Physics Curricular Complexity and Enrollment Barriers Analysis

Ahl G. Balitaon, University of the Philippines Los Baños, Philippines

The Asian Conference on Education & International Development 2026
Official Conference Proceedings

Abstract

The critical low enrollment in the Bachelor of Science in Mathematics and Science Teaching (BS-MST) Physics major at the University of the Philippines Los Baños (UPLB) is frequently attributed to student perception without objective analysis of the program's structure. Physics presents intrinsic academic difficulties, characterized by abstract concepts and heavy reliance on advanced mathematics, contributing to high student anxiety. This study addresses the core question: To what extent do structural and sequential differences between the four BS-MST majors create inherent barriers for the Physics track? Employing a comparative structural analysis based on Curricular Analytics, this research models the curriculum structure as a network to quantify structural complexity using the metrics for delay and blocking factors. The framework assumes that high structural complexity is inversely related to student completion rates. Findings indicate that while the overall unit load is uniform, the Physics major exhibits significantly higher sequential rigidity and sever failure penalty. The core PHYS 71/72 sequence acts as a high blocking factor for multiple downstream specialized courses, imposing maximal constraint and minimal recovery capacity, thereby amplifying academic risk. This structural disadvantage validates student anxieties and functions as an objective disincentive. The study concludes that reducing critical prerequisite dependencies is essential for mitigating this complexity and improving enrollment. This calls for careful curriculum design to curtail overload and enhance implementation.

Keywords: curriculum, analytics, physics

Introduction

The progress of society significantly relies on Science, Technology, Engineering, and Mathematics (STEM) disciplines, yet many specialized programs struggle with attrition and low enrollment (De Jong & Campoli, 2018; Diate & Mordeno, 2021). Enrollment in highly specialized programs, such as the Bachelor of Science in Mathematics and Science Teaching (BS-MST) major in Physics at the University of the Philippines Los Baños (UPLB), faces critical and chronic challenges. While low recruitment is often ascribed to subjective student anxieties about the difficulty of physics, this study posits that the curriculum structure itself may constitute an objective source of disincentive (Hazari et al., 2010; Irene, 2023).

A curriculum designed with excessive structural complexity can directly hinder student progression, thereby increasing the risk of delayed graduation or students choosing to opt out entirely (Heileman et al., 2018; Lin et al., 2025; Orleans, 2007). The primary purpose of this research is to investigate the extent to which structural and sequential differences between the four BS-MST majors (Biology, Chemistry, Mathematics, and Physics) create inherent barriers or disincentives for prospective students. By shifting the focus from student "deficits" to institutional "scaffolds," this analysis seeks to provide a data-driven foundation for curricular optimization.

Literature Review

STEM Persistence and Gatekeeper Courses

Global efforts to bolster the STEM workforce often face challenges related to student attrition and low completion rates. Foundational subjects, commonly termed "gatekeeper" courses (e.g., general chemistry or introductory physics), are often responsible for high attrition rates and increased time to graduation for inadequately prepared students. Negative experiences or poor academic performance in these foundational courses are recognized factors contributing to students leaving STEM pathways (De Jong & Campoli, 2018; Diate & Mordeno, 2021).

Physics is frequently regarded as difficult due to its abstract concepts, reliance on advanced mathematics, and demand for strong problem-solving skills. This intrinsic difficulty often leads to high student anxiety, which is negatively correlated with academic performance (Irene, 2023). For Filipino students, challenges in physics are compounded by issues like unmastered prerequisite skills in literacy and numeracy and a lack of necessary physical facilities or laboratory equipment in schools (Hermoso, 2025; Irene, 2023).

Physics Identity and Career Choice

A student's decision to pursue a field like physics is strongly linked to their "physics identity," a construct influenced by their perceived performance, competence, recognition by others, and interest in the field. High school experiences emphasizing conceptual understanding and real-world/contextual connections positively predict the development of this identity. Conversely, physics careers are often perceived as demanding substantial personal time and lacking opportunities for working with people, resulting in career outcome expectations that can be negatively related to developing a strong physics identity (De Jong & Campoli, 2018).

Curricular Structure and Complexity

Beyond individual experiences, the intrinsic architecture of an academic program significantly influences a student's ability to successfully navigate to graduation. Curricular Analytics treats the curriculum as a complex system and systematically analyzes how structural properties impact student progression.

Structural complexity is quantified by mapping the curriculum as a directed graph where courses are vertices, and prerequisite relationships are defined by edges. Two critical structural factors derived from this model directly predict student risk:

Delay Factor

Measures the length of the longest prerequisite pathway passing through a course, establishing a lower bound on the minimum number of terms required for completion.

Blocking Factor

Quantifies the number of downstream courses for which a single course acts as a prerequisite. A high blocking factor identifies critical gateway courses where failure generates a catastrophic "failure penalty," blocking a large portion of the subsequent curriculum (Heileman et al., 2018).

Curricular Overload and Implementation

A persistent challenge is curriculum overload, which occurs when obsolete content is retained alongside new requirements, increasing the cognitive burden on students (Chen et al., 2023; Chen et al., 2025). Successful curriculum implementation also relies on teacher acceptance, which is mediated by their perceived ease of understanding and integration of the curriculum (Chen et al., 2023; Li et al., 2025; Mâţă and Suciu, 2011). In the Philippine context, teachers face challenges such as inadequate training, heavy workloads, and limited resources, which can hinder the implementation of supportive learning environments (Hermoso, 2025; Irene, 2023).

Methodology

This study utilized a comparative document analysis of the official 2018 BS-MST curricula for the Biology, Chemistry, Mathematics, and Physics majors at UPLB (UPLB, 2018). The methodology focused on three specific stages:

Quantitative Metrics Comparison

The first stage involved extracting and comparing key metrics across the four tracks, including total unit loads, major-specific units, required mathematics units, and general education electives (Basu et al., 2025; UPLB, 2018). This established whether the programs maintained quantitative parity in terms of overall student workload.

Sequential and Structural Network Mapping

Using the official curriculum flowcharts, the study mapped the prerequisite chains for each major as directed acyclic graphs (UPLB, 2018). This step identified courses with high intrinsic structural constraints and characterized the "path hierarchy" of each major (Heileman et al., 2018).

Quantification of Structural Constraints

Specific structural barriers were computed based on the principles of Curricular Analytics. This included calculating the delay factor for the core pedagogical sequence and the blocking factor for the foundational science sequences. The "failure penalty" was quantified by measuring the number of units and semesters a student would be delayed following a non-passing grade in a critical gateway course (Heileman et al., 2018).

Results

Comparative Quantitative Metrics

The review of the required academic workload showed uniformity across the majors, suggesting that total unit burden is not the primary source of structural differentiation. The Biology major requires 141 units, Chemistry and Physics require 140 units, and Mathematics requires 142 units. All curricula share the same foundational calculus sequence (MATH 25, MATH 27, AMAT 19) and core introductory science classes in the first year.

Common Structural Baseline: The MST Chain

All four majors are anchored by a linear seven-semester sequence of Education and MST courses. This sequence establishes a high baseline delay factor for every student in the program.

Linear Chain

MST 101a → 101b → 101c → 101d → MST 123 → MST 200a → MST 200b

Computation

For MST 101a, the delay factor is 7 (vertices on the path) and the blocking factor is 6 (subsequent reachable courses), resulting in a course "cruciality" score of 13. This establishes that the MST pedagogical sequence alone requires a minimum of seven academic terms to complete.

The Physics Major as a Structural Outlier

The primary structural differences emerge in the subsequent sequencing of major-specific courses. The Physics major introduces a highly constrained, linear pathway starting in the second year, contributing significantly to its structural complexity.

Accelerated Sequence

The Physics major mandates the completion of the 10-unit PHYS 71/72 sequence by the end of the second year. In contrast, tracks like Biology and Mathematics often defer PHYS 72 until the third or even fourth year, significantly lowering its structural impact.

High Blocking Factor in Physics

Successful completion of PHYS 72 & 72.1 is the sole prerequisite for three critical specialized courses in the third year: APHY 101 (3 units), APHY 102 (3 units), and PHYS 192.1 (2 units).

The Failure Penalty

A single failure in PHYS 71 in the first semester of the second year creates a massive roadblock. It blocks PHYS 72, which in turn blocks 8 units of specialized major work in the third year, effectively delaying graduation by one full academic year.

Discussion

The analysis confirms that the BS-MST Physics major is structurally disadvantaged, as its curriculum is structured in a way that maximizes academic risk. This rigidity transforms the inherent difficulty of the program into an existential threat to timely graduation.

Rigidity and Recovery Capacity

The strictly linear nature of the Physics track represents an “anti-pattern” of high complexity. While students in other tracks have parallel sequences that allow them to continue major-specific work even if they fail a foundational science course, the Physics major offers the lowest “degrees-of-freedom” for academic recovery. This structure institutionalizes student anxiety by ensuring that the consequences of a single non-passing grade are catastrophic (Irene, 2023).

Implications for Curricular Reform

Curriculum development efforts should aim to move from “gatekeeping” to “scaffolding” (Sampson et al., 2024). Strategies to reduce the blocking factor of critical courses like PHYS 72 include:

Curricular Deconstruction

Using the Ebel framework to separate “need to know” foundational concepts from “nice to know” content, allowing specific required modules to be integrated concurrently into specialized courses rather than acting as strict roadblocks (Chen et al., 2023; Hazari et al., 2010).

Converting Prerequisites to Co-requisites

Redesigning the curriculum map to allow specialized Applied Physics courses to be taken concurrently with foundational sequences, drastically increasing degrees of freedom and preventing a one-year stall for minor setbacks (Crişan and Enache, 2015; Hazari et al., 2010; So et al., 2024).

Instructional Scaffolding

Implementing active learning models, such as inquiry-based learning and digital simulations, to lower the cognitive barrier and reduce failure rates in high-blocking gateway courses (Irene, 2023; Sastre-Vazquez et al., 2013).

Conclusion

This comparative analysis confirms that structural and sequential differences create inherent barriers for students considering the BS-MST Physics track. While total units are comparable across all majors, the Physics major suffers from significantly higher sequential rigidity and a disproportionately severe failure penalty. The program's reliance on linear prerequisite chains acts as a structural filter that discourages enrollment and amplifies the inherent difficulty of the subject.

To fix enrollment, the institution must “fix the graph” by reducing structural complexity and increasing recovery capacity. Restructuring the curriculum to allow for parallel pathways and modular integration of foundational concepts is essential for securing the future of the physics education pipeline.

Acknowledgement

The author gratefully acknowledges the Institute of Physics and the Math and Science Teaching Program under the College of Arts and Sciences, UPLB, for their administrative and technical support. Furthermore, this participation was made possible through the financial support of the Academic Development Fund’s Oral Presentation in National or International Conferences (OPNIC) Grant from the Office of the Vice Chancellor for Academic Affairs, UPLB. Finally, the author expresses his deepest love and gratitude to his wife, son, and family for their unwavering support and inspiration.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that Grammarly, an AI-assisted writing software, was used in proofreading and refining the language used in the manuscript. The usage was limited to correcting grammatical and spelling errors and rephrasing statements for accuracy and clarity. The author further declares that, apart from Grammarly, no other AI or AI-assisted technologies have been used to generate content in writing the manuscript. The ideas, design, procedures, findings, analyses, and discussion are originally written and derived from careful and systematic conduct of the research.

References

Basu, P., Malik, D. J., & Graunke, S. (2025). A 24-year longitudinal study on a STEM gateway general chemistry course and the reduction of achievement disparities. *PLoS ONE*, *20*(2), e0318882. https://doi.org/10.1371/journal.pone.0318882

Chen, A. M. H., Brown, S., Mark, K., & McBane, S. (2023). An overview of instructional approaches and decision-making strategies to curtail curricular overload. *American Journal of Pharmaceutical Education*, *87*(1), 100013. https://doi.org/10.1016/j.ajpe.2022.12.001

Chen, A. M. H., Thornby, K., & Law, A. V. (2025). Curricular assessment blueprint and needs analysis for the social, administrative, and behavioral foundational sciences. *American Journal of Pharmaceutical Education*, *89*(1), 101346. https://doi.org/10.1016/j.ajpe.2024.101346

Crişan, A., & Enache, R. (2015). Increasing curricular quality at the adult training programs level. A possible approach. *Procedia - Social and Behavioral Sciences*, *203*, 180–185.

De Jong, D., & Campoli, A. (2018). Curricular coaches' impact on retention for early-career elementary teachers in the USA: Implications for urban schools. *International Journal of Mentoring and Coaching in Education*. https://doi.org/10.1108/IJMCE-09-2017-0064

Diate, K., & Mordeno, I. C. V. (2021). Filipino physics teachers' teaching challenges and perception of essential skills for a supportive learning environment. *Asia Research Network Journal of Education*, *1*(2), 61–76.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978–1003. https://doi.org/10.1002/tea.20363

Heileman, G., Abdallah, C., Slim, A., & Hickman, M. (2018). Curricular Analytics: A Framework for Quantifying the Impact of Curricular Reforms and Pedagogical Innovations. *arXiv preprint arXiv:1811.09676*. https://doi.org/10.48550/arXiv.1811.09676

Hermoso, J. S. (2025). Strategies and challenges in teaching physics: The anxiety levels and academic performance of physics learners. *AIDE Interdisciplinary Research Journal*, *12*, 832–942.

Irene, E. A. (2023). Evaluation of teacher education curricula and its relevance to licensure examination using Context, Input, Process and Product (CIPP) model. *Social Sciences & Humanities Open*, *8*(1), 100607. https://doi.org/10.1016/j.ssaho.2023.100607

Li, P.-A., Liou, C.-H., Tai, W.-H., Yu, I.-C., Tsai, G.-T., & Chen, Y.-S. (2025). Constructing pedagogical identity through experiential curriculum: A grounded theory study of facilitators in outdoor education. *International Journal of Educational Research*, *134*, 102857. https://doi.org/10.1016/j.ijer.2025.102857

Lin, M.-Y., Hong, J.-C., Chin, T.-J., & Chen, N. (2025). The influence of preschool teachers' critical thinking attitude on their perceived ease of understanding and integrating, and attitude toward implementation of a new curriculum. *Thinking Skills and Creativity*, *57*, 101868. https://doi.org/10.1016/j.tsc.2025.101868

Mâţă, L., & Suciu, A. I. (2011). The curricular innovative model focused on developing pedagogical competences of teachers of Language and communication. *Procedia Social and Behavioral Sciences*, *12*, 274–282.

Orleans, A. V. (2007). The condition of secondary school physics education in the Philippines: Recent developments and remaining challenges for substantive improvements. *The Australian Educational Researcher*, *34*(1), 33–54.

Sampson, S., Nelson, A., Cardarelli, R., & Roper, K. L. (2024). Ensuring the "health" of a curricular program evaluation: Alignment and analytic quality of two instruments for use in evaluating the effectiveness of an interprofessional collaboration curriculum. *Evaluation and Program Planning*, *102*(1), 102377. https://doi.org/10.1016/j.evalprogplan.2023.102377

Sastre-Vazquez, P., D'Andrea, R., Villacampa, Y., & Navarro-Gonzalez, F. J. (2013). The curricular value of mathematics in non-mathematics degree. *Procedia - Social and Behavioral Sciences*, *93*, 1663–1667.

So, K., Lee, S. Y., & Choi, Y. (2024). Teachers' sense-making of the decentralizing curriculum reform policy: A comparative case study in South Korea. *International Journal of Educational Research*, *125*, 102331. https://doi.org/10.1016/j.ijer.2024.102331

University of the Philippines Los Baños. (2018). *2018 Bachelor of Science in Mathematics & Science Teaching (BS-MST) Curriculum (Major in Biology, Chemistry, Mathematics, and Physics) & Flowcharts*. Institutional Document.