LEVEL'S OF STUDENT'S KNOWLEDGE ACCORDING TO BLOOM'S TAXONOMY ON THE TOPICS OF GRAVITY AND COSMOLOGY IN UPPER SECONDARY SCHOOLS

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Abstract

This study investigates upper secondary school students' conceptual and procedural knowledge in gravitation and cosmology within the framework of Bloom's Taxonomy, encompassing the cognitive domains from remembering to evaluating, in alignment with curriculum standards and competency-based learning outcomes. The study aims to elucidate how the abstract and conceptually demanding nature of these physics domains shapes the development of higher-order thinking skills and scientific literacy. The research addresses cognitive performance across Bloom's levels, comparative understanding between gravitation and cosmology concepts, and persistent conceptual misconceptions in physics education. A mixed-methods research design was implemented, involving 100 students and 4 physics teachers from two secondary schools in Klinë. Data were collected through validated instruments, semi-structured interviews, and qualitative analysis of student-produced artifacts derived from simulations and presentations. Findings indicate alignment with Bloom's Taxonomy, with a predominance of higher-order cognitive processes, particularly analysis and evaluation. The results further indicate that students' performance is significantly influenced by prior knowledge, pedagogical strategies, textbook quality, and the integration of digital learning technologies.

Keywords: Bloom's Taxonomy, conceptual and procedural knowledge, gravitation, cosmology, conceptual misconceptions, physics education.

Introduction

Physics is a fundamental discipline of the natural sciences that studies matter, energy, space, and time as well as their interactions, providing the conceptual foundation for both natural sciences and engineering. In the contemporary curriculum, it is approached through the scientific method as an integrated process that includes empirical observation, hypothesis formulation, controlled experimentation, and data analysis, with the aim of constructing scientific models and laws. Within this framework, physics education aims at developing students' scientific competencies through the integration of experimental experience with conceptual knowledge construction. According to the National Research Council, effective learning is built upon linking prior knowledge with empirical evidence, enabling the development of stable and transferable understandings. In line with this approach, the contemporary curriculum directs the learning process toward the development of critical thinking, scientific reasoning, and problem-solving as key competencies of the 21st century. In modern physics, gravitation is conceptualized in classical mechanics as a universal attractive force between masses, whereas in general relativity it is understood as the curvature of spacetime caused by mass and energy, forming the basis for interpreting cosmological phenomena on a universal scale. Bloom's Taxonomy represents a hierarchical framework for classifying cognitive levels, ranging from remembering and understanding to analyzing, synthesizing and evaluating, and this is widely used in educational planning and assessment. In this study, it serves as an analytical instrument for assessing students' cognitive levels in the topics of gravitation and cosmology, while considering didactic factors such as teaching strategies and prior knowledge. Despite the theoretical importance of these domains, previous studies indicate persistent difficulties in students' conceptual understanding of gravitation and cosmology, particularly regarding abstract representations and the transition from classical to relativistic models, highlighting a gap in effective instructional approaches. Methodologically, this study employs a mixed-methods research design, combining quantitative data from validated assessment instruments with qualitative insights derived from semi-structured interviews and analysis of student-produced artifacts, ensuring a comprehensive evaluation of cognitive performance and conceptual understanding. This research aims to contribute to the improvement of physics teaching practices by providing an empirical basis for optimizing didactic approaches in alignment with contemporary curriculum requirements. In particular, the findings are expected to inform teacher training, enhance instructional strategies, and support the development of improved curricular and textbook materials in the domains of gravitation and cosmology.

Literature Review

Contemporary learning theories have shifted from behaviorist toward constructivist and socio-cognitive perspectives, emphasizing knowledge construction rather than reproduction. Bransford, Brown, and Cocking argue that meaningful learning occurs through integration of new information with prior knowledge structures, enabling transfer across contexts (Bransford, J .D., Brown, A. L., & Cocking, R. R., 2000). Illeris extends this view by conceptualizing learning as a multidimensional process involving cognitive, emotional, and social dimensions (Illeris, 2018). In this framework, Bloom’s taxonomy provides a structured hierarchy of cognitive processes from lower- to higher-order thinking, alongside a classification of knowledge types (factual, conceptual, procedural, metacognitive). From a socio-constructivist perspective, Vygotsky emphasizes socially mediated learning within the Zone of Proximal Development (Vygotsky, 1978), while Bandura highlights observational learning as a mechanism linking cognition and environment (Bandura, 1986). In physics education, research consistently shows that learning is more effective when based on conceptual modelling rather than memorization. McDermott and Redish emphasize mental models, conceptual reasoning, and misconceptions analysis as key components of effective physics learning (McDermott, L. C., & Redish, E. F., 1999). Hestenes further supports a model-based instructional approach. A common misconception in gravitation is the belief that heavier objects fall faster than lighter ones, despite the fact that their acceleration is independent of mass in the absence of air resistance. In modern physics, gravitation is interpreted as a transition from Newtonian force-based description to Einstein’s geometric spacetime framework. At the cosmological scale, Weinberg and Mukhanov provide theoretical foundations for cosmic expansion and structure formation. Within science education frameworks such as PISA (OECD, 2019), scientific literacy is defined not as recall of knowledge, but as the ability to interpret, analyze, and apply scientific concepts in real-world contexts. These theoretical perspectives provide the foundation for the present study’s analysis of students’ conceptual development in gravitation and cosmology.

Methodology

This study is based on Bloom’s Taxonomy as a framework for analyzing the teaching and learning of gravitation and cosmology concepts in upper secondary physics education. A mixed-methods research design was employed, integrating quantitative and qualitative approaches to provide a comprehensive evaluation of students’ cognitive achievement and conceptual understanding. The research was conducted in the gymnasium “Luigj Gurakuqi” and IAAP “Fehmi Agani” in Klina, involving 100 students and 4 physics teachers. The student sample included learners from grade XI and XII, comprising both female and male participants. In “Luigj Gurakuqi” Gymnasium, the sample consisted of 22 male and 28 female students (ages 16-17) corresponding to 45% male and 55% female participants. In IAAP “Fehmi Agani”

Technical Upper Secondary School, the sample included 30 male and 20 female students (ages 16-17), corresponding to 60% male and 40% female participants. Students were selected through random sampling to ensure equal representation within the study group. Data were collected using multiple instruments, including structured tests, student questionnaires, semi-structured teacher interviews, and analysis of student-produced artefacts generated through simulations and classroom presentations. All instruments were aligned with the national curriculum and structured according to Bloom’s Taxonomy, and were reviewed for content validity prior to use. Findings were organized using tables and graphs to support systematic comparison and interpretation of results. The study examined students’ cognitive performance across Bloom’s levels, variations in understanding gravitation and cosmology concepts, and key factors influencing learning outcomes, including prior knowledge, instructional approaches, textbook quality, and the use of digital technologies in physics education. Quantitative data were analysed using descriptive statistics, including means and frequencies, while qualitative data were coded thematically to identify recurring patterns in understanding and misconceptions. The research addresses persistent difficulties in students’ understanding of abstract concepts in gravitation and cosmology, particularly gravitational interactions, relativistic frameworks, cosmic expansion, dark matter, and dark energy.
The main aim of the study is to evaluate students’ cognitive achievement according to Bloom’s Taxonomy and to examine the role of interactive teaching strategies and digital simulations in enhancing conceptual understanding and scientific reasoning. Ethical approval and informed consent from participants and guardians were obtained prior to data collection.

Results and discussion

The demographic characteristics of research sample, including age, gender, and percentage distribution for each Upper Secondary Schools, are summarized in the following tables. Data are presented separately for “Luigj Gurakuqi” and IAAP “Fehmi Agani” whereas combined graphs are used only when student responses were identical or showed minimal statistical variation. This approach enables clearer interpretation and comparison of students’ cognitive achievement in gravitation and cosmology.

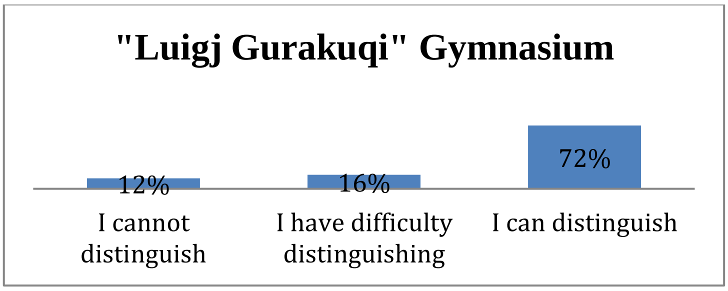

Figure 1. Percentage of students’ ability to distinguish between mass and weight at “Luigj Gurakuqi” Gymnasium

Most student 72% can distinguish between mass and weight, 8% report difficulties , while 6% are unable to make the distinction.

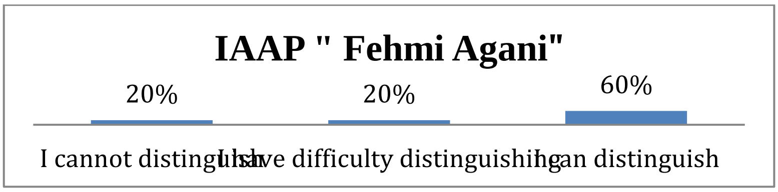

Figure 2. Percentage of students’ ability to distinguish between mass and weight at IAAP “Fehmi Agani”

60% of students can distinguish between mass and weight, 10% report difficulties, and 10% are unable to make the distinction.

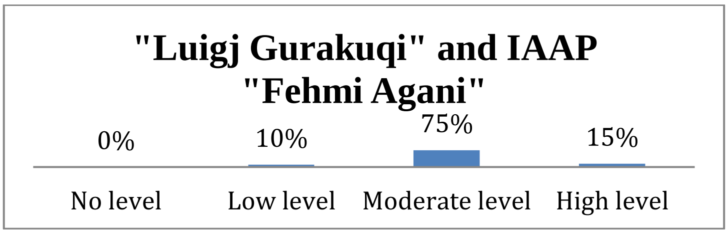

Figure 3. Level of students 'ability to reproduce the universal law of gravitation without textbook assistance

75% of students can reproduce the concept and mathematical formulation without textbook support, 15% show high level, and a 10% a low level.

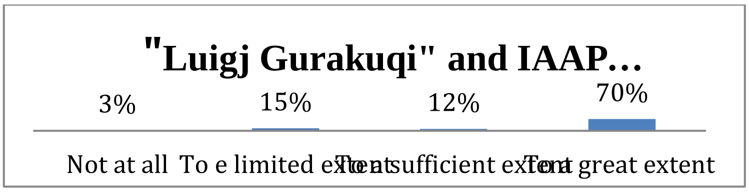

Figure 4. Student' understanding of the attraction of bodies toward Earth's center of mass under the action of gravitational field.

Among the 100 students, 70% reported a very good understanding of the phenomenon, 12% good, 15% sufficient, and 3% no understanding.

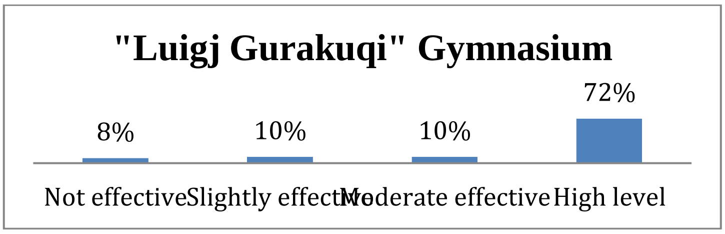

Figure 5. Students' ability to transfer theoretical principles of gravitation to new problem situations.

72% of students' report of being highly effective in applying gravitational principles to new problem situations, 10% moderate, 10% low, 8% are unable to perform this transfer successfully.

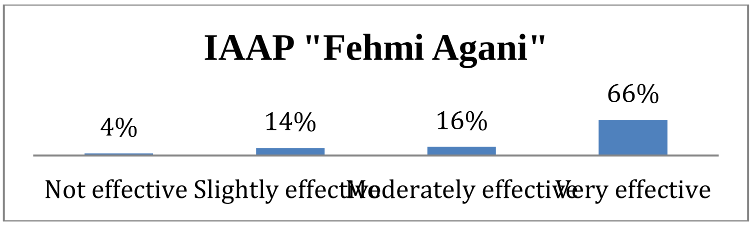

Figure 6. Students' ability to transfer theoretical principles of gravitation to new problem situations.

66% of students from technical track report high effectiveness in applying gravitational principles to new problem situations, 16% moderate, 14% slightly effective, and 4% are unable to perform this transfer successfully.

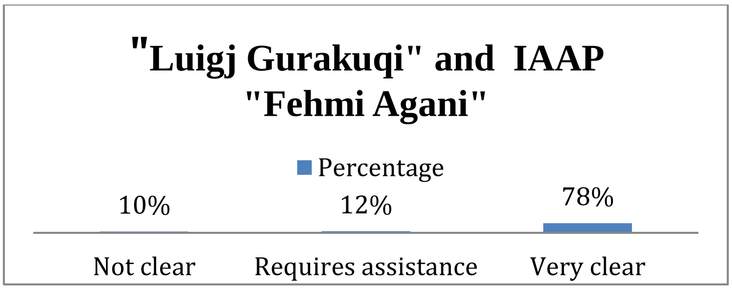

Figure 7. Students' understanding and analysis of how mass and distance influence gravitational force between two objects.

According to the figure 78% of students clearly analyze the effect of mass and distance on gravitational force between two bodies, 12% require assistance, and 10% do not understand the relationship.

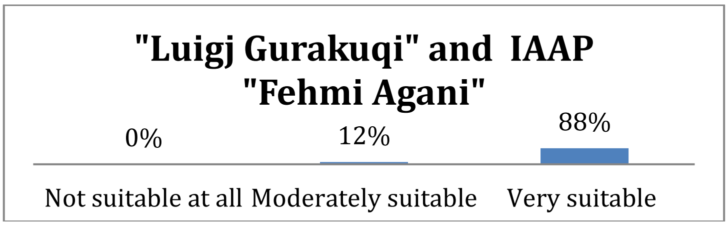

Figure 8. Students' evaluation of the suitability teaching methods for facilitating understanding of gravitation and cosmology concepts.

88% of students consider the teaching methods (simulations, examples, discussions) highly appropriate, while 12% rate the as moderately appropriate.

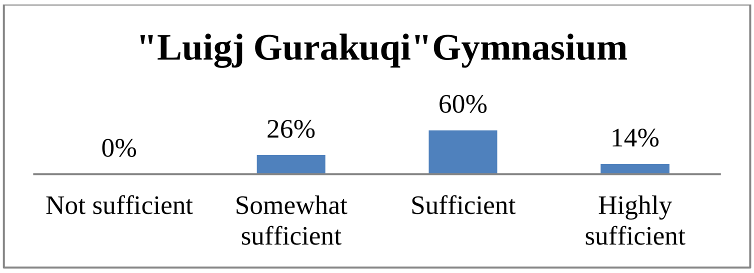

Figure 9. Students' evaluation of textbook clarity and sufficiency for understanding modern theories on the origin of the Universe.

60% of students consider the textbook content sufficiently clear for understanding modern theories on the origin of Universe, 14% find it very clear and adequate, while 26% report that it provides limited information.

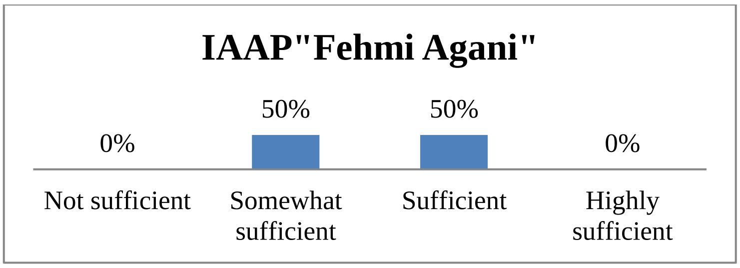

Figure 10. Students' evaluation of textbook clarity and sufficiency for understanding modern theories on the origin of the Universe.

50% of students find the textbook sufficiently clear, while 50% consider it provides limited information.

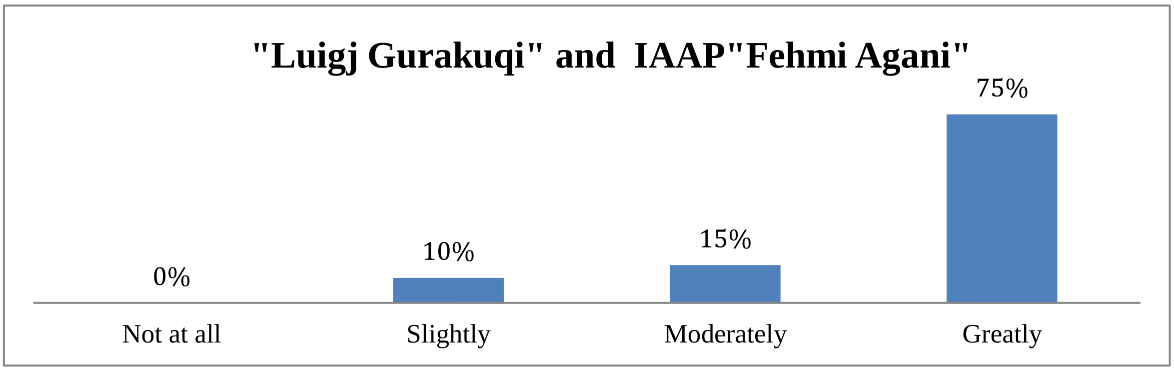

Figure 11. Active teaching methods and conceptual understanding of gravity

75% of students state that active teaching methods greatly support the shift from memorization to conceptual understanding of the law of gravitation, 15% report a moderate effect, and a 10% a low effect.

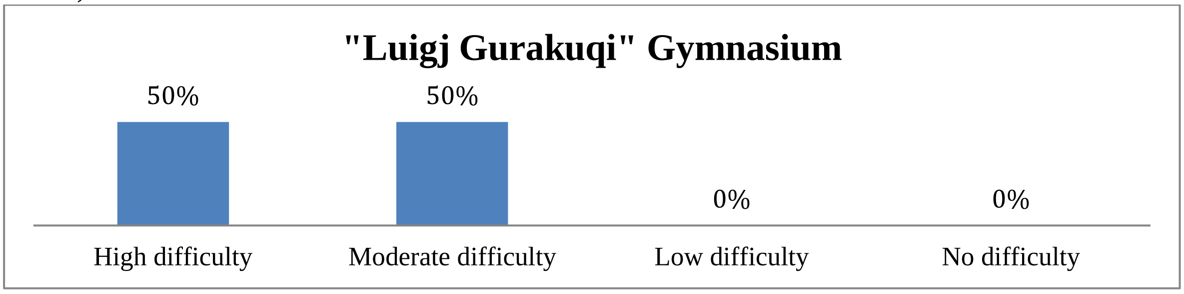

Figure 12.Students' difficulty in visualizing abstract concepts such as space time curvature

60% report moderate difficulties, 20% low, and 20% high difficulties in visualizing and understanding these concepts.

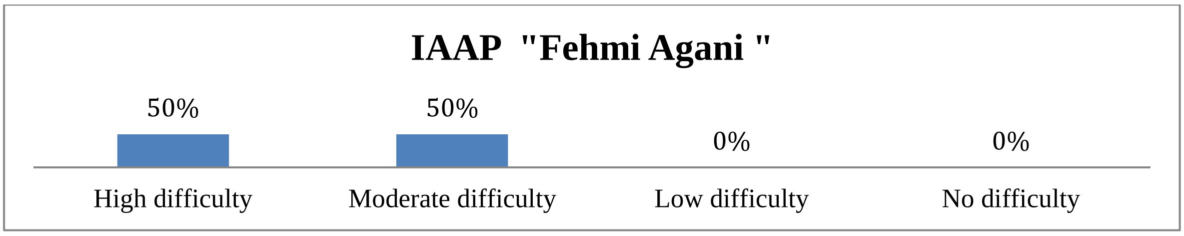

Figure 13. Students' difficulty in visualizing abstract concepts such as space time curvature

50% report moderate and 50% high difficulties, indicating a significant learning challenge requiring improved teaching approach

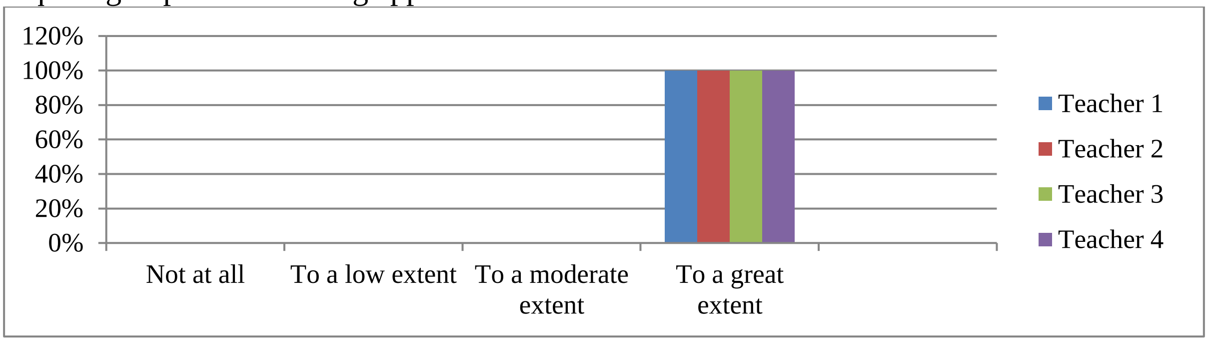

Figure 14. Assessment of the impact of simulations and virtual laboratories

All teachers 100% strongly agree that simulations and virtual laboratories enhance the visualization of abstract phenomena such as space time curvature.

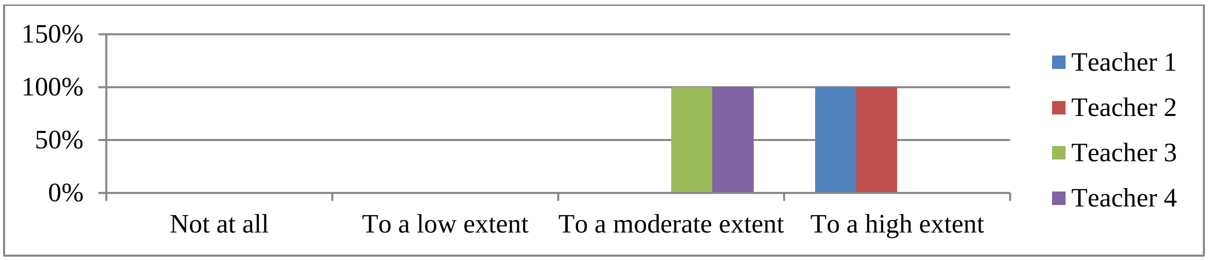

Figure 15. Application of gravitational knowledge in real-life and astrophysical contexts

Teachers at “Luigj Gurakuqi” rate this ability higher, while those at “Fehmi Agani” at a moderate level, both results indicate a positive level of application of gravitational knowledge.

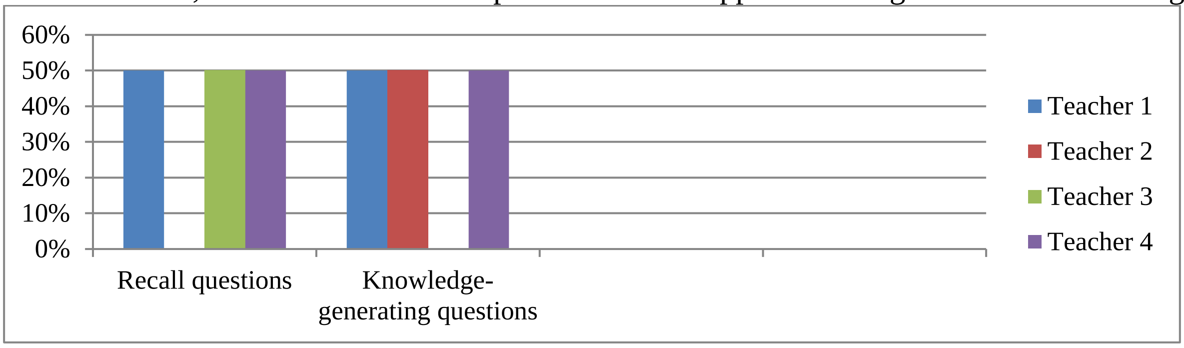

Figure 16. Types of questions for assessing and generating students’ knowledge

Two teachers use both types, while two use one type depending on students’ needs.
The comparative summary synthesizes the main findings across all indicators, highlighting major similarities and differences between the two schools.
Students from “Luigj Gurakuqi” Gymnasium exhibit slightly higher performance in conceptual understanding and knowledge transfer (72%vs 60%), particularly in distinguishing mass and weight and applying gravitational principles to novel problem situations. Both institutions show strong understanding of core concepts, including the universal law of gravitation (75%) and gravitational field interpretation (70%), indicating a solid shared foundation knowledge. Active teaching methods are highly valued in both institutions (88%), while teachers confirm the effectiveness of digital simulations (100%). However, differences are more evident in abstract reasoning and visualization of complex concepts, where students from IAAP “Fehmi Agani” Technical Upper Secondary School report higher levels of difficulty (up to 50%), suggesting a need for enhanced conceptual and visual support. These variations reflect differences in instructional approaches, curricular emphasis, prior conceptual preparation, and exposure to active learning and visualization-based strategies, which may influence students’ ability to construct abstract scientific concepts and transfer knowledge to novel problem solving situations.

Conclusion

Findings of this study indicate generally high levels of students’ conceptual understanding of gravitation and cosmology, with strong performance in fundamental concepts and effective application of knowledge in most cases. Active teaching methodologies and digital simulations were identified as highly effective in supporting conceptual learning and visualization of abstract phenomena, while textbooks were considered moderately sufficient depending on context. However, persistent difficulties were observed in understanding highly abstract concepts, highlighting the need for further didactic support. Overall, the results confirm all research hypotheses, demonstrating that Bloom's Taxonomy-based analysis, combined with interactive teaching strategies, significantly enhances students' cognitive achievement and conceptual development in physics education

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