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From Taxonomies to Rubrics: SOLO-based Formative Assessment to Improve Understanding of Population Dynamics

Fika Ariani*, Suyanto, Lia Yuliana, Asriyah and Laily Rahmah
Universitas Negeri Yogyakarta
Yogyakarta, Indonesia

Abstract. This study investigates the design and implementation of a SOLO-based (structure of observed learning outcomes) formative assessment rubric to enhance upper secondary students' conceptual understanding of population dynamics in Geography. Employing a reflective qualitative design, data were collected through document analysis, students' written work, classroom observations, and teacher reflections to examine how the rubric was adapted, operationalized, and interpreted in practice. The rubric was developed by translating the SOLO hierarchy into domain-specific criteria aligned with the intended learning outcomes, thereby ensuring coherence between instructional goals and assessment practices. The findings indicate a clear progression in students' cognitive responses, evidenced by movement from multistructural recall to relational explanations and, in some instances, extended abstract reasoning. The rubric also promoted metacognitive engagement, enabling students to identify their current level of understanding and regulate their learning. For teachers, it functioned as a diagnostic tool for delivering process-oriented and criterion-referenced feedback. While the study's scope was limited to a single class and the topic constrains wider generalizability, the results underscore the pedagogical potential of SOLO-based formative assessment to cultivate higher-order thinking and conceptual depth in Geography education. Further research involving broader samples and longitudinal designs is recommended to validate and extend these insights.

Keywords: SOLO taxonomy; formative assessment; rubrics; population dynamics**.**

1. Introduction

In recent years, the paradigm of deep learning and the cultivation of higher-order thinking competencies have gained increasing attention among educators (Dargan et al., 2020; Golovko, 2017), particularly with the introduction of the

*Corresponding author: Fika Ariani; *fikaariani.2022@student.uny.ac.id*

structure of observed learning outcomes (SOLO) taxonomy as a framework for measuring the depth of student understanding. However, a growing misconception has emerged among teachers who assume that the use of SOLO entirely replaces Bloom's taxonomy, which has long served as the foundational model for formulating learning objectives and assessments (Chan et al., 2002). This assumption is problematic because it overlooks essential aspects of Bloom's framework that remain valuable when designing comprehensive learning goals. In reality, educational literature emphasizes that Bloom's and SOLO taxonomies should not be viewed as competing models but as complementary systems that serve different yet interrelated purposes.

Bloom's taxonomy provides a hierarchical structure for developing thinking skills from lower- to higher-order levels (Hachoumi et al., 2025) and assists teachers in designing learning objectives aligned with cognitive processes such as remembering, understanding, applying, analyzing, evaluating, and creating (Anderson & Krathwohl, 2001; West, 2023). Alternatively, the SOLO taxonomy offers a more detailed framework for assessing the quality and complexity of student responses, making it particularly effective for evaluating the depth of conceptual understanding (Ilhan & Gezer, 2017; Nithyanandam, 2020). Thus, integrating both taxonomies allows teachers to align instructional goals with assessment practices, ensuring that students' cognitive development is measured not only by stages of thinking but also by the quality of their understanding.

Studies such as those by Gurunath et al. (2021) confirm that the SOLO taxonomy is an effective tool for analyzing the depth of students' conceptual understanding through their written responses, making it highly useful for designing formative and summative assessments that progressively evaluate students' cognitive development. Similarly, Nor and Idris (2010) emphasized that assessments developed using the SOLO framework prioritize the creation of conceptual thinking rubrics, in which each SOLO level represents the depth and quality of reasoning focused on the learning process, rather than the final product. This characteristic allows the SOLO taxonomy to be applied effectively in promoting higher-order thinking skills across various learning domains.

Building on this foundation, Biggs and Collis (1982) introduced the SOLO taxonomy as a comprehensive framework for evaluating and understanding student learning in multiple disciplines. The taxonomy categorizes learning outcomes into five hierarchical levels—prestructural, unistructural, multistructural, relational, and extended abstract—each reflecting increasing cognitive complexity. Subsequent studies, such as those by Boulton-Lewis (2006) and Svensäter and Rohlin (2022), have reinforced its validity and utility in educational contexts, showing that SOLO-based assessments can guide students' cognitive growth toward more complex levels of understanding.

Grounded in these theoretical and empirical insights, the present study was designed to develop a formative assessment rubric that aligns learning objectives with assessment practices in Geography education, particularly on the topic of population dynamics. Bloom's taxonomy was employed to structure the learning objectives from lower- to higher-order cognitive levels, while the SOLO taxonomy was used to assess the quality and complexity of students' understanding. Integrating these two taxonomies ensures constructive alignment between instructional design and assessment, enabling teachers to monitor students' cognitive development more deeply and provide meaningful feedback that strengthens conceptual understanding.

2. Literature Review

2.1 Taxonomy and Rubrics

Taxonomies and rubrics serve as complementary tools in organizing and evaluating learning within educational settings. Taxonomies, commonly used across disciplines such as biology, library science, and education, function to categorize and structure information, thereby facilitating easier understanding and retrieval of complex concepts (Saito et al., 2020). In contrast, rubrics are evaluative instruments designed to measure the quality of student performance based on clearly defined criteria or standards (Brookhart & Chen, 2015; Pang et al., 2022). Together, these tools enhance teaching and learning effectiveness by helping educators design structured instruction and transparent assessment practices (English et al., 2022).

When teachers apply taxonomies in lesson planning, they can align instruction with specific learning goals and cognitive levels, ensuring that students move progressively from basic to higher-order thinking skills (Adams, 2015). The integration of rubrics further strengthens this process by providing consistent and descriptive feedback that allows students to identify their strengths and areas for improvement (Chen & Qi, 2023). In this sense, combining taxonomies and rubrics creates a coherent pedagogical system that promotes knowledge transfer, deep learning, and critical thinking.

For example, a science teacher might use Bloom's taxonomy to scaffold lesson objectives that gradually encourage students to develop analytical and creative skills during experiments and projects. When accompanied by a rubric aligned with the taxonomy, students clearly understand performance expectations and receive targeted feedback on their abilities to analyze data, draw conclusions, and communicate results effectively (Patterson, 2020). This integration not only deepens engagement and comprehension but also cultivates student autonomy and motivation for continuous learning (Fateme & Fatemah, 2025).

2.2 Structure of Observe Learning Outcome (SOLO)

The SOLO model, developed by Biggs and Collis (1982), provides a comprehensive framework for assessing and understanding students' learning across disciplines. It focuses on analyzing the quality of student responses and classifying learning outcomes into five hierarchical levels of cognitive development: prestructural, unistructural, multistructural, relational, and extended abstract. The characteristics of each level are summarized in Table 1.

Table 1: SOLO modes

SOLO levels	Description
Prestructural	Learners show limited understanding and are unable to complete tasks effectively. Their responses often reflect minimal use of working memory, irrelevant ideas, or meaningless repetitions, indicating that they have not yet grasped the core of the problem.
Unistructural	Learners begin to present relevant ideas or facts related to the task. Although their use of working memory is still limited, it shows progress from the prestructural level. However, their understanding remains fragmented, with no meaningful connection between identified elements.
Multistructural	Learners present several relevant but disconnected ideas, reflecting partial understanding of the concept. Each idea stands alone without clear links, though their ability to recall and process multiple pieces of information has improved compared to the unistructural level.
Relational	Learners integrate multiple relevant ideas into a coherent and logical understanding. They can relate and justify connections between concepts, marking a shift from surface to deeper learning that reflects higher-order thinking.
Extended abstract	Learners extend their understanding by applying concepts to new contexts. Their responses are coherent, reflective, and demonstrate prediction, hypothesis testing, and generalization beyond the original scope of learning.

Caro et al. (2025) stated that the SOLO taxonomy serves as a reference for establishing and assessing the expected level of learning complexity at each stage of a teacher training program. The SOLO serves as a framework for measuring the depth of students' understanding of learning outcomes across three learning phases: appropriation, consolidation, and application and reflection (Malik et al., 2021). The SOLO model is regarded as a strong cognitive and developmental framework for enhancing learning, assessment, and curriculum development in mathematics across various educational contexts (Adeniji et al., 2022).

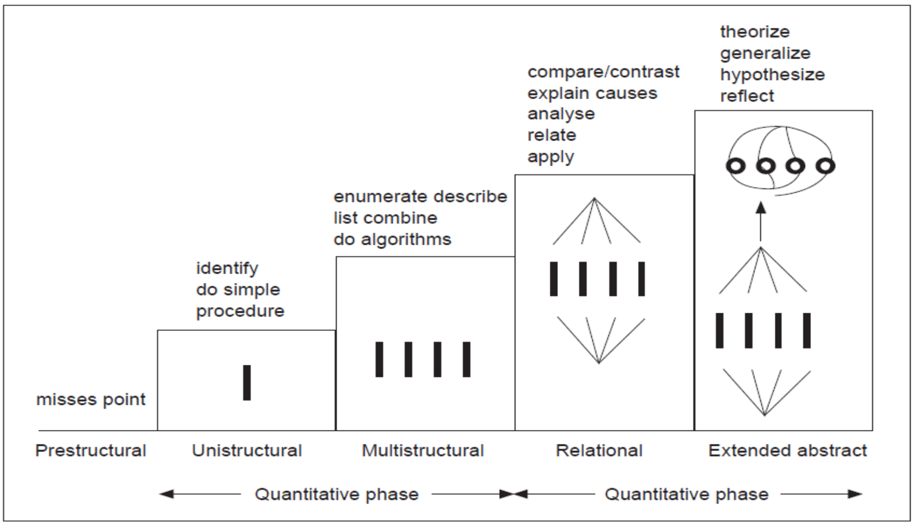

Figure 1: SOLO taxonomy (Biggs & Collis, 1982)

The SOLO taxonomy (Biggs and Collis, 1982), like Bloom's taxonomy (1956), provides a hierarchical framework for understanding how student performance develops in complexity as learning progresses. It assumes that students' understanding evolves gradually, becoming more structured and articulated through continuous engagement with learning tasks. Thus, this taxonomy serves as a guide for teachers and researchers to analyze the depth and organization of student thinking, moving from simple conceptual recall toward complex reasoning and abstraction.

Beyond its hierarchical model, SOLO distinguishes between *declarative knowledge*, knowledge of facts and theories, and *functional knowledge*, which refers to the ability to apply understanding in real contexts. Maintaining a balance between these two dimensions fosters deep learning rather than surface memorization. Vera et al. (2019) identified three main functions of the SOLO framework: as a tool for cognitive classification, as a reference for evaluating curriculum alignment, and as a foundation for constructive alignment in teaching and assessment.

Building on this versatility, Zhou et al. (2024) demonstrated the integration of SOLO in automata-based adaptive assessments, which allows evaluation to be more responsive to students' cognitive development. Their findings show that SOLO-based adaptive systems enhance flexibility and efficiency compared to traditional assessments that rely solely on right or wrong answers. Similarly, Svensäter and Rohlin (2022) applied the SOLO framework to design a model integrating formative and summative assessments, in which formative feedback based on relational understanding guided student learning, and subsequent summative evaluations measured progress using the same cognitive structure. The improvement observed in students' conceptual understanding underscores the potential of the SOLO taxonomy to unify both assessment types, ensuring coherence between learning development and evaluation standards.

2.3 Formative Assessments in Education

Formative assessment is an ongoing process designed to collect evidence of student learning to improve instruction and learning outcomes, rather than to make final judgments about achievement. It functions as an assessment for learning, enabling teachers and students to identify current understanding, address learning gaps, and take corrective actions. The effectiveness of formative assessment lies in the quality of feedback, which must be specific, timely, and actionable to promote self-regulation and deeper learning (Hattie & Timperley, 2007).

Black and Wiliam (1998) highlighted that formative assessment becomes most effective when teachers can interpret learning evidence and adjust instruction, accordingly, making assessment an integral part of pedagogy. Similarly, Nicol and Macfarlane-Dick (2006) emphasized that formative assessment fosters student autonomy by encouraging self-monitoring and reflection. Therefore, formative assessment should be viewed not merely as a measurement tool but as a continuous developmental process that drives meaningful learning through feedback and instructional adaptation.

Formative assessment has proven essential in various educational contexts, improving learning outcomes across disciplines, including medical and dental education. Recent studies support its advantages, particularly through multiple-choice question formats that allow efficient evaluation of broad knowledge areas while providing immediate feedback to facilitate timely learning adjustments (Fatima & Usmani, 2023; Haugen & Lange, 2024). Compared to summative assessment, which determines final grades and certification, formative assessment focuses on process-oriented feedback to help students monitor and enhance their progress without grade-related pressure (Reddi & Javidi, 2025).

The framework of formative assessment promotes active student engagement by enabling learners to recognize their weaknesses and take responsibility for improving their learning outcomes. Teachers, in turn, are encouraged to interpret evidence of student understanding and adjust their instructional strategies to better support progress. This dynamic interaction shifts classroom practice away from traditional, teacher-centered methods toward more dialogic and participatory learning, as illustrated in science education research (Kariri et al., 2022). Moreover, the feedback mechanism at the core of formative assessment plays a critical role in academic success by identifying students at risk of poor performance through the comparison of formative and summative outcomes (Atwa et al., 2024).

In contrast to summative assessment, which contributes directly to final grades and certification, formative assessment focuses on providing constructive feedback that helps students improve continuously without the pressure of grades (Den Boer et al., 2020). Effective formative strategies emphasize feedback and reflection rather than evaluation, thereby fostering a deeper understanding of learning materials. Sluijsmans and Seegers (2018) advocated for establishing a feedback culture that nurtures learning without creating anxiety, while Buck et al.

(2023) highlighted that effective feedback enhances both motivation and achievement when it targets learning processes and strategies. Similarly, Tuckman (1998) found that frequent, low-stakes assessments can improve motivation and performance. Halliday and Callaghan (2024) demonstrated that reducing grade pressure strengthens intrinsic motivation by helping students focus on learning goals and perceived value.

3. Methodology

To clarify analytical orientation, this study employed a descriptive–interpretive approach that focused on identifying, describing, and interpreting patterns of student understanding as reflected in documents, classroom observations, and written work. The descriptive component captured observable features of student responses, while the interpretive component sought to explain the meaning and cognitive progression underlying these responses in relation to the SOLO levels. This approach was chosen because it is suitable for exploring how students construct and deepen conceptual understanding through iterative formative assessment processes.

The SOLO-based rubric was adapted from the descriptors of Biggs and Collis (1982) and adjusted to the topic of population dynamics by contextualizing each level's indicators. Generic SOLO descriptors were refined into domain-specific criteria to ensure alignment with learning objectives and the cognitive demands of the Geography content. The compilation of learning objectives with operational verbs through Bloom's taxonomy and the compilation of cognitive levels using the SOLO taxonomy are shown in the following table:

Table 2: Alignment between Bloom's taxonomy and SOLO taxonomy levels

Bloom's taxonomy (Anderson & Krathwohl, 2001)	SOLO taxonomy (Biggs & Collis, 1982)
Creating Evaluating	Extended Abstract
Analyzing Applying	Relational
Understanding	Multistructural
Remembering	Unistructural
-	Prestructural

The main advantage of the SOLO taxonomy, compared to Bloom's taxonomy, lies in the presence of the prestructural level, which is the stage in which students do not yet have a meaningful understanding of a concept. At this stage, student responses are often irrelevant or indicate misconceptions because they are not yet able to connect information to the correct knowledge structure. This level is not found in Bloom's taxonomy because Bloom only classifies cognitive abilities that have been formed, such as remembering to creating, without considering the initial conditions at which understanding does not yet exist.

The presence of the prestructural level in SOLO provides high diagnostic value, allowing teachers to identify the starting point of learning, recognize misconceptions, and provide appropriate feedback and guidance to help students move from ignorance to more complex and meaningful understanding. This study developed a formative assessment rubric based on the SOLO taxonomy that covers all levels of student understanding development, from prestructural to extended abstract, so that it can systematically map the quality of students' understanding of the concept of population dynamics.

The participants in this study consisted of 38 students enrolled in Grade XI at SMA (Negeri 8 Mataram). This group represented a single intact class that engaged in the learning sequence on population dynamics. Specifying the sample size and grade level helps strengthen the study's reproducibility and provides a clearer understanding of the instructional context in which the SOLO-based formative assessment was implemented.

The data gathering tools were prepared through a structured development process. The essay prompts were designed based on the intended learning outcomes and SOLO cognitive levels, ensuring that each question elicited evidence of conceptual depth. Classroom observation notes followed a reflective protocol focusing on students' reasoning, participation, and response to feedback. The rubric, essay tasks, and observation guidelines were reviewed for coherence to ensure that all instruments collectively captured students' cognitive development across the SOLO hierarchy.

To provide greater clarity on how student responses were evaluated, a visual representation of the SOLO-based rubric used in this study is presented in Table 3. The rubric contains adapted descriptors that align with the learning objectives and the cognitive demands of the population dynamics topic.

Table 3: SOLO-based rubric used in the study

SOLO level	Descriptor	Indicators (contextualized to population dynamics)
Prestructural	The response shows limited or no understanding of the concept.	Gives unrelated or incorrect information.
Unistructural	The response shows understanding of one relevant aspect.	Identifies one demographic factor (e.g., birth rate).
Multistructural	The response includes several relevant ideas but lacks integration.	Lists multiple demographic factors without connecting them.
Relational	The response integrates ideas into a coherent explanation.	Explains causal relationships (e.g., how population growth affects the environment).
Extended abstract	The response extends beyond the task to generate new insights or applications.	Proposes innovative solutions or generalizes concepts to new contexts.

The analysis was conducted through document analysis and interpretive reflection, examining the correspondence between rubric descriptors, student work, and classroom observations. Data from teacher observations and reflections were analyzed qualitatively using a descriptive-interpretive approach to identify patterns of student understanding improvement according to SOLO levels. Furthermore, data triangulation was conducted between student assignment documents, observation results, and reflective notes to ensure the validity of the findings. This analysis also aimed to measure the extent to which the use of SOLO-based rubrics facilitates a constructive learning process and is oriented towards improving the quality of conceptual understanding.

In the context of this research, the SOLO taxonomy is used as both an assessment tool and a pedagogical approach in the learning process. This research demonstrates how the taxonomy can be adapted to various evaluation needs, particularly in measuring students' levels of understanding. The SOLO taxonomy developed in this context serves as the primary source of research data and serves as a basis for systematically assessing the quality of student learning outcomes.

4. Result

4.1 Determining Learning Objectives

The learning objectives in this study were formulated so that the students were able to develop innovative strategies to overcome the impact of population density on the availability of natural resources and the environment. These objectives were oriented towards the development of higher-order thinking skills in accordance with the revised Bloom's taxonomy by Anderson and Krathwohl (2001), which places the operational verb "compose" or create (C6) at the highest cognitive level. At this stage, students are not only asked to understand and analyze population problems, but they also required to integrate various concepts and information to produce new strategies that are creative, solution-oriented, and relevant to the context of their surroundings.

4.2 Adaptation of the SOLO Taxonomy Rubric at the Multistructural Level

The analysis of the data, conducted through a descriptive interpretive approach, revealed clear patterns of students' cognitive progression across the SOLO levels. The rubric analysis showed that students initially demonstrated multistructural responses, identifying several demographic factors without articulating their relationships. As instruction and feedback progressed, more students produced relational responses, linking variables such as population growth, environmental pressure, and socioeconomic impacts in coherent explanatory chains. Only a small number of students reached the extended abstract level, in which they generated broader solutions and transferred concepts to unfamiliar contexts.

The document analysis of students' written work further supported these patterns. Early essays tended to list concepts without integration, while later essays demonstrated improved causal reasoning, with some students proposing preventive strategies for demographic challenges. For example, one student explained how rapid urbanization could increase environmental risks and then proposed policy-based mitigation strategies, illustrating a relational-to-extended abstract shift.

Classroom observation notes reinforced these findings, showing that students gradually responded to feedback by refining explanations, asking higher-order questions, and making connections between concepts. These observations indicated that formative feedback contributed to students' movement toward higher SOLO levels. Overall, the triangulated analysis of rubrics, essays, and classroom interactions illustrated a consistent improvement in conceptual depth and the ability to apply knowledge to broader contexts.

The essay questions that were given by teachers to students to measure understanding, as well as a reflective tool that guided students to think critically, creatively, and practically in dealing with complex population issues in real life were to:

- Explain the relationship between population growth and national food security, and develop innovative strategies to balance it with the sustainable availability of natural resources.
- Explain how climate change and urbanization could alter Indonesia's population structure in the next 20 years, and propose sustainable solutions for local governments.
- Imagine you are a regional planner, design an integrated policy model combining social, economic, and environmental aspects to control population growth and improve residents' quality of life sustainably.

To assess students' conceptual understanding of population dynamics, the essay questions were evaluated using a rubric developed based on the SOLO taxonomy. This rubric provided clear criteria for analyzing the depth and quality of student responses at each level of understanding, from prestructural to extended abstract, as shown in Table 4.

Table 4: Essay grading criteria based on SOLO taxonomy levels

Solo taxonomy level	Description of student understanding	Essay grading criteria
Prestructural	Students demonstrate a misconception or irrelevant understanding of population issues. They are unable to answer questions with appropriate concepts.	- The answer is general and out of context. - There is no use of population geography concepts. - There is no connection between causes, impacts, or solutions.
Unistructural	Students are able to mention one main aspect or idea, but have not explained it in depth.	- Mentioning a single causal or impact factor without explanation. - Using a simple population concept.
Multistructural	Students are able to explain several relevant factors or ideas, but they are still separate and do not yet show the relationship between aspects.	- Describes 2–3 causal and impact factors. - The explanation is still descriptive and lacks a causal relationship. - There is no attempt to integrate ideas.
Relational	Students begin to connect various factors and concepts into a logical and structured whole.	- There is a causal relationship between population growth, natural resources, and the environment. - Demonstrates a systemic understanding of the relationships between variables. - Provides solutions based on conceptual relationships.
Extended abstract	Students are able to generalize and create new ideas or models based on integrated understanding.	- Develop innovative strategies or models to address population issues. - Demonstrate reflective, predictive, and creative thinking skills. - Draw conclusions that transcend the learning context.

4.3 Explanation of the Task and How the Rubric is Structured and Implemented

The formative essay assignment based on the SOLO taxonomy at the extended abstract level was designed with the aim of enabling students to integrate various concepts of population dynamics, generalize knowledge into real-world contexts, and develop innovative ideas or strategies to address population issues sustainably. This objective aligns with the learning outcomes of Geography Phase F, namely analyzing the relationship between population growth, distribution, and utilization of natural resources towards sustainable development. In the context of the SOLO taxonomy, this assignment was directed at achieving the highest level of thinking, namely the extended abstract, in which students were expected to not only be able to understand and relate various concepts, but also create new solutions that are applicable and contextual.

Before the implementation, teachers prepared several important planning documents, including a lesson implementation plan containing learning objectives, indicators, and the formative assessment methods used. Furthermore, teachers developed a SOLO-based assessment rubric to assess students' depth of understanding, an essay assignment instruction sheet containing three open-ended questions related to population dynamics, and a student self-reflection sheet to help them assess the development of their understanding and critical thinking skills. Each of these instruments was integrated to ensure that the formative assessment was systematic, transparent, and oriented toward the learning process.

The implementation phase began with contextualizing and stimulating activities, in which the teacher presented current phenomena related to population issues, such as population growth data, urbanization, or the food crisis, to build students' prior knowledge at the relational stage. Afterward, the teacher provided instructions for an open-ended or analytical essay assignment that students had to complete individually. The teacher explained that this assignment was formative, not summative, so its primary purpose was to deepen understanding and thinking skills, not to produce a final grade. Students then wrote an essay that analyzed the relationships between concepts and design innovative solutions based on their reflections and knowledge. Throughout the writing process, the teacher played an active role as a facilitator by providing direct and on-the-spot feedback so students could refine their argumentative logic or expand the connections between the concepts they used.

After the essays were collected, the teacher conducted a feedback session using sample student answers (without giving the students' names) to identify differences in the quality of understanding at each SOLO level. Through this discussion, students learned to recognize the characteristics of descriptive (multistructural) answers, analytical (relational), and generalist and innovative (extended abstract) answers. This approach helped students understand how their thinking developed from simply explaining facts to creating new, more meaningful ideas.

During the implementation, teachers and students produced several important documents. First, an essay instruction sheet and assessment guide were created to explain the expectations and success criteria for the assignment. Second, a five-level SOLO assessment rubric was formed that allowed teachers to mark each student's achievement and provide descriptive, rather than numerical, feedback. Third, a student reflection sheet was used to record understanding, difficulties, and improvement plans after receiving feedback. Fourth, teacher observation notes were made, which contained records of students' argumentative and critical thinking skills during writing or discussions. Fifth and finally, a learning portfolio, a collection of student essays and their revisions, served as evidence of the students' cognitive and reflective development.

The final stage of this assessment was follow-up and reflection on learning. Teachers analyzed students' answers using the SOLO rubric to identify patterns of understanding development from relational to extended abstract. The results of this analysis were used to adjust subsequent learning, for example by increasing data exploration activities, reflective discussions, or academic debates so that students continued to develop in-depth understanding. Students were then given the opportunity to revise their essays based on teacher feedback, so they experienced a continuous learning process through reflection and self-improvement.

5. Discussion

Based on the research results, through rubrics, students are not only guided to understand the concept of population dynamics descriptively, but also to analyze, integrate, and generalize various interrelated social, economic, and environmental factors. The use of rubrics based on the SOLO taxonomy plays a role in the development of higher-order thinking skills. This supports the previously presented research findings of Svensäter and Rohlin (2022), which stated that the SOLO taxonomy can be used for in-depth analysis to develop and assess cognitive complexity. This finding is also similar to what was reported by Triana et al. (2023), that higher-order thinking skills lead to elements of critical thinking.

The rubric structure, which explains the characteristics of understanding at each level (from prestructural to extended abstract), helps students understand how their thinking develops and what needs to be improved. The rubric also encourages self-reflection, allowing students to recognize their current understanding and strive for more complex levels of thinking. This aligns with Biggs and Collis's (1982) argument that the SOLO taxonomy can map the growth of understanding quality from low to high levels in a systematic and measurable manner.

The rubric development process was carried out systematically by adapting indicators of population concept understanding to five levels of SOLO, ranging from prestructural to extended abstract. Teachers developed criteria that illustrated the gradual development of students' thinking, from the ability to identify a single factor, to designing innovative and contextual solutions. This aligns with the research findings of Rembach and Dison (2016), which showed that the rubric was developed by adapting SOLO to suit course context and student characteristics.

In its implementation, rubrics are provided alongside assignment instructions and concrete examples, so students understand the learning expectations at each level. This process makes assessment more transparent and participatory, as students clearly understand what is being assessed and how to improve. This aligns with a research report presented by Adeniji et al. (2022), which revealed that the SOLO model accurately reflects student learning outcomes and establishes a direct link to student performance, correlating with the principle of providing rubrics alongside assignment instructions. This alignment ensures that students clearly understand the expected performance levels at each cognitive stage, thus encouraging transparency and active participation in the formative assessment process.

Through rubrics, teachers can provide descriptive feedback that focuses on students' thinking processes, not just the final results. Students gain a concrete picture of their strengths and weaknesses in understanding concepts, which then serves as a basis for improving their thinking and learning strategies. This concept aligns with research conducted by Nicol and Macfarlane-Dick (2006), in which it was explained that, in the context of formative assessment, SOLO-based rubrics function not only as assessment tools but also as reflective learning tools. This also aligns with the research conducted by Evangelou and Kotsis (2023), who observed that reflection in the constructivist approach and SOLO assessment will allow students to revise and deepen their understanding, which is essentially a form of reflection on their own knowledge.

Although the implementation results showed positive impacts, this study also identified several challenges and obstacles in implementing the SOLO-based rubric. First, the process of developing a detailed and contextual rubric requires time and a strong conceptual understanding from teachers so that each descriptor truly reflects students' cognitive achievements. Dharmasaroja (2023) also found the same obstacle, that feedback and assessment at the beginning of the lesson would be more effective with a small number of students.

Second, some students initially had difficulty understanding the differences between levels in the rubric, so repeated familiarization and explanations were needed so that they could use the rubric as a self-reflection tool. Research by Tomperi and Aksela (2014) also found the same problem as the current study, in which the difficulty in implementing the SOLO taxonomy in the classroom was not in teachers' theoretical understanding, but in its practical application. Obstacles occurred when teachers had to adapt or design learning instructions based on SOLO cognitive levels in real contexts.

The use of SOLO-based rubrics provides an opportunity to strengthen students' comprehensive academic skills. Through a reflective and gradual process, students learn to connect concepts, reason about cause-and-effect relationships, and develop logical and creative scientific arguments. Rubrics help students understand that learning is not just about memorizing information, but also about connecting, evaluating, and creating new knowledge. Academically, this improves students' scientific writing, critical thinking, and academic communication skills.

Overall, these findings reinforce the theoretical claim that structured criteria, such as SOLO descriptors, can guide students toward deeper learning by clarifying expectations and supporting the process of conceptual restructuring. When combined with formative feedback, the rubric becomes more than a measurement tool; it functions as an instructional support that helps students articulate, revise, and extend their understanding.

6. Conclusion

This study demonstrates that adapting the SOLO taxonomy into a formative assessment rubric can effectively facilitate students' higher-order thinking in understanding population dynamics. Through structured criteria that describe the progression of understanding from the prestructural to the extended abstract level, the rubric supports students in moving beyond recalling and explaining concepts toward analyzing relationships, integrating ideas, and generating innovative strategies related to demographic issues. Its implementation promotes transparency and active engagement, enabling students to identify their current level of understanding and reflect on their learning progress.

For teachers, the rubric serves as a practical tool for providing descriptive and constructive feedback that emphasizes the quality of students' thinking processes rather than the final product. Although the development and use of such rubrics require conceptual clarity and sufficient preparation time to ensure that each level accurately reflects cognitive progression, their application offers meaningful pedagogical innovation that enhances academic reasoning, self-reflection, and creative problem-solving.

The findings contribute to the growing literature on SOLO-based formative assessment by showing how structured criteria and timely feedback can support students' progression toward deeper conceptual understanding. However, the study is limited to a single class and a specific geography topic, which may affect the generalizability of the results. Future research is recommended to explore the use of SOLO-based rubrics across different subjects and educational levels, and to examine the development of students' understanding through longitudinal data to validate the effectiveness of this approach further.

7. Conflict of Interest

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