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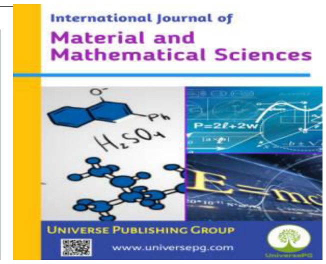

Measuring Student Performance in Mathematics in the Modern World Course Using Bloom's and Solo Taxonomies

Romell A. Ramos[1], Miraflor C. Gutierrez[1], Elizabeth Socorro P. Carandang[2]*, and Rochelle R. Caguete[2]

[1]College of Education, University of Batangas, Philippines; and [2]College of Arts and Sciences, University of Batangas, Philippines.

*Correspondence: elizabeth.carandang@ub.edu.ph (Elizabeth Socorro P. Carandang, PhD, College of Arts and Sciences, University of Batangas, Philippines).

ABSTRACT

The quality of learning could be determined by observing students' performance through the use of SOLO (Structure of the Observed Learning Outcome) and Bloom's taxonomies, which are a few of the educational frameworks that can be used to examine the level of students' mathematical skills and performance. The descriptive method utilizing documentary analysis and testing methods was used as instruments involving 1239 students from the different programs, where the attainment levels were computed based on the index of mastery. The results showed that majority of the learning outcomes in Bloom's taxonomy are not well distributed since are mostly under application, analysis, synthesis, and evaluation levels only, while the SOLO thinking levels are also not well distributed where mostly targeting the multi-structural and the relational levels. Meanwhile, mapping the items in the major examinations showed that most of the items target comprehension, application, and analysis in Bloom's taxonomy, while multi-structural and relational levels in the SOLO taxonomy. Furthermore, data revealed that the students are not able to attain the expected level of thinking using the assessment instrument since it cannot provide evidence of performance/attainment in the other thinking levels such as knowledge, synthesis, evaluation, uni-structural, and extended abstract. Overall, Bloom's and Solo Taxonomies are crucial tools for evaluating how well students are doing in mathematics in the modern world course. It gives teachers a framework for creating tests and lessons aligned with specific objectives for learning and aids in a deeper comprehension of mathematical ideas.

Keywords: Student performance, Bloom's taxonomy, SOLO taxonomy, and Mathematics in modern world.

INTRODUCTION:

Traditionally, teachers have predominantly favored the content-based approach to teaching. However, the implementation of outcomes-based education (OBE) in higher education (HE) has shifted the focus towards course outcomes and learners' specialization areas. The Philippine Commission on Higher Education's (CHED) Handbook on Typology, OBE, and Institutional Sustainability Assessment (ISA) (2014) emphasizes the necessity for Filipino students to be globally competitive through high-quality education that equips them with essential competencies and attitudes. Consequently, the government initiated the transition from input-based to outcomes-based education in higher education in 2014, placing students at the forefront of educational planning. As educational reform progresses, there's also a push for standards-based reform in mathematics education, aiming to elevate academic standards for all students. A notable issue in Filipino mathematics education is the students' tendency to perceive the subject as a collection of disconnected facts and procedures rather than a coherent system of ideas and operations reflecting real-world patterns and relationships. This underscores a global shift in the perception of mathematics.

Furthermore, various factors, including teaching and evaluation methods, have contributed to students' limited success and performance in mathematics. Reports indicate high failure rates, poor understanding of mathematical concepts among students, and the adverse effects of exams (Conn, 2017). Additionally, researchers have observed a stigma surrounding mathematics, which fosters negative attitudes towards learning the subject. These negative perceptions persist in students' minds and can lead to psycho-somatic reactions, indicating that the stigma is deeply ingrained (Corpuz & Saldanan, 2015). Consequently, students may develop a desire for math-related activities or discussions to conclude quickly, reflecting their aversion to the subject. On the contrary, students often lack opportunities to demonstrate their own understandings and outputs in mathematics courses, as assessment typically relies on conventional paper-and-pencil tests. These tests often present difficulties in a decontextualized manner, reinforcing the perception of unrelated concepts. Meeting the predetermined criteria is the sole focus for passing these tests, rather than understanding the underlying reasoning behind problem-solving methods. Consequently, students tend to mimic the problem-solving processes demonstrated by their teachers rather than engaging in critical thinking. In some cases, students may leave questions blank if they differ even slightly from what they've encountered before, indicating a lack of adaptability and critical thinking skills. To address these issues, outcomes-based education (OBE) provides support for math educators to implement teaching strategies that emphasize not only how to teach but also what methods to use, what learning experiences to provide, and what assessment tools to employ to connect abstract concepts to real-life applications. The primary rationale for adopting OBE is to enhance learning outcomes, leading to initiatives such as CHED Memo-randum Order (CMO) No. 40 Series of 2012, which shifts recognition and accreditation standards in higher education institutions (HEIs) from an input-based to an outcomes-based approach.

Moreover, the Commission on Higher Education has revised the general education curriculum, significantly reducing the number of course units from 63 to 36, with Mathematics in the Modern World being one of the core courses (Valencia, 2015). This course empha-sizes the practical application of algebra in everyday scenarios encountered by students, aiming to cultivate an appreciation for mathematics across various professions and endeavors (DLSU, 2015). The over-arching goal of Mathematics in the Modern World is to provide students with problem-solving opportunities that demonstrate the relevance and utility of mathe-matics in diverse contexts. To enhance the teaching and learning experiences within the course, it is imperative to evaluate its impact on both students and teachers while aligning instructional practices with the intended course outcomes. OBE necessitates effective instruction and innovative instructional materials to ensure that students are achieving these outcomes. Furthermore, students' proficiency in mathematics is essential for enhancing their performance in the subject and applying it in everyday life and future endeavors. Developing mathematical skills not only boosts confidence but also fosters the ability to interpret mathematical concepts, utilize technology, critically analyze issues, and solve problems effec-tively. Problem-solving, in particular, is a fundamental mathematical skill that holds significant importance. Therefore, it's crucial to assess the extent to which students have mastered these skills. Educational frameworks such as the Structure of the Observed Learning Outcome (SOLO) Taxonomy and Bloom's Taxonomy are valuable tools for evaluating students' mathematical skills and performance.

The SOLO Taxonomy provides a systematic and understandable framework for assessment, accessible to both teachers and students. It categorizes students' skill levels into five hierarchical categories: pre-structural, uni-structural, multi-structural, relational, and extended abstract (Putri *et al.,* 2017). This taxonomy not only aids in assessment but also high-lights cognitive diversity and students' responses to different levels of thinking. Conversely, the updated version of Bloom's Taxonomy emphasizes higher-order thinking skills such as analyzing, evaluating, and creating. It posits that lower-order thinking skills are foundational for higher-order thinking skills (Agarwal, 2019). Adhering to the Revised Bloom's Taxonomy (RBT) levels when creating assessment materials promotes inclusivity and enhances students' capacity for higher-order thinking in mathematics.

Originally designed for assessment purposes, these frameworks are invaluable for evaluating students' readiness and performance. By observing students' responses, educators can gauge the quality of learning. Recognizing the significance of these frameworks, researchers and mathematics educators have conducted studies using Bloom's and SOLO Taxonomy to measure students' performance in courses like Mathematics in the Modern World. Utilizing these frameworks enables educators to develop mathematical tasks that not only assess but also enhance students' higher-order thinking abilities and performance effectively. In general, the objectives of the study are to evaluate student performance in the Statistical Analysis and Software Application course utilizing Bloom's and SOLO Taxonomies. Specifically, the aims are to:

1. Determine the distribution of student learning outcomes according to the thinking levels outlined in Bloom's and SOLO Taxonomies.
2. Align the items of the major examination with the thinking levels delineated in Bloom's and SOLO Taxonomies.
3. Determine whether students achieve the anticipated level of thinking as indicated by the results of major examinations and performance tasks.

METHODOLOGY:

This action research utilized a descriptive design incorporating documentary analysis and testing methods. The researchers analyzed the approved syllabus for the Mathematics in the Modern World course and aligned the student learning outcomes (SLOs) with the thinking levels outlined in Bloom's and SOLO taxonomies. The final examination, comprising 50 multiple-choice items with four options each, was employed to assess the attainment of the SLOs. The examination was designed based on the approved table of specifications. A total of 1239 students participated in the study, representing various programs including Engineering (N=818, 66.02%), CAMS (N=47, 3.79%), BSN (N=181, 14.61%), and CTHM (N=193, 15.58%). They undertook the proctored examination simultaneously for 1.5 hours and were permitted to use mathematical formulas and calculators. Attainment levels were determined using the index of mastery, calculated as the ratio of students who correctly answered a particular item/question to the total number of students who took the test.

Data analysis was conducted using frequency count and percentage. Test papers and answer sheets were retained by professors/ instructors in accordance with university guidelines for examinations. To ensure confidentiality and anonymity, only test scores and item analytics were retained for subsequent analysis.

RESULTS AND DISCUSSION:

Student Learning Outcomes, Bloom's and SOLO Taxonomy of Thinking Levels

Table 1 illustrates the distribution of student learning outcomes in the Mathematics in the Modern World course across different thinking levels of the Bloom's and SOLO taxonomies. It is noteworthy that the majority of the learning outcomes (N = 18, 68.23%) are situated beyond the comprehension level, targeting application (N = 10, 38.46%), analysis, synthesis, and evaluation (N = 8, 30.77%) levels. This suggests that the course emphasizes higher-order thinking skills in various activities and assessments provided to students. However, it is observed that the learning outcomes are not evenly distributed across the different levels of the Bloom's taxonomy, and not all topics include the development of higher-order thinking skills (Sokhandan A., 2024).

Furthermore, the distribution of student learning outcomes in the course does not adequately cover the various levels of thinking in the SOLO taxonomy. The majority of outcomes target the multi-structural (N = 8, 30.77%) and relational (N = 10, 38.46%) levels. It is observed that certain SOLO levels are not addressed in some course topics. This observation is supported by a study conducted by Saidat *et al.* (2020), which concluded that the SOLO and Bloom's models effectively represent students' learning outcomes.

Table 1: Distribution of Student Learning Outcomes of the Mathematics in the Modern World Course to the Bloom's and SOLO Taxonomy Levels

Course Topics / Student Learning Outcomes	Bloom's Taxonomy						SOLO Levels			
	K	C	Ap	An	S	E	US	MS	R	EA
A. Mathematics in Our World		**2**	**2**	**1**			**1**	**3**	**1**	
Describe the relationship of nature and mathematics		✓						✓		
Describe other patterns in mathematics in nature		✓						✓		
Explicate Fibonacci numbers, Pascal's Triangle, and their origin			✓						✓	
Illustrate how the Fibonacci sequence as expressed in nature			✓					✓		
Discover the pervasiveness of the Golden Ratio in nature and art				✓			✓			
B. Mathematical Language		**2**	**1**				**1**		**2**	
Identify the words and phrases used in mathematics		✓					✓			
Translate English words and phrases into mathematical symbols and expressions		✓							✓	
Apply mathematical terms, language, and symbols correctly to solve problems			✓						✓	
C. Logic		**1**	**2**	**1**	**2**			**1**	**4**	**1**
Discuss the vocabulary, syntax, and semantics of propositional logic		✓						✓		
Interpret formulas and sentences of symbolic logic in mathematical structures			✓						✓	
Use skillfully the mathematical statements to produce logically valid, correct and clear arguments				✓					✓	
Assess arguments for validity					✓				✓	
Apply the concept of truth tables to validate propositions and arguments			✓						✓	
Justify the correct use of reasoning in mathematical language					✓					✓
D. Polya's Rule of Problem Solving and Recreational Mathematics			**2**	**1**		**1**	**1**	**1**	**1**	**1**
Discover the different key concepts of problem-solving				✓			✓			
Explain the steps/procedures in solving problems			✓						✓	
Illustrate the different heuristic methods in solving non-routine problems			✓					✓		
Propose strategies and methods to solve problems creatively						✓				✓
E. Data Management		**1**	**2**			**1**		**2**	**1**	**1**
Discuss the basic statistical terms		✓						✓		
Explain the basic concepts of sampling and sampling techniques			✓						✓	
Illustrate the different statistical data collection methods and procedures			✓					✓		
Construct textual, tabular and graphical presentation of data						✓				✓
F. Geometric Designs	**1**	**1**	**1**			**1**	**1**	**1**	**1**	**1**
Describe the symmetry in nature		✓						✓		
Recognize the different terms related to symmetry	✓						✓			
Interpret the concepts of the different types of transformation			✓						✓	
Construct designs integrating the element of symmetry and geometric transformation						✓				✓
Total	**1**	**7**	**10**	**3**	**2**	**3**	**4**	**8**	**10**	**4**

Note: K-Knowledge, C-Comprehension, Ap-Application, An-Analysis, S-Synthesis, E-Evaluation, US-Uni-Structural, MS-Multi-Structural, R-Relational, EA-Extended Abstract

However, the study also highlighted a direct correlation between students' performances and their SOLO levels. Additionally, it was suggested that the SOLO and Bloom's models could elucidate various developmental theories and aid in the development of mathematics curricula.

Mapping of Major Examination with the Bloom's and SOLO Taxonomy of Thinking Levels

Table 2 Distribution of Test Items/Questions in the Major Examination of Mathematics in the Modern World Course According to Bloom's and SOLO Taxonomies. **Table 2** displays the distribution of test items/ questions in the major examination of the Mathematics in the Modern World course according to Bloom's and SOLO Taxonomies. It is evident that certain thinking levels are not assessed in the examination instrument. The majority of items/questions target comprehension (N = 15, 30.00%), application (N = 21, 42.00%), and analysis (N = 14, 28.00%) in the Bloom's taxonomy, while multi-structural (N = 17, 34.00%) and relational (N = 33, 66.00%) levels are emphasized in the SOLO taxonomy. However, the assessment instrument used does not provide insight into students' performance or attainment in other thinking levels such as knowledge, synthesis, evaluation, uni-structural, and extended abstract. This finding resonates with the studies conducted by Atasoy & Konyalihatipoglu, (2019) and Easdown *et al.* (2019), who argued that the SOLO model effectively assesses students' mathematical understanding across various grade levels. However, it was also noted that the SOLO model may not accurately represent students' knowledge when multiple-choice questions are utilized, as the responses may contain limited information.

Table 2: Distribution of Major Examination Questions to the Bloom's and SOLO Taxonomy of Thinking Levels.

Course Topics/Student Learning Outcomes	Number of Questions	Bloom's Taxonomy						SOLO Levels			
		K	C	Ap	An	S	E	US	MS	R	EA
A. Nature of Mathematics	11		3	3	5				5	6	
B. Mathematical Language	7		2	3	2				2	5	
C. Logic	8		2	6					2	6	
A. Data Management	14		4	7	3				4	10	
B. Problem Solving	5		2	2	1				2	3	
C. Geometric Design	5		2		3				2	3	
Total	50		15	21	14				17	33	

Note: K-Knowledge, C-Comprehension, Ap-Application, An-Analysis, S-Synthesis, E-Evaluation, US-Uni-Structural, MS-Multi-Structural, R-Relational, EA-Extended Abstract

Source: Mathematics Department, Table of Specification for Mathematics in the Modern World, 2022

Students' Attainment of the Learning Outcomes

Table 3: Attainment Levels of the Student Learning Outcomes.

Course Topics	Index of Mastery	Remarks
A. Nature of Mathematics	0.58	Average Competency
B. Mathematical Language	0.64	Average Competency
C. Logic	0.64	Average Competency
D. Data Management	0.56	Average Competency
E. Problem Solving	0.52	Average Competency
F. Geometric Design	0.34	Low Competency
Descriptive	**Statistics**	
Mean	28.23	
Standard deviation	11.05	
Skewness	-0.16	
Kurtosis	-0.15	

Legend: 0.96-1.00 mastered, 0.86-0.95 closely approximating mastery; 0.66-0.85 moving towards mastery, 0.35-0.65 average, 0.15-0.34 low, 0.05-0.14 very low, 0.00-0.14 absolutely no mastery.

CONCLUSION AND RECOMMENDATIONS:

Based on the data collected, the researchers drew several conclusions from the study. Firstly, the distribution of learning outcomes in Bloom's taxonomy appears to be skewed, with a predominant focus on application, analysis, synthesis, and evaluation levels. Conversely, in the SOLO thinking levels, the distribution is also uneven, with the majority of outcomes targeting the multi-structural and relational levels, indicating a lack of balance across various cognitive domains. Secondly, upon mapping the items in major examinations, it became evident that the assessment predominantly emphasizes comprehension, application, and analysis in the Bloom's taxonomy, aligning closely with multi-structural and relational levels in the SOLO taxonomy. However, other thinking levels such as knowledge, synthesis, evaluation, uni-structural, and extended abstract are not adequately addressed in the assessment instrument. Lastly, despite satisfactory performance observed in certain learning outcomes, students appear to struggle with attaining the expected level of thinking as measured by the assessment instrument. This limitation in assessment effectiveness is particularly notable in its inability to provide evidence of performance or attainment in the aforementioned thinking levels, potentially hindering a comprehensive evaluation of students' mastery of the subject matter. To enhance the instructional delivery of the Mathematics in the Modern World course, several recommendations are proposed. Firstly, a comprehensive review and revision of the course syllabus are essential to ensure an equitable distribution of learning out-comes across various thinking levels. This will help address the current imbalance observed in the distribution of outcomes within Bloom's taxonomy. Secondly, it is imperative to target different thinking levels within each course topic to promote a more holistic approach to learning. By incorporating activities and assessments that cater to a range of cognitive domains, students will have opportunities to develop their critical thinking skills more effectively. Thirdly, the assessment instruments used, particularly major examinations, should be carefully designed to include questions or items that effectively measure each thinking level. It is crucial to ensure that questions are evenly distributed across all thinking levels to provide a comprehensive evaluation of students' understanding and mastery of the subject matter. Lastly, mapping other learning activities and assessment instruments against the various thinking levels is essential to gauge students' attainment levels comprehensively. This will allow instructors to assess the effectiveness of different instructional methods and tailor their teaching strategies accordingly to address any gaps in student understanding across different cognitive domains. Overall, implementing these recommendations will contribute to a more balanced and effective instructional approach in the Mathematics in the Modern World course.

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CONFLICTS OF INTEREST:

The authors declare that they have no conflicts of interest related to this research study.

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