Visualizing Complexity in Curricula through Data-Driven Analytics

Mahshad Akbarsharifi, The University of Arizona

Mahshad Akbarsharifi is an M.S. student in Electrical and Computer Engineering at the University of Arizona. Her research interests include artificial intelligence, machine learning, predictive modeling, and data analytics, with an emphasis on developing computational approaches for complex, data-rich problems. She has contributed to projects involving machine learning applications in educational data, student success and retention modeling, curriculum analytics, and the analysis of academic pathways. Her broader interests include the design of intelligent systems, interdisciplinary applications of AI, and the use of data-driven methods to support evidence-based decision-making and innovation.

Prof. Gregory L. Heileman, The University of Arizona

Gregory (Greg) L. Heileman currently serves as the Associate Vice Provost for Academic Affairs and Professor of Electrical and Computer Engineering at the University of Arizona.

Kristina A Manasil, The University of Arizona

Kristi Manasil is a second-year PhD student in the College of Information Science at the University of Arizona. She received her bachelor's degree in Computer Science from the University of Arizona. Her areas of focus are data visualization, machine learning, learning analytics, and educational data mining.

Melika Akbarsharifi, The University of Arizona

Melika Akbarsharifi is a PhD student in Software Engineering at the University of Arizona, studying under Professor Gregory L. Heileman. Her research at the Curricular Analytics Lab focuses on applying machine learning and data analysis to improve educational outcomes. Key contributions include developing a cohort-tracking analytics platform that supports efforts to increase graduation rates by identifying and addressing curricular barriers.

Melika has co-authored papers presented at conferences such as the ASEE Annual Conference and Exposition, exploring the intersection of curriculum complexity and student performance. Her technical expertise spans multiple programming languages and cloud computing, supporting her work on innovative educational technologies.

Roxana Akbarsharifi, The University of Arizona

Roxana Akbarsharifi is a PhD student in Software Engineering at the University of Arizona. Her research focuses on educational analytics and developing tools to improve student outcomes and support academic success. Her research interests include software engineering, data analytics, and data visualization, with an emphasis on applying these technologies to solve educational challenges and enable data-driven decision making in higher education.

Visualizing Complexity in Curricula through Data-Driven Analytics

Abstract

Institutional factors play an important but often overlooked role in how students move through their degree programs. There has been wide attention given to instructional challenges such as course difficulty, sequencing, and prerequisite design. However, factors like course fill rates, offering frequency, instructor availability, and enrollment capacity also have a strong impact on student progress and degree efficiency. These institutional constraints often operate invisibly, shaping the degrees of freedom that students have when organizing their schedules or recovering from a setback. When combined with instructional challenges, they can create structural bottlenecks that limit students' ability to progress, thus extending time to degree and exacerbating equity gaps in access to required courses. While instructional and institutional factors have typically been examined separately, their interaction often produces structural bottlenecks that remain invisible without integrated analysis. Understanding how these factors interact, and making those interactions visible, is key to improving how programs are designed, scheduled, and managed across the institution. This paper presents a data-driven curriculum analytics platform that visualizes both instructional and institutional elements within a single, interactive framework. The system models a degree plan as a directed graph, where courses are represented as nodes and prerequisite relationships as edges. It then integrates institutional data such as course fill rates, offering patterns, and enrollment pressure with instructional data, including DFW rates, sequencing dependencies, and course complexity. Together, these layers reveal where and why students encounter barriers as they move through a program, allowing users to test potential interventions and assess their ripple effects across the curriculum. The platform provides situational awareness for faculty, advisors, and administrators, helping them identify, interpret, and address the dynamic interactions that constrain student movement. While engineering programs exemplify the challenges of limited scheduling flexibility, the framework applies broadly to any field where instructional and institutional structures combine to influence student outcomes. By layering the instructional and institutional data, the system supports data-informed decision-making that can lead to more efficient, equitable, and sustainable degree pathways.

1 Introduction

Improving student success across academic programs remains a central concern for institutions of higher education. While the proposed framework is discipline-agnostic, engineering curricula are used throughout this paper as illustrative examples due to their dense prerequisite structures and limited scheduling flexibility. Despite sustained efforts to enhance retention and graduation rates, many engineering programs still experience delayed student progression, continued attrition, and uneven student outcomes. While student preparedness and instructional quality are frequently cited as contributing factors, prior work in curricular analytics suggests that the structure of the curriculum itself plays a significant role in shaping students' academic pathways [1, 2, 3].

Curricula are not simply collections of courses but complex systems of interconnected requirements shaped by prerequisite relationships, sequencing constraints, and scheduling limitations. These structural features shape how students progress through a degree program and influence their ability to recover from common disruptions in progression, such as course failure or delayed enrollment. Prior research in curricular analytics has demonstrated that structural characteristics—such as prerequisite chain length, the presence of bottleneck courses, and the concentration of curricular dependencies—are strongly associated with student completion rates and time to degree [1, 2]. However, most existing analyses treat curriculum structure as a static artifact, largely independent of instructional conditions and institutional constraints [3, 4].

At the same time, instructional factors such as pass rates, course availability, and enrollment capacity play a critical role in shaping students' experiences within a curriculum. A course that appears structurally central may pose little barrier if it is frequently offered and has high success rates, whereas a less central requirement may significantly impede progress if it has limited capacity or high failure rates. Despite this interaction, structural and instructional factors are often examined in isolation, limiting institutions' ability to fully understand how curricular design influences student outcomes.

This paper presents a visual analytics framework that integrates structural and instructional dimensions of curricula into a unified representation.

Building on prior work in curricular analytics [2, 3, 4], we model degree programs as directed graphs in which courses are represented as nodes and prerequisite relationships as edges. This representation is augmented with instructional data such as pass rates, enrollment demand, and offering frequency to capture how students experience the curriculum in practice. By combining these dimensions, the proposed framework enables stakeholders to identify bottlenecks, evaluate the impact of curricular design decisions, and explore how changes to individual courses or requirements may affect overall student progression.

The primary contribution of this work is the design of an interactive, data-driven visualization system that allows stakeholders to explore how curriculum structure and instructional conditions jointly affect student progression. Rather than relying on predictive models or aggregate outcome metrics alone, the system makes prerequisite relationships, course performance, and enrollment pressure visible within a single interface. This design enables faculty, advisors, and administrators to identify bottlenecks, examine trade-offs, and reason about potential curriculum and resource changes before they are implemented.

The remainder of this paper is organized as follows. Section 2 reviews related work on curricular analytics and structural modeling of degree programs. Section 3 describes the data model and visualization framework used to integrate structural and instructional information. Section 4 presents examples illustrating how the system can be used to identify bottlenecks and evaluate potential interventions. Finally, Section 5 discusses implications, limitations, and directions for future work.

2 Background and Related Work

Research on student success in higher education has traditionally focused on individual-level factors such as academic preparation, demographic characteristics, and instructional quality [5, 6]. More recently, attention has expanded toward understanding how the structure of academic programs themselves influences student progression and degree completion [1]. This shift has given rise to a growing body of work on curricular analytics, which seeks to formalize and quantify the ways in which curriculum design shapes educational outcomes [2, 3, 4].

2.1 Curriculum Structure and Student Progression

Early research on student persistence primarily examined demographic variables, academic preparedness, and institutional support mechanisms [5, 6]. While these factors remain important, they do not fully explain observed disparities in student progression across programs with similar student populations. An increasing body of research has shown that structural features of curricula—such as prerequisite chains, course sequencing, and scheduling constraints—play a significant role in shaping student success [1, 2, 12, 13].

Heileman et al. introduced a formal framework for analyzing curricular structure using graph-based representations, in which courses are modeled as nodes and prerequisite relationships as directed edges [1, 2, 3, 4]. Within this framework, degree programs can be evaluated in terms of their structural complexity, capturing how constraints propagate through a curriculum. Measures such as delay factor, blocking factor, and centrality quantify how individual courses influence the flow of students through a program. Empirical studies using these metrics have demonstrated strong correlations between structural complexity and key outcomes such as time to degree and graduation rates [1, 2].

This line of work reframes curricula not merely as collections of courses but as interconnected systems whose design can amplify or mitigate barriers to student progress. However, while these models provide valuable insight into the structural properties of curricula, they largely treat courses as homogeneous entities, abstracting away differences in instructional quality, course availability, and student performance.

2.2 Instructional Factors and Course-Level Variability

Parallel to research on curricular structure, a substantial body of work has examined instructional factors that influence student success [5, 6]. Prior studies have shown that course-level characteristics—such as grading practices, instructional design, faculty experience, and class size—can significantly affect student outcomes. In addition, institutional constraints including limited seat availability, infrequent course offerings, and uneven distribution of instructional resources may create bottlenecks that delay student progression, even when curricula are well designed on paper [5].

Learning analytics research has leveraged institutional data such as grades, enrollment patterns, and course repetition to identify risk factors and predict student outcomes [5, 6]. While these approaches provide valuable insights, they often treat courses as independent units rather than as components of an interconnected curricular system. As a result, they may overlook how localized instructional challenges interact with broader structural constraints to shape students' academic trajectories.

More recent work has begun to bridge this gap by combining structural and performance-based metrics [1, 2, 3, 4]. However, many of these efforts rely on aggregate statistics or black-box predictive models that offer limited interpretability. For advisors, curriculum committees, and academic leaders, understanding why particular pathways fail—and how specific courses contribute to those failures—is as important as predicting outcomes. This limitation highlights the need for approaches that integrate instructional performance with curricular structure in a transparent and interpretable manner.

2.3 Visual Analytics for Curriculum Analysis

Visualization has emerged as an effective means for making complex educational data interpretable to a wide range of stakeholders, including faculty, advisors, and administrators [5, 6]. Prior research has demonstrated the value of visual analytics for exploring enrollment trends, identifying at-risk students, and supporting academic planning [7, 8, 9]. However, many existing systems emphasize temporal dashboards or tabular summaries, offering limited support for understanding the structural relationships inherent in curricular design.

Graph-based visualizations of curricula provide a promising alternative by making prerequisite structures, dependency patterns, and potential bottlenecks explicit [1, 2]. When augmented with quantitative measures such as course pass rates, enrollment pressure, and historical progression patterns, these visualizations can offer deeper insight into how curricular design choices influence student outcomes [1, 2, 3, 4].

Despite this potential, relatively few systems integrate structural and instructional data within a single, unified visual framework. Existing tools often focus either on static curriculum maps or on isolated performance metrics, which limits their ability to support holistic analysis of student progression [2, 4]. As a result, there remains a need for visualization approaches that not only depict curriculum structure but also contextualize it with empirical data reflecting how students actually experience the curriculum.

2.4 Positioning of the Present Work

The work presented in this paper builds directly on prior research in curricular analytics while addressing key gaps in existing approaches [1, 2, 3, 4]. Specifically, we extend structural models of curricula by integrating instructional data such as pass rates, enrollment patterns, and course availability into a unified visual representation. This integration allows users to examine how structural constraints and instructional conditions jointly influence student progression.

Unlike purely analytical or predictive models, the proposed system emphasizes interpretability and exploratory analysis [2, 3]. It enables stakeholders to visually identify bottlenecks, compare alternative curricular configurations, and reason about potential interventions before policy changes are implemented. In this way, the framework supports a shift from reactive, outcome-based evaluation toward proactive, design-oriented curriculum analysis.

By situating structural complexity within a broader instructional context, this work contributes to a more holistic understanding of how curricula function in practice [1, 4]. The resulting framework provides a foundation for evidence-based curricular decision-making and opens new avenues for research at the intersection of learning analytics, educational data visualization, and curriculum design.

3 System Overview

This section presents the architecture, data model, and analytical workflow of the proposed visual analytics system. The system is designed to integrate structural and instructional data into a unified representation that enables stakeholders to explore, interpret, and reason about curricular complexity. By combining graph-based modeling with interactive visualization, the system supports both descriptive and exploratory analysis of degree programs.

Figure 1 provides an overview of the proposed visual analytics system.

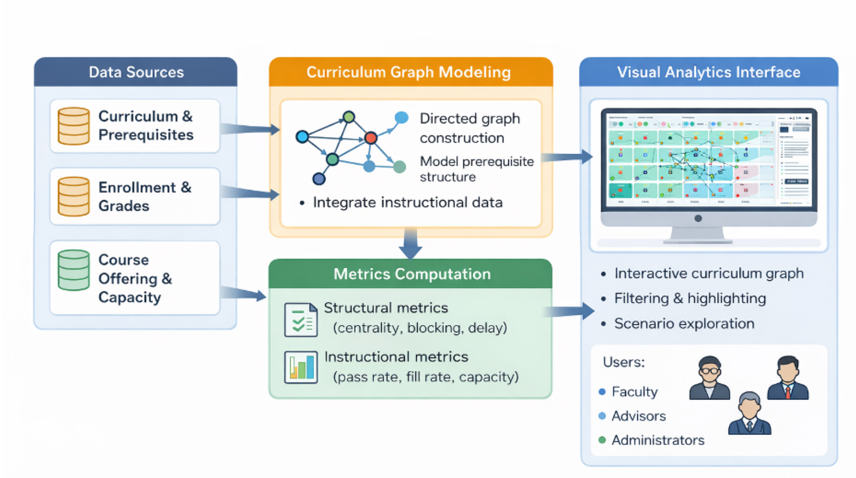

Figure 1: Overview of the visual analytics system, showing data inputs, curriculum graph modeling, metric computation, and interactive visualization used to support curricular analysis.

3.1 Design Goals

The primary objective of the system is to make curricular complexity interpretable and actionable for a wide range of stakeholders, including faculty, curriculum committees, advisors, and administrators. To achieve this goal, the system was designed with the following principles in mind:

- **Structural fidelity:** accurately represent prerequisite relationships and curricular dependencies.
- **Instructional integration:** incorporate course-level performance and availability data alongside structural information.
- **Interactivity:** enable users to explore, filter, and interrogate the curriculum from multiple perspectives.
- **Transparency:** make sources of complexity visually and analytically explicit rather than hidden in aggregated metrics.
- **Scalability:** support curricula of varying sizes and disciplinary structures without loss of interpretability.
- **Accessible visual encoding:** use a colorblind-friendly palette and a categorical encoding that can represent multi-designated courses, such as those that satisfy both general education and major requirements.

Together, these principles guide the system's architecture and visualization design.

3.2 Data Model and Inputs

The system represents a curriculum as a directed graph $G = (V, E)$, where each vertex $v \in V$ corresponds to a course and each directed edge $(u, v) \in E$ represents a prerequisite or co-requisite relationship. This representation aligns with formal models used in prior curricular analytics research and enables direct analysis of structural properties within a degree program [1, 2, 3, 4].

Each node in the graph is annotated with a set of instructional attributes that characterize how the course functions in practice. These attributes include course pass rate derived from historical grade distributions, enrollment demand represented through capacity utilization metrics such as course fill rate, offering frequency indicating how often the course is available within an academic year, and course level or classification such as lower-division or upper-division. All attributes are sourced from institutional data systems and normalized to support meaningful comparison across courses and academic terms.

Edges encode prerequisite constraints and are directed to reflect the required ordering of courses within the curriculum. Co-requisite relationships are represented either as bidirectional edges or as grouped constraints, depending on the institutional data representation. This unified graph model supports both topological analysis of curricular structure and quantitative annotation of instructional characteristics, enabling integrated analysis of how structural and instructional factors interact [1, 2].

3.3 Structural and Instructional Metrics

Building on prior curricular analytics research, the system computes several structural metrics directly from the curriculum graph to characterize prerequisite constraints [1, 2, 3, 4]. These include delay factor, which measures the length of prerequisite chains that must be completed before a course can be reached; blocking factor, which counts the number of downstream courses whose availability depends on a given course; and centrality, which measures how frequently a course lies on paths connecting early and late stages of the curriculum. Together, these metrics describe how strongly individual courses constrain progression through the degree program [1, 2, 10].

In addition to structural metrics, the system incorporates instructional metrics derived from institutional records. These include course pass rates based on historical grade distributions, repeat rates that capture how often students must retake a course, and enrollment pressure represented through capacity utilization metrics such as course fill rate. These measures capture how courses perform operationally, independent of their position in the curriculum.

Structural and instructional metrics are modeled as separate but jointly interpretable dimensions. This separation allows analysts to distinguish courses that are structurally important but function reliably from those that create delays due to instructional factors such as low pass rates or limited seat availability. By examining both dimensions together, the system supports more precise identification of the sources of delay and constraint within a curriculum.

Figure 2 illustrates the relationship between structural and instructional metrics for a representative portion of the curriculum.

Figure 2: Structural and instructional metrics for a representative portion of the curriculum, highlighting a longest prerequisite path and associated delay, blocking, and centrality values.

3.4 Visualization Design and Interaction

The core of the system is an interactive visualization that integrates structural and instructional data within a single interface. Courses are represented as nodes arranged in a directed graph that preserves prerequisite relationships while maintaining a term-based layout to support readability and progression analysis [1, 2, 3, 4].

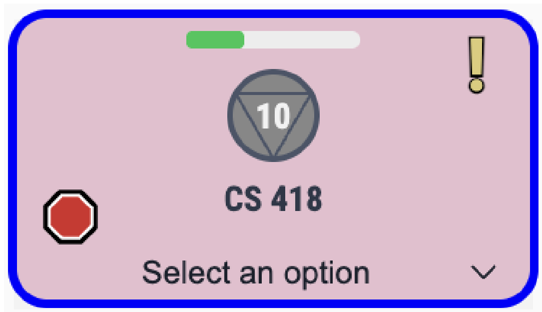

Figure 3: Close-up view of an individual course tile showing visual encodings for course role (background color), requisite type (inner marker), instructional performance indicators, and institutional availability cues. This view supports detailed interpretation of node-level information that is not visible in the full curriculum overview.

Figure 3 provides a detailed view of within-node encodings that are difficult to discern in the zoomed-out overview shown in Figure 2.

Node background color encodes the course's role within the degree program, distinguishing major requirements, general education courses, technical electives, and free electives. Within each node, an inner circular marker uses a separate color encoding to represent requisite relationships, distinguishing prerequisite, co-requisite, strict co-requisite, and related constraint types. These encodings employ a colorblind-friendly palette to ensure accessibility and consistent interpretation.

Structural relationships between courses are conveyed through directed edges that encode prerequisite and co-requisite constraints [1, 2]. Instructional and institutional indicators are conveyed directly on each node using compact visual glyphs, including performance bars representing DFW-related outcomes, fill rate indicators reflecting capacity utilization, and icon-based cues indicating term availability or blocking status.

Detailed quantitative values and additional structural metrics, such as complexity, blocking factor, delay factor, and centrality, are revealed through interactive tooltips [1, 2, 3, 4]. Analytic interaction is primarily driven through global toggle controls, which allow users to emphasize courses and dependencies based on specific structural, instructional, or institutional conditions, such as longest prerequisite paths, blocking relationships, high DFW rates, limited term availability, or high fill rates, consistent with established visual analytics interaction principles [11]. These controls dynamically adjust visual emphasis across the curriculum to surface potential bottlenecks and risk factors without altering the underlying structure.

Selecting an individual course provides supporting detail-on-demand inspection, revealing authoritative course information such as description, credit hours, and minimum grade requirements. This interaction supports contextual understanding but is not the primary mechanism for analysis.

3.5 Analytical Use Cases

The system supports several analytical use cases relevant to curriculum planning and evaluation. It enables the identification of bottleneck courses by jointly visualizing structural importance and instructional performance indicators. By making prerequisite structures, dependency chains, and blocking relationships explicit, the system supports the evaluation of curricular design decisions and allows stakeholders to reason about the potential effects of proposed changes.

Overlaying instructional metrics such as DFW rates, fill rates, and term availability helps distinguish between structural constraints and instructional challenges. While the system does not perform automated simulation, it supports exploratory scenario analysis by enabling users to examine how changes to high-impact courses or constraints may influence student progression across the curriculum. Through these capabilities, the system functions as a decision-support environment for curriculum analysis rather than a predictive or optimization-based tool.

4 Discussion

The results presented in this work illustrate the value of jointly considering structural and instructional dimensions of curricula when analyzing student progression. Integrating graph-based representations of curricular structure with empirical instructional data enables the identification of patterns and constraints that are difficult to observe when these dimensions are examined in isolation. This section discusses the implications of these findings for curriculum design and academic decision-making, and reflects on the insights gained through application of the proposed framework.

4.1 Interpreting Structural and Instructional Interactions

A key insight of this work is that curricular complexity arises from the interaction between structural design and instructional conditions, rather than from either dimension alone. Courses that appear unproblematic when examined in isolation may become significant barriers when situated within tightly constrained prerequisite networks. Conversely, courses that occupy structurally central positions do not necessarily impede progress when they are supported by high pass rates and adequate instructional capacity.

By integrating structural metrics such as delay, blocking, and centrality with instructional indicators including pass rates and course availability, the proposed framework makes these interactions explicit. This integration enables the system to distinguish between courses that are structurally important but instructionally resilient and those that combine structural importance with instructional vulnerability. Such distinctions are critical for prioritizing intervention efforts, as they allow stakeholders to target resources toward courses most likely to constrain student progression.

4.2 Implications for Curriculum Design and Reform

These results indicate that curriculum design decisions should be evaluated not only in terms of content coverage and alignment with disciplinary standards, but also with respect to their structural and operational consequences. Traditional curriculum review processes often rely on qualitative judgment or localized performance indicators, which can obscure system-level constraints and bottlenecks. In contrast, the proposed framework offers a quantitative and visual means of examining how individual courses shape overall program flow.

For instance, the system can surface situations in which a single course exerts a disproportionate influence on student progression due to the combined effects of high enrollment demand and low pass rates. In such cases, targeted interventions—such as enhanced instructional support, adjustments to prerequisite requirements, or the introduction of alternative pathways—may be more effective than broad, program-wide reforms. This approach reflects a growing emphasis in higher education on strategic, data-informed decision-making to guide curricular improvement.

4.3 Implications for Equity and Student Experience

Beyond considerations of efficiency and time to degree, the proposed framework also has important implications for equity. Structural bottlenecks can disproportionately affect students with limited scheduling flexibility, including those balancing employment, caregiving responsibilities, or other external constraints. By making such bottlenecks visible within the curriculum, the system allows institutions to identify where structural features may contribute to uneven student outcomes.

In addition, the visualization of curricular pathways enables stakeholders to examine whether certain courses or sequences systematically create higher-risk progression patterns. This capability supports a shift from reactive responses—addressing challenges only after students encounter difficulties—to more proactive curricular design approaches that seek to reduce structural barriers before they result in delayed progress or attrition.

4.4 Limitations

While the proposed system provides useful analytical capabilities, several limitations should be noted. First, the reliability of the analysis is dependent on the quality and completeness of the underlying institutional data. Inconsistencies in course coding, incomplete historical records, or unmodeled policy exceptions may introduce uncertainty into the resulting metrics and visualizations.

Second, the framework does not explicitly represent qualitative aspects of instruction, such as pedagogical approaches, instructional practices, or classroom climate, which can substantially influence student outcomes. These factors are reflected only indirectly through aggregate performance indicators rather than being modeled directly.

In addition, the system assumes relatively stable curricular structures and does not currently account for dynamic changes such as mid-year curriculum revisions or ad hoc policy adjustments. Although the framework supports exploratory scenario analysis, the validity of such analyses depends on the extent to which the input data and modeled assumptions reflect actual institutional conditions.

4.5 Future Work

There are several ways this work could be extended in the future. One natural extension is the inclusion of longitudinal, student-level data, which would allow the system to represent individual progression paths rather than aggregate course behavior. This would make it possible to examine how different students experience the same curricular structure over time.

Another direction involves exploring limited predictive or simulation-based analyses to examine how specific changes—such as modifying prerequisites or increasing course capacity—might affect progression patterns. These analyses would be intended to support exploratory planning rather than precise outcome prediction.

Finally, applying the framework across multiple programs or institutions could help identify common structural patterns and highlight differences in curricular organization. Such comparisons would provide useful context for curriculum committees without requiring direct standardization across institutions.

5 Conclusion

This work presents a visual analytics framework that integrates structural and instructional dimensions of curricula into a unified, interpretable representation. By representing degree programs as directed graphs and integrating institutional performance and availability indicators at the course level, the system enables direct inspection of how structural constraints and instructional conditions jointly contribute to curricular bottlenecks. Rather than treating curriculum structure and instructional conditions as independent factors, the proposed approach highlights how their interaction shapes student progression, bottlenecks, and time-to-degree outcomes.

Through interactive visualization and integrated metrics, the framework supports exploratory analysis by faculty, advisors, and administrators, enabling stakeholders to identify high-impact courses, evaluate trade-offs, and reason about potential interventions before changes are implemented. By emphasizing transparency and interpretability, the system complements existing analytic approaches and provides a practical tool for curriculum design, resource planning, and academic decision-making.

Overall, this work demonstrates that integrating graph-based curricular representations with institutional data provides a practical foundation for systematic, interpretable curriculum analysis across programs of varying size and structure.

References

[1] G. T. Heileman, A. Slim, and C. T. Abdallah, "The complexity of curricula and its impact on student success," *Journal of Engineering Education*, vol. 106, no. 4, pp. 637–666, 2017.

[2] G. T. Heileman, A. Slim, and M. Hickman, "Measuring curricular complexity," *Journal of Engineering Education*, vol. 107, no. 3, pp. 396–419, 2018.

[3] G. T. Heileman, C. T. Abdallah, and A. Slim, "Curricular analytics: A framework for quantifying the impact of curricular reforms and pedagogical innovations," in *Proceedings of the ASEE Annual Conference*, 2019.

[4] A. Slim, G. T. Heileman, and C. T. Abdallah, "Curriculum visualization and analysis using graph-based methods," in *Proceedings of the ASEE Annual Conference*, 2019.

[5] V. Tinto, *Leaving College: Rethinking the Causes and Cures of Student Attrition*. University of Chicago Press, Chicago, IL, USA, 1993.

[6] A. W. Astin, *What Matters in College: Four Critical Years Revisited*. Jossey-Bass, San Francisco, CA, USA, 1993.

[7] K. Verbert, E. Duval, J. Klerkx, S. Govaerts, and J. L. Santos, "Learning analytics dashboard applications," *American Behavioral Scientist*, vol. 57, no. 10, pp. 1500–1509, 2014.

[8] K. E. Arnold and M. D. Pistilli, "Course signals at Purdue: Using learning analytics to increase student success," in *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*, 2012, pp. 267–270.

[9] T. Susnjak, A. G. D. McKenzie, and L. M. Ryan, "Learning analytics dashboards: A review of the state of the art," *IEEE Transactions on Learning Technologies*, vol. 15, no. 1, pp. 1–15, 2022.

[10] M. E. J. Newman, *Networks: An Introduction*. Oxford University Press, Oxford, UK, 2010.

[11] D. A. Keim, J. Kohlhammer, G. Ellis, and F. Mansmann, "Mastering the information age: Solving problems with visual analytics," Eurographics Association, 2010.

[12] G. L. Heileman et al., "Are Engineering Degrees Really More Complex? Characterizing the Complexities of Academic Programs by Discipline," in *ASEE Annual Conf. & Expo.*, 2025.

[13] A. Slim et al., "Causal Inference Networks: Unraveling the Complex Relationships Between Curriculum Complexity, Student Characteristics, and Performance in Higher Education," in *ASEE Annual Conf. & Expo.*, 2024.