ISSN 2529-9824

Research Article

Exam Performance in Road Engineering Courses Through Bloom's Taxonomy

Desempeño en exámenes en cursos de Ingeniería de Carreteras a través de la Taxonomía de Bloom

Yasmany García-Ramírez: Universidad Técnica Particular de Loja, Ecuador.
ydgarcia1@utpl.edu.ec

Date of Reception: 28/05/2024

Acceptance Date: 06/08/2024

Publication Date: 30/09/2024

How to cite the article:

García-Ramírez, Y. (2024). Exam performance in Road Engineering Courses through Bloom's Taxonomy [Desempeño en exámenes en cursos de Ingeniería de Carreteras a travé de la Taxonimoía de Bloom]. *European Public & Social Innovation Review*, 9, 1-16. https://doi.org/10.31637/epsir-2024-930

Abstract:
Introduction: Ensuring civil engineers possess robust technical skills is vital, particularly in road engineering. However, a gap exists between theoretical knowledge and practical application, prompting research to refine instructional approaches. Exams play a key role in evaluating skills, with Bloom's taxonomy being one method used for assessment. **Methodology**: This study analyzed road geometric design and operation exams at Universidad Técnica Particular de la Lonaja (UTPL, Ecuador), spanning two semesters. Fourteen exams from 2020 to 2022 were randomly selected and retrospectively categorized using Bloom's Taxonomy levels and verbs. **Results:** Lower Bloom's levels generally yielded higher grades, with some nuances observed. An association between Bloom's level range and levels was noted. Out of 80 questions, 13 (16,25%) reached the threshold for higher-order thinking skills. **Discussions:** The study underscores the importance of designing exam questions to assess higher-order thinking skills, addressing challenges within exam constraints. Analyzing outcomes through Bloom's Taxonomy offers insights into student learning, emphasizing the integration of theoretical knowledge and practical application. **Conclusions**: Aligning exam questions with required cognitive skills is crucial, suggesting improvements in instructional approaches. By leveraging Bloom's Taxonomy, educators can enhance teaching effectiveness. Future research should refine exam evaluation methods and promote theoretical-practical integration in civil engineering education.

Keywords: civil engineering; technical skills; Bloom's Taxonomy; exam assessment; road engineering education; higher-order thinking skills; instructional approaches; practical application.

Resumen:
Introducción: Garantizar que los ingenieros civiles posean sólidas habilidades técnicas es vital, especialmente en ingeniería vial. Sin embargo, existe una brecha entre el conocimiento teórico y la aplicación práctica, lo que ha llevado a investigaciones para perfeccionar enfoques instructivos. Los exámenes desempeñan un papel clave en la evaluación de habilidades, siendo la taxonomía de Bloom un método utilizado para la evaluación. **Metodología**: Este estudio analizó exámenes de diseño geométrico y operación vial en la UTPL, Ecuador, abarcando dos semestres. Se seleccionaron al azar catorce exámenes de 2020 a 2022 y se categorizaron retrospectivamente utilizando niveles y verbos de la taxonomía de Bloom. **Resultados:** Los niveles de Bloom más bajos generalmente arrojaron calificaciones más altas, con algunas sutilezas observadas. Se señaló una asociación entre el rango de nivel de Bloom y los niveles. De 80 preguntas, 13 (16,25%) alcanzaron el umbral para habilidades de pensamiento de orden superior. **Discusión**: El estudio resalta la importancia de diseñar preguntas de examen para evaluar habilidades de pensamiento de orden superior, abordando desafíos dentro de los límites del examen. El análisis de resultados a través de la Taxonomía de Bloom ofrece información sobre el aprendizaje del estudiante, enfatizando la integración del conocimiento teórico y la aplicación práctica. **Conclusiones**: Alinear las preguntas de examen con las habilidades cognitivas requeridas es crucial, lo que sugiere mejoras en los enfoques instructivos. Al aprovechar la Taxonomía de Bloom, los educadores pueden mejorar la efectividad de la enseñanza. La investigación futura debería refinar los métodos de evaluación de exámenes y promover la integración teórico-práctica en la educación en ingeniería civil.

Palabras clave: ingeniería civil; habilidades técnicas; Taxonomía de Bloom; evaluación de exámenes; educación en ingeniería vial; habilidades de pensamiento de orden superior; enfoques instructivos; aplicación práctica.

1. Introduction

Enhancing technical skills is paramount for civil engineers, given the dynamic nature of their profession and the multifaceted challenges they encounter. Construction firms seek engineers proficient in technical, computer, linguistic, and interpersonal competencies (Gerek & Efeoglu, 2015). The American Society of Civil Engineers (ASCE) has delineated four key categories—foundational, engineering fundamentals, technical, and professional—comprising 21 competencies deemed essential for civil engineers (American Society of Civil Engineers, 2019). In the realm of civil engineering, road engineers face similar imperatives, with the continuous evolution of the field underscoring the criticality of honing technical skills to maintain competitiveness (Danial & Misnan, 2023). Moreover, road engineers bear the responsibility of ensuring the safety, security, and functionality of road networks, necessitating a diverse skill set (Pritchard, 2019). Consequently, an integrated approach that addresses both professional and technical skill development is imperative within engineering education (Litzinger, 2000).

Universities play a pivotal role in cultivating engineering skills, and ongoing research aims to enhance pedagogical approaches to meet societal needs effectively. Some studies advocate for the integration of technical knowledge and professional skills through real-world research projects, offering mutual benefits for both academia and the profession (O'Sullivan & Cochrane, 2009). Others emphasize the importance of considering the societal impact of engineering solutions and propose incorporating this aspect into technical engineering courses (DeJong-Okamoto et al., 2005). Regardless of the active learning techniques employed in the classroom, it is widely agreed that passing an exam is often a requisite for completing a course. To ensure that these exams effectively assess whether an engineer has acquired the necessary skills, careful planning is essential. Moreover, beyond course completion, exams are also utilized in the professional certification processes of some countries. One method of achieving this alignment is through the use of Bloom's taxonomy.

Bloom's taxonomy (Bloom, 1956) has been widely utilized to assess the cognitive level attained by students in engineering subjects, with its revised version introduced in 2001 (Anderson & Krathwohl, 2001). This taxonomy provides a framework for measuring cognitive levels of learning and comprehension, classifying them into six hierarchical levels: remembering, understanding, applying, analyzing, evaluating, and creating. The first level, Remembering, involves recalling facts and basic concepts. Understanding, the second level, requires explaining ideas or concepts in one's own words. Applying, the third level, involves using learned information in new situations or contexts. Analyzing, the fourth level, entails breaking down information into its component parts and understanding relationships between them. Evaluating, the fifth level, involves making judgments based on criteria and standards. Finally, Creating, the sixth level, requires generating new ideas, products, or ways of thinking by combining existing knowledge and skills in novel ways. These levels represent increasingly complex mental processes, with each level building upon the previous one to foster deeper understanding and critical thinking skills.

The six levels of Bloom's taxonomy delineate progressively more intricate cognitive processes, spanning from basic information recall to the ability to synthesize and innovate. The American Society of Civil Engineers (ASCE) has adopted Bloom's Taxonomy, incorporating its six levels into educational practices (American Society of Civil Engineers, 2019). This taxonomy serves as a valuable tool for enhancing education, as evidenced by research findings (Dorodchi et al., 2017). For example, studies have revealed a prevalent imbalance in exam content, with a predominant focus on lower-order cognitive skills conducive to rote memorization, while higher-order skills like analysis, evaluation, and creativity receive comparatively less emphasis (Chandio et al., 2016).

There are few studies in the field of civil engineering that relate exams to Bloom's taxonomy. One such study investigated the cognitive levels attained according to Bloom's taxonomy in an introductory reinforced concrete design course (Dymond et al., 2019). The results showed that students achieved an average Bloom cognitive level of 2.9 in the course, but the study suggests that additional educational experiences are needed to reach a Bloom level of 4 or higher upon graduation. Another study used the classical Bloom's Taxonomy to evaluate examination questions in several courses an engineering faculty (Ogunwolu et al., 2018). The results show that the course examination questions are deficient in the crucial two uppermost levels of the Bloom's taxonomy. No studies related to road geometric design or operation were found. Road engineers play a critical role in the design, construction, and maintenance of transportation infrastructure, including highways, bridges, and tunnels. The nature of their work demands a high level of technical proficiency across various domains, including structural engineering, materials science, and transportation planning.

In this context, the objective of the article is to analyze exam performance in road geometric design and operation courses using Bloom's Taxonomy levels for cognitive analysis. By examining the cognitive processes involved in learning these subjects, the aim is to provide valuable insights into the effectiveness of current instructional methods and assessment practices in fostering technical skill development among civil engineering students. Through this analysis, the study seeks to bridge the gap between theoretical knowledge and practical application, ultimately equipping future civil engineers with the skills and competencies needed to address real-world challenges in road construction and design effectively. The research employed a rigorous methodology to analyze exam performance in road geometric design and operation courses using Bloom's Taxonomy levels for cognitive analysis. Exams were randomly collected from courses related to the Civil Engineering program at Universidad Técnica Particular de Loja (Ecuador) between 2020 and 2022. The performance of 291 students was evaluated, encompassing a diverse range of learners and providing a comprehensive representation of skill acquisition and cognitive development in the targeted courses. This methodology allowed for the identification of areas of strength and weakness in student learning, paving the way for targeted interventions and enhancements in civil engineering education.

This study holds significant implications for the advancement of civil engineering education and practice. By analyzing exam performance in road geometric design and operation courses using Bloom's Taxonomy levels, the research offers valuable insights into the cognitive processes involved in learning these subjects. The findings can inform educators and curriculum developers about the effectiveness of current instructional methods and assessment practices in fostering technical skill development among civil engineering students. Furthermore, the research contributes to ongoing discussions in engineering education aimed at optimizing learning experiences and improving student success rates. By identifying areas where students struggle or excel in different cognitive domains, institutions can make informed decisions to enhance the quality of education and better prepare graduates for the complexities of modern engineering practice. Building upon the established framework of Bloom's taxonomy, the study seeks to bridge the gap between theoretical knowledge and practical application in civil engineering education. Now, to delve deeper into the investigation, the attention turns to the methodology employed and the specific objectives guiding the study.

2. Methodology

2.1. Course Structure and Content Overview

In this study, our objective was to analyze examinations related to road geometric design and operation, as taught across two semesters at the Universidad Técnica Particular de Loja (UTPL) in Ecuador. Specifically, these topics are covered within the courses "Road Construction I" and "Road Construction II." It's worth noting that "Road Construction I" and the first part of "Road Construction II" are exclusively dedicated to road design, which serves as the foundational knowledge taught initially. Subsequently, after students have grasped road design principles, "Road Construction II" focuses on analyzing road operation. With these two courses, the intention is to provide students with a comprehensive understanding of roads, encompassing both their design and operational aspects.

Table 1.

Course Content Distribution for Road Geometric Design and Operation

N° de topic	Topic	Course	Design / operation
1	Introduction	Road construction I	Design
2	Driving	Road construction I	Design
3	Traffic Study	Road construction I	Design
4	Route Analysis	Road construction I	Design
5	Horizontal Geometric Design	Road construction I	Design
6	Consistency Analysis	Road construction I	Design
7	Vertical Geometric Design	Road construction I	Design
8	Transversal Geometric Design	Road construction I	Design
9	Road Capacity Analysis	Road construction I	Operation
10	Overtaking and Climbing Lane	Road construction II	Operation
11	Emergency Escape Ramp	Road construction II	Operation
12	Road Signage	Road construction II	Operation
13	Prediction of Traffic Accidents	Road construction II	Operation

Source: Author's elaboration based on the course contents (2024).

2.2. Examination selection

At UTPL, a variety of assessments, including midterms, finals, and, if needed, recovery or re-sit exams, are conducted throughout the Road Construction I and II courses. For this study, exams administered between 2020 and 2022 in these courses were randomly selected for analysis, resulting in 14 exams being included. These exams sometimes had two sections of students, labeled as A and B, with similar difficulty levels in the questions. For example, Group A exams were held in the morning, and Group B exams in the afternoon. However, it's important to note that the numerical values used in calculations varied between these sections. Class enrollment for these courses ranged from 11 to 58 students. While most students took both midterms and finals, there were cases where some students withdrew from the course or missed the midterm but took the final exam, as seen in exams E03 and E04, and between exams E05 and E06. The exams had durations ranging from 1 to 2 hours. In some instances, the allotted time was insufficient for students to complete all available questions. Students were required to answer questions sequentially, without the option to choose where to begin. The re-sit exam was only taken by students who did not pass during the regular evaluations within the semester, namely the midterm and final exams, which is why there were fewer students in this section.

Table 2.

Details of Selected Exams for Analysis

Exam code	N° questions/Exam/Time of resolution	Course	Academic period	Class section* (N° of students)
E01	4 /midterm exam/ 1 hour	I	April-August 2020	A (41)
E02	8 / re-sit exam / 2 hours			A (11)
E03	9 / midterm exam / 1.5 hours	II	October 2020 - February 2021	A (32), B (19)
E04	4 / final exam / 1.5 hours			A (32), B (20)
E05	3 /midterm exam/ 1 hour	I	April-August 2021	A (57), B (58)
E06	11 /final exam/ 1.5 hours			A (57), B (57)
E07	4 / midterm exam / 2 hours	I	October 2021 - February 2022	A (29), B (43)
E08	11 /final exam/ 1.5 hours			A (24), B(43)

* Across different class sections, exams were designed to have similar levels of difficulty, but the numerical values used in calculations were adjusted.

Source: Author's elaboration (2024).

2.3. *Assignment of Bloom's Taxonomy Levels and Verbs*

The exams listed in Table 2 were initially not categorized according to Bloom's taxonomy levels. Therefore, each question was retrospectively categorized using the six levels of the revised Bloom's taxonomy, along with the corresponding verbs from Table 3. To ensure objectivity and minimize bias, researchers utilized ChatGPT 3.5 (OpenAI, 2023) for this task. The content of road design and operation subjects, along with questions related to Bloom's Taxonomy, was inputted into the platform for analysis. Subsequently, the professor of both subjects reviewed and confirmed the assigned taxonomy levels and selected appropriate verbs from Table 3. Any necessary adjustments to the classification were made for clarity, providing additional context where needed. While the verbs in Table 3 offer a general idea of the cognitive level associated with each Bloom's taxonomy level, it's important to note that only a subset of these verbs is typically used in exam questions.

Table 3.

Verbs used for the 6 levels of the Revised Bloom's Taxonomy

Bloom's Taxonomy Level					
1 Remember	**2 Understand**	**3 Application**	**4 Analysis**	**5 Evaluation**	**6 Creation**
Define	Explain	Apply	Analyze	Evaluate	Create
List	Describe	Use	Compare	Judge	Design
Recall	Summarize	Solve	Contrast	Assess	Generate
Memorize	Interpret	Demonstrate	Differentiate	Critique	Invent
Recognize	Paraphrase	Calculate	Examine	Justify	Construct
Identify	Classify	Implement	Investigate	Decide	Develop
Label	Illustrate	Execute	Categorize	Recommend	Formulate
Name	Compare	Operate	Infer	Select	Produce
State	Contrast	Show		Determine	Plan
	Understand				

Source: Author's elaboration based on Bloom's Taxonomy (2024).

2.4. Data Processing and Analysis

The database underwent a refinement process to exclude unanswered questions due to time constraints, ensuring a more accurate analysis. Unanswered questions, indicating lack of time, were removed from consideration. For example, if a question aligned with Bloom's level 1 received a zero average score, it was because no responses were recorded, not necessarily due to excessive difficulty. Each student's exam scores were meticulously organized to correspond to the evaluated exams, maintaining clarity and consistency in the data organization.

Subsequently, the refined database facilitated the calculation of average Bloom level values for each assessment, enabling the identification of overarching trends. Statistical analyses, including box and whisker plots, regression analysis, among others, were conducted using Minitab 14 software (State College, 2005). Additionally, the average exam score, graded out of 100 points, was determined to compare the average Bloom level assigned across different subjects, alongside other relevant factors.

3. Results

3.1. Exam Grade and Bloom Level Analysis

Table 4 displays the average, maximum, and minimum grades achieved in each exam, along with the corresponding Bloom level of the questions, the average Bloom level, and the range of Bloom levels. Notably, the table reveals a considerable variation in the complexity levels of the exams. For instance, Exam E03 demonstrates lower complexity, while Exam E05, with a score of 4.7, indicates higher complexity. Interestingly, there is a notable scarcity of questions at Bloom levels 1, 2, and 6, with the majority falling within levels 2 to 5. On average, exams evaluate up to 2 Bloom levels, although in 3 cases, 3 levels were assessed. Additionally, after the data cleaning process, the last 4 questions from Assessment E06 were excluded, resulting in a total of 80 questions across all exams.

Table 4.

Summary of Exam Grades and Bloom Levels

Exam code	Section	Grades			Number of questions in the Bloom's Level						Average Bloom's level	Bloom's level range*
		Average	Max	Min	1	2	3	4	5	6		
E01	A	8.9	16.8	0	-	-	3	-	1	-	3.5	3
E02	A	25.0	41.0	7.0	-	1	4	2	1	-	3.4	3
E03	A	60.7	80.0	28.0	5	-	4	-	-	-	1.9	2
	B	68.2	89.0	32.0								
E04	A	44.0	77.5	15.0	-	-	2	1	1	-	3.8	2
	B	33.9	55.0	10.0								
E05	A	16.6	45.0	0	-	-	1	-	1	1	4.7	3
	B	25.7	55.0	5.0								
E06	A	4.8	20.0	0	-	-	6	4	1	-	3.6	2
	B	32.6	60.0	0								
E07	A	19.9	50.0	0	-	-	2	-	1	1	4.3	3
	B	24.4	77.5	0								
E08	A	26.0	65.0	0	-	-	6	4	1	-	3.5	2
	B	32.1	70.0	5.0								

* maximum Bloom's level minus minimum Bloom's level from all questions in the exam. – no question fell within this Bloom's level.

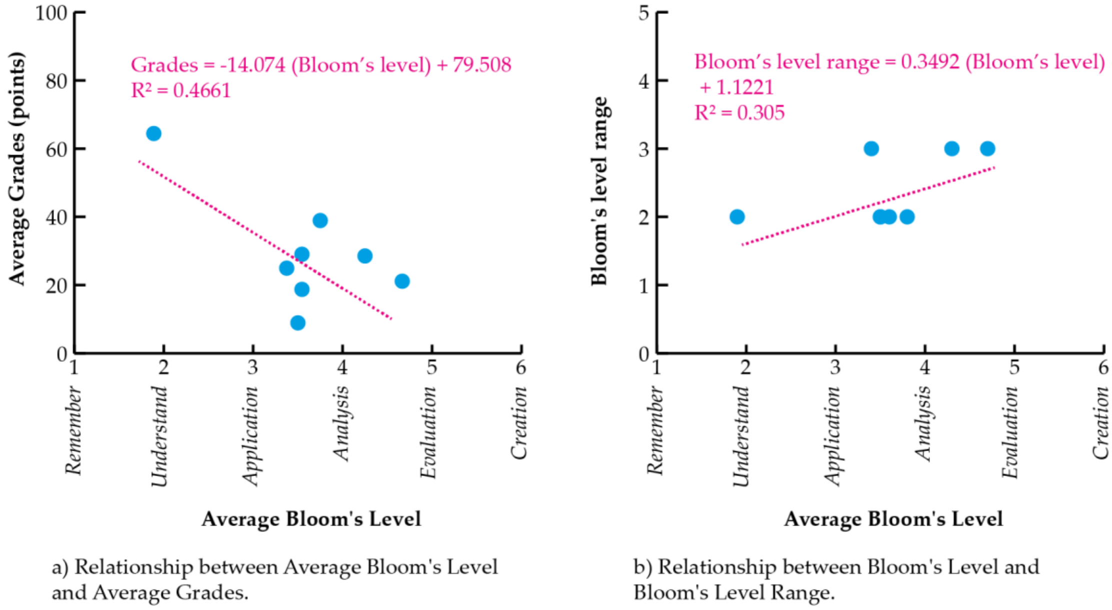
Source: Author's elaboration (2024).

It is noteworthy that exams with higher cognitive levels have minimum scores higher than those with lower cognitive levels. For instance, for exam E03 with an Average Bloom's level of 1.9, the minimum scores are 28 and 32, while others do not exceed zero points. Additionally, some exams have minimum scores equal to zero, indicating that students did not successfully answer any questions on those exams.

To explore the relationship between the Average Bloom's level, average grades, and Bloom's level range, Figure 1 was created. In Figure 1a, the average grades obtained from Table 4 were analyzed alongside their corresponding Average Bloom's level. Moreover, a linear regression line was incorporated into Figure 1 to depict the association between these factors ($R^2 = 0.47$). This line demonstrates a decrease in average grades as the Bloom's level increases. It's worth noting that a data point on the lower end significantly influences the trend, and eliminating it would negate the observed correlation.

Figure 1.

Relationship between Average Bloom's Level, Average Grades and Bloom's Level Range.



Source: Author's elaboration (2024).

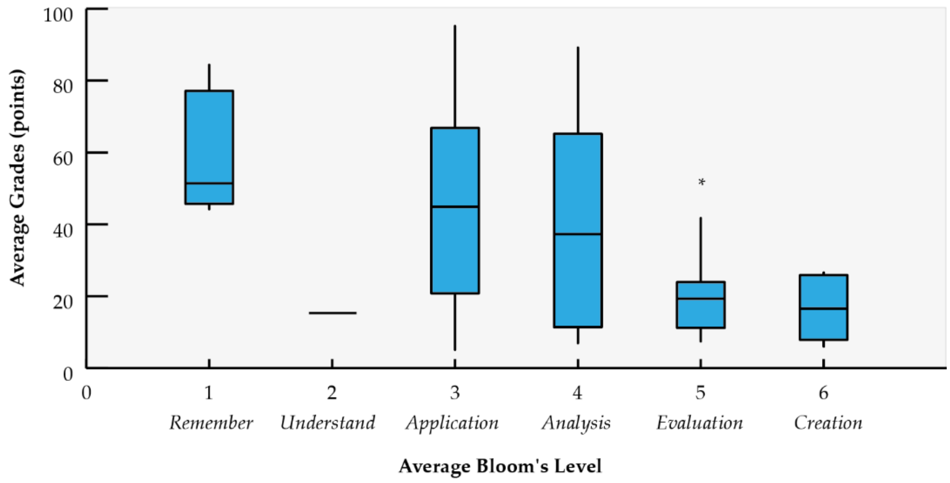
In Figure 1b, the Bloom's level and the Bloom's level range extracted from Table 4 are depicted. A regression line with an R^2 value of 0.31 is also presented. This line suggests that as the assessed Bloom's level increases, a larger Bloom range is anticipated. However, if the data point for "Understand" is removed, the coefficient of determination would approach zero, indicating no relationship. The potential range of evaluation spans from 0 to 5, signifying that all questions are at the same Bloom level.

3.2. Analysis of Exam Results and Bloom Levels

When all exam questions are aggregated into a single database and plotted alongside their respective Bloom levels, the resulting box and whisker plot depicted in Figure 2 emerges. Here, it's evident once more that as Bloom levels ascend, grades tend to decrease, a trend persisting even at the highest levels. Notably, Bloom level 2 is absent in the analyzed exams due to the scarcity of such questions, indicating potential inclusion in future iterations. Predominantly, questions gravitated towards Bloom levels 3 or 4. Furthermore, Bloom levels 5 and 6 exhibit proximity in values. The overall average Bloom level for all exam questions stands at 3.5.

Figure 2.

Relationship between Average Grades and Bloom Levels

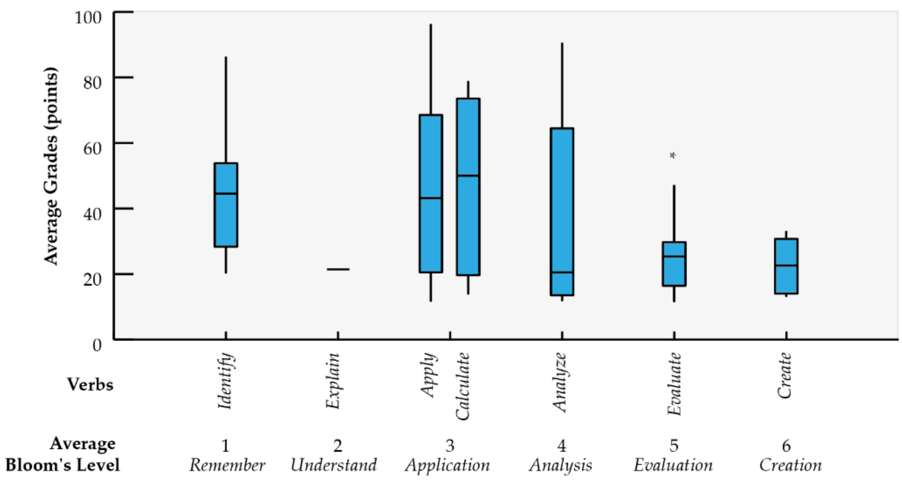


Source: Author's elaboration (2024).

In Figure 2, it's evident that levels 5 and 6 exhibit low dispersion, which can be attributed to the limited number of questions at these levels. Conversely, levels 3 and 4 demonstrate higher dispersion and similar median, suggesting no significant differences in their scores. Furthermore, levels 3 to 6 display a more even distribution of data, with the median situated around the center of the boxplot. In contrast, cognitive level 1 is positioned at the lower end, likely due to the scarcity of data, especially considering that only one exam included questions at this level. In contrast, Figure 3 illustrates the verbs associated with each Bloom level, alongside their correlation with grades. Level 1 predominantly employs the verb "Identify"; level 2, "Explain"; level 3, "Apply" and "Calculate"; level 4, "Analyze"; level 5, "Evaluate"; and level 6, "Create". Level 3 attains the highest grades, particularly with the verb "Apply", possibly due to its calculative nature within the realm of road topics. Conversely, a variety of verbs and Bloom levels yield lower values. Notably, average values are lowest with the verbs "Evaluate" and "Create" at levels 5 and 6, respectively, consistent with previous observations.

Figure 3.

Verbs Associated with Bloom Levels and their Correlation with Grades



Source: Author's elaboration (2024).

3.3. Analysis of Individual Question Performance

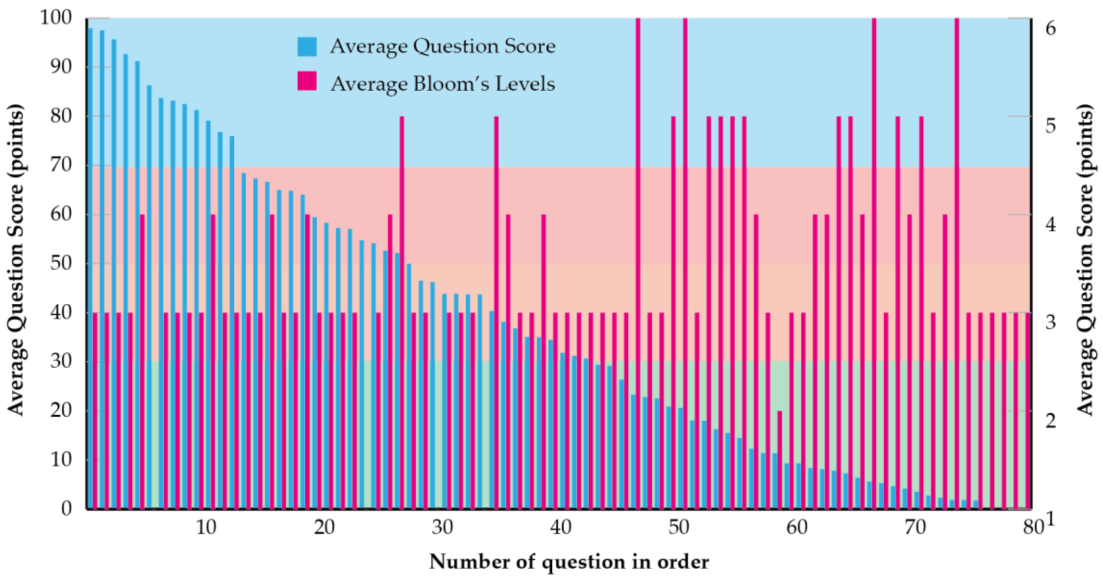
To evaluate individual questions, we constructed Figure 4, which illustrates the relationship between the grades of each question and its Bloom level. Ideally, higher grades would correspond to lower Bloom levels and vice versa. However, this pattern is not consistently observed. Notably, the question with the highest average grade is at Bloom level 3, while the question with the lowest score also falls at level 3. Although a clear direct trend is lacking, the figure indicates that higher Bloom levels tend to be situated towards the right side, which aligns with the expectation that higher levels are more challenging for students.

On another note, when a line is drawn at the 70% threshold—the minimum level required to pass each question—it becomes apparent that most questions, on average, are not passed by students. Only 13 questions (16.25%) out of 80 reached this threshold, which is concerning as it reflects the overall performance of the evaluated student group. In this instance, for the 70% average grade, the Bloom level was 4.2. These 13 questions had an average Bloom level of 3 (min=1, max=4). There were 15 questions (18.75%) falling between 50-70% of the average grade with an average level of 3.2 (min=2, max=5). Questions within the 30-50% grade range were 15 (18.75%) with an average level of 3 (min=1, max=5). Additionally, 37 questions (46.25%) with an average level of 3.94 (min=2, max=6) scored less than 30%. This trend remains consistent, except for the 30-50% range, where higher levels correspond to lower grades.

Furthermore, four questions (5%) were at Bloom level 1, one question (1.25%) at Bloom level 2, 47 questions (58.75%) at level 3, 13 questions (16.25%) at level 4, 11 questions (13.75%) at level 5, and only 4 questions (5%) at level 6.

Figure 4.

Relationship between Grades and Bloom Levels for Individual Questions



Source: Author's elaboration (2024).

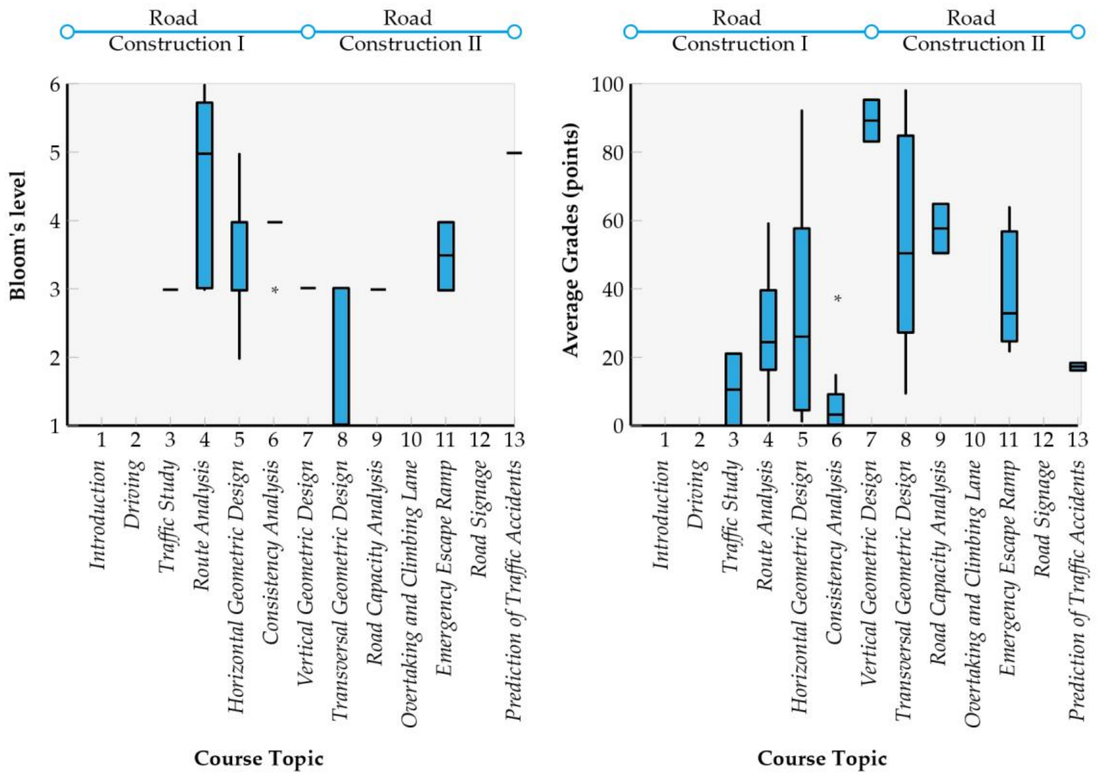
3.4. Evaluation of Exam Topics and Average Grades

To evaluate the topics covered in all the exams, Figure 5 presents a boxplot analysis. Initially, it's observed that topics 1, 2, 10, and 12 were not included in these exams, although this omission does not imply they were not evaluated overall. The plot also highlights that topic 4, focusing on route analysis, is consistently associated with the highest Bloom levels assessed, while topic 8, concerning transversal geometric design, tends to be linked with the lowest Bloom levels.

From Figure 5a, it can be observed that there isn't a clear progression in the exams regarding the different cognitive levels. For instance, Road Construction I start with higher cognitive levels and decreases as the course progresses, while Road Construction II begins with lower cognitive levels and ends with higher ones. It would be interesting to see a progression of knowledge in both courses, such as evaluating all cognitive levels in both courses or assessing levels 1-4 in Road Construction I and levels 3-5 in Road Construction II. This could help develop the competencies required for road engineers across both courses. However, this should be further investigated in subsequent studies.

Figure 5.

Boxplot Analysis of Exam Topics, Average Grade, and Bloom's Level



a) Relationship between Bloom's Level of the Questions and Course Topics.

b) Relationship between Average Grades and Course Topics.

Source: Author's elaboration (2024).

Additionally, Figure 5b displays the boxplot of topics alongside their average grades. Notably, Furthermore, Figure 5b illustrates the boxplot of topics along with their average grades. Remarkably, Road Construction I (topics 1-6) starts with lower averages, gradually increases, and then decreases by week 6. Typically, in a course progressing through Bloom levels, higher grades would be expected initially, with a decline at higher Bloom levels. This trend is apparent in Road Construction II (topics 7-13). However, variations may arise depending on the course's structure and how content is presented to students. Ideally, topic grades would exhibit less dispersion, provided that exams are planned from the outset with Bloom levels in mind.

4. Discussion

The analysis of exam performance in road geometric design and operation courses using Bloom's Taxonomy levels has yielded valuable insights into the cognitive processes underlying student learning in civil engineering. Overall, this study observed that questions with lower Bloom's levels tended to yield higher average grades, while those with higher Bloom's levels resulted in lower average grades. A previous study found that Bloom’s levels did not consistently correlate with student performance (Dymond et al., 2019). In a study across various electrical, electronic, and telecommunications engineering subjects, few results were found in the higher-order learning area of the cognitive level (Jones et al., 2009). It also noted that while these higher-order skills are certainly necessary in an engineering or technology graduate, demonstrating them in an exam can be quite challenging, if only due to the limited time available. Another study in introductory programming courses found that students scored between 61% and 76% for exams across the first to fourth Bloom's levels (Dorodchi et al., 2017). The highest grade was achieved in the course that progressively covered all four cognitive levels.

On the other hand, the Bloom's level range was found to be associated with the Bloom's levels; however, this may be specific to the analyzed data, as removing the most influential assessment eliminates this relationship. This is corroborated by a previous study which found a connection between Bloom's levels and Bloom's level ranges (Dymond et al., 2019). However, another study discovered that designing tests with appropriate challenge levels facilitates students' smooth transition into deeper learning (Dorodchi et al., 2017). This suggests that there is indeed a relationship between Bloom's level range and students' grades. Therefore, there should be a relationship between Bloom's level range and Bloom's levels because if an exam includes questions covering all cognitive levels, it would result in a higher range value, potentially leading to higher grades. However, further investigation is needed to delve into this relationship in future studies.

An in-depth analysis of individual question scores provides valuable insights into the alignment between question difficulty, Bloom's levels, and student performance. Contrary to expectations of higher scores in lower Bloom's levels, this study unveils a nuanced relationship, with some higher-level questions outperforming their lower-level counterparts. This finding is consistent with previous research, which also found no significant correlation between the cognitive level of the question and student grades in a study on a Reinforced Concrete Design Course (Dymond et al., 2019). However, it is suggested that academics focus on designing examination questions that align with the required cognitive skills, acknowledging that there is still room for improvement in this regard (Jones et al., 2009).

The implications of these findings suggest that when analyzing whether the inclusion of certain academic strategies, such as flipped classrooms, enhances students' academic performance, exams should have similar Bloom's levels. This ensures comparability between exams; otherwise, introducing another variable that cannot be controlled may confound the results. Particularly in these subjects, exam assessments should be redesigned based on these findings. This notion finds support in a study that utilized Bloom’s Taxonomy of Learning to standardize engineering courses, promoting comparability among courses and facilitating student mobility (Hoffmann, 2008).

Future studies in this area should delve deeper into the relationship between Bloom's taxonomy levels, Bloom's level range, and student performance in civil engineering education. Specifically, research could focus on designing exams with questions covering all cognitive levels to explore the impact on the overall Bloom's level range and student grades.

Additionally, investigations into the effectiveness of different instructional methods on student performance could benefit from ensuring exams maintain consistent Bloom's levels. Moreover, longitudinal studies tracking students' progress throughout their civil engineering education could provide valuable insights into the long-term effects of instructional approaches and assessment practices. Furthermore, exploring the applicability of Bloom's taxonomy in other engineering disciplines beyond road engineering could expand the understanding of its utility in evaluating student learning outcomes. Overall, future research endeavors should aim to refine teaching and assessment practices in civil engineering education to better prepare students for the challenges of the field and improve their academic and professional success.

While this study provides valuable insights into exam performance in road engineering courses using Bloom's Taxonomy levels, there are several limitations to consider. Firstly, the findings may not be generalizable beyond the specific context of the analyzed data from Universidad Técnica Particular de Loja (UTPL) in Ecuador, potentially limiting the broader applicability of the results. Secondly, the retrospective categorization of exam questions using Bloom's Taxonomy levels may introduce subjectivity and bias, despite efforts to minimize this through the utilization of ChatGPT 3.5. Additionally, the exclusion of unanswered questions from the analysis due to time constraints may impact the comprehensiveness of the dataset and potentially skew the results. Furthermore, the association observed between Bloom's level range and Bloom's levels may be specific to the analyzed data, highlighting the need for caution in extrapolating these findings to other contexts. Finally, while the study offers insights into the alignment between question difficulty, Bloom's levels, and student performance, it does not delve into potential factors influencing this relationship, such as teaching methods or student engagement. Addressing these limitations in future research endeavors would further enhance our understanding of exam performance assessment in civil engineering education.

This study contributes to the ongoing research concerning the use of Bloom's taxonomy in civil engineering courses, particularly those related to road engineering. By employing the taxonomy, educators can gain a deeper understanding of the content and processes they are teaching and assessing, thereby highlighting any discrepancies between the curriculum and assessment methods (Kastberg, 2003). Furthermore, the analysis of the study results enables the identification of trends in student performance and sheds light on the correlation between cognitive levels and grades. Moreover, it offers insights into the effectiveness of teaching and evaluation methods utilized in civil engineering education. Ultimately, this study aims to provide guidance to educators and curriculum developers in improving teaching and assessment practices within civil engineering programs, thereby better equipping students to tackle the challenges of the field and enhancing their academic and professional success.

5. Conclusion

In conclusion, this study offers valuable insights into the relationship between Bloom's Taxonomy levels, exam performance, and cognitive processes in civil engineering education. Our analysis revealed that questions with lower Bloom's levels generally yielded higher average grades, while higher-level questions tended to result in lower grades. This nuanced relationship underscores the importance of carefully aligning exam difficulty with the cognitive skills required for each course. Furthermore, the association between Bloom's level range and student grades highlights the need for comprehensive assessments that cover a spectrum of cognitive levels. Educators should consider these findings when designing exam assessments and implementing instructional strategies to enhance student learning. By fostering a better understanding of the cognitive demands of civil engineering courses, we can improve teaching practices and optimize student success. Additionally, our study underscores the importance of standardizing exam assessments to ensure comparability and facilitate educational research and curriculum development efforts. Ultimately, by leveraging Bloom's Taxonomy as a framework for cognitive analysis, we can enhance the quality of civil engineering education and better prepare students for the challenges of the profession.

6. References

American Society of Civil Engineers (2019). *Civil Engineering Body of Knowledge: Preparing the Future Civil Engineer*. American Society of Civil Engineers. https://doi.org/10.1061/9780784415221

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives*. Longman.

Bloom, B. S. (1956). *Taxonomy of Educational Objectives*. Edwards Brothers.

Chandio, M. T., Pandhiani, S. M., & Iqbal, R. (2016). Article Bloom's Taxonomy: Improving Assessment and Teaching-Learning Process. *Journal of Education and Educational Development*, *3*(2), 203-221. https://files.eric.ed.gov/fulltext/EJ1161460.pdf

Danial, N., & Misnan, M. S. (2023). Leadership issues for road project engineers. *IOP Conference Series: Earth and Environmental Science*, *1274*(1), 1-24. https://doi.org/10.1088/1755-1315/1274/1/012029

DeJong-Okamoto, N., Rhee, J., & Mourtos, N. (2005). Incorporating the Impact of Engineering Solutions on Society into Technical Engineering Courses. *Global Journal of Engineering Education*, *9*(1), 77-87. https://scholarworks.sjsu.edu/aero_eng_pub/2/

Dorodchi, M., Dehbozorgi, N., & Frevert, T. K. (2017). "I wish I could rank my exam's challenge level!": An Algorithm of Bloom's Taxonomy in teaching CS1. *Proceedings - Frontiers in Education Conference, FIE, 2017-October, 1–5*. https://doi.org/10.1109/FIE.2017.8190523

Dymond, B. Z., Swenty, M., & Carroll, J. C. (2019). Comparing Exam Performance in a Reinforced Concrete Design Course with Bloom's Taxonomy Levels. *Journal of Civil Engineering Education*, *146*(1). https://doi.org/10.1061/(ASCE)EI.2643-9115.0000002

Gerek, I. H., & Efeoglu, I. E. (2015). What qualifications and skills are important for civil engineers? A job advertisement analysis. *MakeLearn & TIIM 2015 Joint International Conference*, 689-695. http://www.secretcv.com

Hoffmann, M. H. W. (2008). Using Bloom's taxonomy of learning to make engineering courses comparable. *19th EAEEIE (European Association for Education in Electrical and Information Engineering) Annual Conference - Formal Proceedings*, 205-209. https://doi.org/10.1109/EAEEIE.2008.4610187

Jones, K. O., Harland, J., Reid, J. M. V., & Bartlett, R. (2009). Relationship between examination questions and Bloom's taxonomy. *Proceedings - Frontiers in Education Conference, FIE*. https://doi.org/10.1109/FIE.2009.5350598

Kastberg, S. E. (2003). Using Bloom's taxonomy as a framework for classroom assessment. *The Mathematics Teacher*, *96*(6), 402-405. https://bit.ly/4ctOSom

Litzinger, T. A. (2000). An integrated approach to developing professional and technical skills in engineering undergraduates. *ASEE Annual Conference Proceedings*, 859-870. https://doi.org/10.18260/1-2--8468

Ogunwolu, L., Ajibola, E. O., & Sosimi, A. (2018). An approach for critical evaluation of examination questions in an engineering faculty using the classical bloom taxonomy. *Nigerian Journal of Technology*, *37*(4), 1065-1075. https://doi.org/10.4314/NJT.V37I4.28

OpenAI. (2023). ChatGPT (versión de abril) [Modelo de lenguaje de gran tamaño]. https://chat.openai.com/

O'Sullivan, A., & Cochrane, T. (2009). Preparing better engineers: Compulsory undergraduate research projects that benefit universities and the profession. *ASEE Annual Conference and Exposition, Conference Proceedings, 14.973.1-14.973.12*. https://doi.org/10.18260/1-2--4746

Pritchard, M. S. (2019). Safety, security, and serviceability in road engineering. *Accident Analysis & Prevention*, 127, 172–176. https://doi.org/10.1016/J.AAP.2019.02.026

State College. (2005). Minitab 14.2 Statistical Software [Computer program] (14.2). PA: Minitab, Inc. www.minitab.com

AUTHOR CONTRIBUTIONS, FUNDING, AND ACKNOWLEDGMENTS

Funding: This research did not receive any external funding.

Acknowledgments: The author extends their gratitude to the Universidad Técnica Particular de Loja for their support to this text, which forms an integral component of the teaching innovation project titled "Reto STEM: Innovación en el Diseño Geométrico de Carreteras"

Conflict of interest: The author declares no conflict of interest.

AUTHOR:

Yasmany García-Ramírez:
Universidad Técnica Particular de Loja.

Yasmany García-Ramírez is a Civil Engineer (UTPL, Ecuador, 2006), specialized in Mountain Roads (UNSJ, Argentina, 2009), and holds a Ph.D. in Civil Engineering (UNSJ, 2014). He is an associate professor at UTPL, where he teaches undergraduate and graduate courses in geometric road design. Currently, he leads a master's program in Civil Engineering with an emphasis on mountain roads. He has around 40 publications, including books, journals, and conference proceedings related to roads and civil engineering education.

ydgarcia1@utpl.edu.ec

Índice H: 9
Orcid ID: https://orcid.org/0000-0002-0250-5155
Scopus ID: https://www.scopus.com/authid/detail.uri?authorId=57211524440
Google Scholar: https://scholar.google.com/citations?user=kBY8DVsAAAAJ&hl=es
ResearchGate: https://www.researchgate.net/profile/Yasmany-Garcia-Ramirez