks (SOLO) due to persistent evolutionary misconceptions (Biggs & Collis, 1982). This dual cross-analysis provides a significantly more granular diagnostic tool for teacher educators to address specific structural gaps in pre-service teachers' pedagogical content knowledge.

METHODOLOGY

This study employed a mixed-methods approach through a qualitative content analysis design, enhanced by non-parametric inferential statistical analysis. The research was conducted at the Biology Education Study Program, Universitas Islam Negeri Syarif Hidayatullah Jakarta, during the Odd Semester of the 2025/2026 Academic Year, within the Basic Biology course focusing on Animal Evolution and Speciation. The research subjects were determined using a total sampling (saturated sampling) technique based on the *intact class* principle (Sugiyono, 2019), involving all first-year students distributed across three parallel classes, with a grand total of 84 students.

The primary data collection tool was a question-posing sheet equipped with a stimulus article concerning a case study on vertebrate animal evolution and speciation. The research procedure was divided into three stages: (1) The preparation stage, which included compiling the stimulus article, designing the question-posing sheet, and constructing the taxonomy analysis indicator matrix; (2) The implementation stage, where students were given 15 minutes to independently read and analyze the article, followed by 20 minutes to formulate critical questions without any discussion; and (3) The completion stage, consisting of



collecting the documents, transcribing the interrogative sentences into a digital format, and assigning anonymity codes to the subjects (M-01, M-02, etc.). The primary variables or observational focuses measured in this study were the cognitive level characteristics and the structural reasoning complexity of the students' questions.

The content analysis process applied to the students' questions was guided by two operational analysis rubrics adapted from Krathwohl (2002) for the Revised Bloom's Taxonomy and Biggs & Collis (1982) for the SOLO Taxonomy. The operational framework utilized by the researcher as a guideline for double-coding is presented in Table 1 and Table 2.

Table 1. Guidelines for Student Question Analysis Based on the Revised Bloom's Taxonomy

Cognitive Level	Indicator Description	Example of Question Sentence Patterns
C1: Remember	Retrieving relevant knowledge from long-term memory.	What is the definition of...? When was the era of...? Mention/State...!
C2: Understand	Determining the meaning of instructional messages, including oral, written, and graphic communication.	Explain how...? What is the difference between...?
C3: Apply	Carrying out or using a procedure in a given situation.	Calculate the frequency of...? Based on law X...?
C4: Analyze	Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.	Why does relationship X cause Y...? Analyze...!
C5: Evaluate	Making judgments based on criteria and standards.	Is evidence X strong enough...? Critique...!
C6: Create	Putting elements together to form a novel, coherent whole or make an original product.	How to design a simulation of...? Formulate a hypothesis...!

(Source: Krathwohl, 2002)

The unit of students' questions was analyzed using a theoretical triangulation technique through a double-coding procedure. Each question item underwent a two-stage mapping process: first, it was classified into the cognitive process dimensions of the Revised Bloom's Taxonomy (C1–C6); second, it was mapped into the cognitive response levels of the SOLO Taxonomy (*Prestructural*, *Unistructural*, *Multistructural*, *Relational*, and *Extended Abstract*).



Table 2 Guidelines for Student Question Analysis Based on the SOLO Taxonomy

SOLO Level	Question Sentence Structure Characteristics	Interconceptual Relationship
<i>Prestructural</i>	The question has no relationship with the evolutionary material, is irrelevant, or contains a fatal misconception.	No correct/relevant concepts are present.
<i>Unistructural</i>	The question focuses strictly on a single piece of information or a single, independent (isolated) concept.	Connecting a single concept.
<i>Multistructural</i>	The question contains several concepts/information, but they still appear as a separate list and are not yet functionally connected.	Displaying more than 1 concept in a parallel/separate manner.
<i>Relational</i>	The question successfully connects several concepts into a logical, cause-and-effect unity regarding evolutionary mechanisms.	Integrating concepts into a single reasoning system.
<i>Extended Abstract</i>	The question operates at a broad theoretical level, is capable of generalizing concepts, or elevates the problem to a new abstract principle.	Developing a conceptual system into a new macro/theoretical principle level.

(Source: Biggs and Collis, 1982)

The qualitative data resulting from the coding process were then transformed into discrete quantitative data on an ordinal scale. The statistical models used to present the comparative data were descriptive statistics in the form of percentage fractions and cross-tabulation (*crosstabulation*). Subsequently, an analysis prerequisite test was conducted using the Shapiro-Wilk Normality Test.

Given that the data characteristics were on an ordinal scale, the inferential statistical analysis proceeded with the Spearman's Rho (or Kendall's Tau-b) Non-Parametric Correlation Test to examine the associative hypothesis regarding the relationship between Bloom's cognitive levels and the SOLO reasoning complexity levels within the instruments developed by the students. All statistical calculations were executed using SPSS version 24 software.

RESULTS



Students' questioning skills serve as a primary tool for teachers to detect the depth of students' conceptual understanding of the subject matter (Kusuma et al., 2023). In this study, the depth of the relationship between the cognitive process dimension (Revised Bloom's Taxonomy) and the complexity of reasoning logic (SOLO Taxonomy) found in the questions independently constructed by the students is mapped integratively via the cross-tabulation matrix in Figure 1.

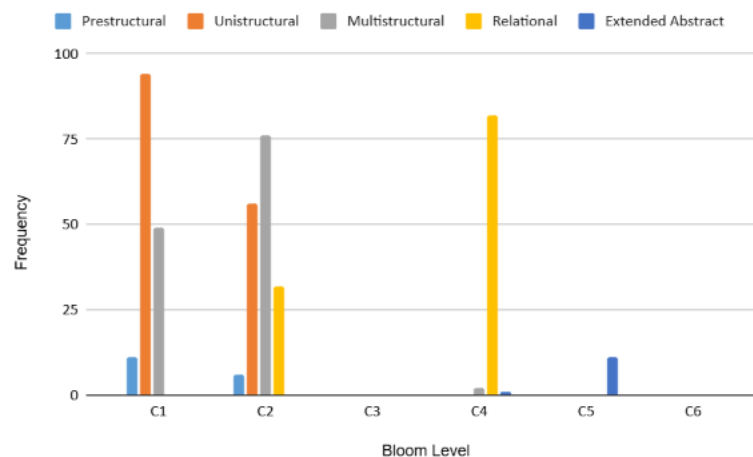


Figure 1. Frequency Distribution of Pre-service Biology Teachers' Questions based on Bloom's and SOLO Taxonomies Cross-tabulation

Based on the mapping in Figure 1, a stark gradation phenomenon is observed in the students' thinking profiles, where the volume of questions accumulates massively within the lower-order thinking skills (LOTS) domain. At the Remembering (C1) and Understanding (C2) levels, the students' reasoning structures are heavily dominated by the Unistructural and Multistructural categories, although the C2 level begins to manifest a minor portion of Relational-type thinking. Interestingly, a complete zero distribution of data occurs at the Applying (C3) level across all stages of the SOLO taxonomy, indicating that the question instruments formulated by the students tend to overlook aspects of law application or concrete phenomenon calculations. Conversely, within the higher-order thinking skills (HOTS) domain, the data distribution is fully focused on the Analyzing (C4) level which is predominantly occupied by the Relational reasoning structure and the Evaluating (C5) level, where all questions successfully reach the Extended Abstract stage. Another notable weakness is reflected in the complete absence of any student-generated questions capable of reaching the highest level, Creating (C6).



To empirically validate the hypothesis regarding a linear relationship between categories from both taxonomic perspectives, a non-parametric correlation test was conducted, the results of which are summarized in Table 3.

Table 3 Non-Parametric Correlation Analysis Between Bloom's Cognitive Levels and SOLO Reasoning Structures

Variable Pair	Correlation Coefficient	Significance Value	Sample Size
Bloom - SOLO	0,707**	<0,001	420

**Correlation is significant at the 0.01 level (2-tailed).

The statistical analysis in Table 3 demonstrates that the research hypothesis is accepted. The positive Spearman's rho correlation coefficient reflects that the degree of relationship closeness between the variables falls into the very strong category.

DISCUSSIONS

This quantitative finding provides a robust theoretical confirmation that an increase in the cognitive process dimension level within students' questions directly aligns in a linear fashion with the increasing complexity of their reasoning responses. When students attempt to elevate the cognitive weight of their questions from mere recall to analysis, they are automatically required by their cognitive structures to interconnect various scientific variables integratively. These questioning skills possess a positive linear correlation with cognitive learning outcomes, as they mirror an individual's metacognitive maturity (Septaria, 2021).

This empirical reality confirms that there is an inseparable link between the level of conceptual understanding and the quality of an individual's questioning skills, driven by complex internal cognitive activities to process, filter, and organize newly acquired information (Yanto et al., 2022). The complexity of students' thinking can be manifested, among other ways, through the form of their questions; if they are only capable of understanding superficial core concepts, the generated questions will similarly revolve only around low cognitive domains (Kusuma et al., 2023). This lack of proficiency in posing high-level questions is also reflected in the actual field performance of pre-service teachers. Generally, the basic questioning skills of pre-service teachers fall into the good category; however, this achievement is not yet linear with their advanced questioning skills, which still



need to be optimized (Ndukang et al., 2023). Pre-service teachers are frequently found to lack the skill to sequence questions from the simplest to the most complex levels, and they remain unable to employ probing questions effectively to delve into students' responses.

Consequently, the management of classroom communication needs to be reformed. Questions should not merely be directed toward specific students who are perceived as smart or capable of answering; instead, they must be distributed fairly and evenly to all students to allow for a wide variation of answers. This intervention is crucial, given that developing effective and proficient questioning skills within the learning process can bring about progressive changes for both teachers and students (Nurhayati et al., 2023). The tangible change experienced by students is the establishment of a healthy educational interaction, ensuring that students are actively engaged in the learning process.

Innovative learning models can be intentionally integrated to achieve this objective; for instance, a socio-scientific issues (SSI)-based learning strategy has proven to significantly enhance the questioning skills of eighth-grade junior high school students by confronting them with dilemmatic real-world science issues (Fahrizal & Badrun, 2022). Through this strategy, empirical data from classroom observations show that students' questioning skills in the experimental class, which initially sat in the sufficient category during the first meeting, experienced a meaningful surge in the second meeting with a high percentage of improvement. The positive effect of stimulating higher-order thinking skills in these learning activities results from the full support of the teacher in facilitating independent exploration and experimentation (Mamu, 2024). This aligns with the critical importance of critical thinking in human daily activities, which dictates that only cognitively capable individuals possess the capacity to continuously grow and develop.

Although Bloom's Taxonomy is highly effective in mapping the hierarchy of mental processes, integration with other instruments, such as the SOLO Taxonomy, remains imperative to dissect the quality of cognitive responses comprehensively. Bloom's Taxonomy emphasizes the targeted types of skills, such as knowledge and analysis, whereas the SOLO Taxonomy focuses on the quality of the cognitive structure or the manner in which that understanding is formed. The epistemological relevance of the SOLO taxonomy is highly evident within the context of science education, where critical and analytical thinking skills are required. At the Relational and Extended Abstract levels, students are expected to



analyze logical relationships between various concepts such as the interconnected processes of photosynthesis and respiration and predict the systemic impacts of complex phenomena like pollution (Erwinsyah, 2025). Thus, the SOLO Taxonomy functions as a diagnostic tool to measure students' cognitive structures, providing a solid foundation for expected pedagogical interventions. This mapping is essential because memorizing cognitive Action Verbs (KKO) without a profound conceptual understanding tends to yield shallow, easily forgotten declarative knowledge (Mumtaz et al., 2025).

In practical terms, the dominance of high achievements at the initial levels, such as Prestructural and Unistructural quantitatively demonstrated by the heavy accumulation of figures at the C1 level in Table 3 indicates that students actually possess a reasonably strong foundation of factual knowledge, yet this is not fully accompanied by integrative thinking capabilities (Nabila et al., 2026). Within the context of the human digestive system topic, students are relatively capable of naming digestive organs and explaining individual organ functions separately, but they experience difficulties when required to explain inter-organ relationships or the regulatory mechanisms of the digestive system comprehensively. Another factor influencing SOLO achievement is students' cognitive readiness and prior knowledge, alongside the fact that SOLO achievements are contextual and influenced by the characteristics of the developed assessment instruments (Nabila et al., 2026). This underpins the variation in reasoning profiles based on disciplinary backgrounds; in short, the SOLO taxonomy levels of science students tend to cluster at the Relational and Extended Abstract levels, whereas the SOLO taxonomy levels of social studies students span more broadly across the Multistructural, Relational, and Extended Abstract levels (Suryanda et al., 2023).

Promoting the transition of students' thinking toward higher relational levels, constructivist biology instruction utilizing Problem-Based, Inquiry-Based, and Collaborative Learning is highly recommended to prevent fragmented conceptual mastery and foster an integrated knowledge structure (Nabila et al., 2026). These active strategies confront students with contextual problems ranging from digestive physiology to abstract, intellectually challenging evolutionary mechanisms thereby encouraging scientific inquiry and peer discussions to deepen their cognitive structures. However, since developing deep, integrative thinking skills still requires significant improvement despite a relatively strong foundation in factual knowledge, this cognitive shift must be supported by gradual, well-planned scaffolding. Implementing tools such as concept mapping or graphic organizers is essential



to visualize the complex interconnections within biological systems, ultimately enhancing the students' capacity to connect interrelated ideas and processes holistically (Nabila et al., 2026).

CONCLUSIONS

Based on the content analysis and associative test results, it is concluded that a very strong, positive, and direct relationship exists between the cognitive levels of Bloom's Revised Taxonomy and the structural reasoning complexity of the SOLO Taxonomy in questions independently formulated by pre-service biology teachers. Although pre-service teachers possess a solid foundational knowledge base as reflected by the high frequency of lower-order thinking skill (LOTS) questions at the Unistructural and Multistructural levels their ability to construct higher-order thinking skill (HOTS) questions at the Relational and Extended Abstract levels remains limited. This indicates a gap between factual concept mastery and pedagogical questioning competence, particularly in addressing complex and abstract biological frameworks such as evolution. To bridge this gap, future research should focus on developing targeted pedagogical interventions, such as explicitly embedding SOLO-based conceptual scaffolding into microteaching and biology instructional design courses. Furthermore, prospective studies are encouraged to evaluate the longitudinal impact of constructivist strategies (e.g., Problem-Based Learning and Socio-Scientific Issues) on pre-service teachers' questioning skills and to extend the research sample across diverse disciplinary backgrounds and multiple teacher training institutions.

DECLARATIONS

AI Usage Declaration

Artificial intelligence (AI) tools were employed responsibly solely for language editing, translation, and manuscript formatting, while all research design, data analysis, and scientific conclusions were conducted independently by the authors.

Author Contributions



Author contributions are represented as follows: PG contributed to conceptualization, methodology, formal analysis, investigation, and drafting the manuscript, while S assisted in data validation, review, and editing.

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Conflict of Interest

The authors declare no conflict of interest, confirm that informed consent was obtained from all participating pre-service biology teachers, and state that the research was conducted at UIN Syarif Hidayatullah Jakarta in Banten, Indonesia

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