Network-Based Trajectory Analysis and Framework Development of Precalculus Curricula

Cristina Flores Vlad Nita John O'Meara Ashwin Vaidya

Montclair State University

Keywords: network theory, curriculum, identity, complexity science, connectivity, precalculus

This synthesis of previous work and ongoing research efforts calls for a network theory mediated analysis to investigate the affordances of curriculum and, in particular, its alignment with student learning processes. The three factors that are identified and considered in this study are the student, curricular materials, and the respective environments from which these members arise and how these act as determinants of curriculum development and design. There are three primary research questions addressed here: **(1)** How does the development of connections between topics within a specific precalculus course's curricular materials (textbook and online learning platform) over the course of a semester influence and/or align with the development of students' connections? **(2)** How does the development of connections between precalculus topics as perceived by students with respect to average path length (APL), clustering coefficient (CC), and the distribution of highly connected topics (Hubs) correlate with their performance in the course? **(3)** To what extent do equitable and identity-based curricular supplements (having students provide specific personal connections to the material, as well as draft problem sessions based on student interests) have an impact on student performance and/or perceived connectivity of precalculus topics?

A network theoretic perspective of various precalculus curricula (O'Meara & Vaidya, 2021) proves helpful in identifying and motivating key features of the subject as they appear in course texts. Based on this framework, an undirected network representation of a specific precalculus course's materials is constructed in which nodes represent topics introduced throughout the materials, and edges represent explicit connections formed between topics. Edges are weighted based on frequency of relation between two given topics, and nodes are weighted based on overall degree distribution. Students are administered an IRB-approved survey on a biweekly basis in which they are provided with sets of topics covered in the course up to a given point. They are then asked to form any connections they see fit, and these self-reported connections are stored as undirected networks whose properties and relevant metrics are analyzed upon each submission period through the end of the semester to gain insight into student learning trajectories. The corresponding poster will display the dynamic nature of the evolution of students' networks, as well as insights into how course performance can be correlated with both features of the students' networks and the course's 'ideal' network structure. This project aims to lay the foundation for meaningful intervention and predictive analytical tools that instructors can make use of in order to identify which students are likely to struggle in the course, and with what particular topics they are failing to fully comprehend. Such an extension is mitigated by a qualitative analysis of identity-based surveys and collaboratively constructed problem sets where the presence of personal connections in this medium are compared and correlated to the students' connected network structures and their overall performance in the course.

The implications of this work seek to assist in the optimization of the complex system synthesizing various feedback-based designs within educator roles, student response, and the interactions between the two as they pertain to various stages of the curriculum development process. The results of this study aim to provide a deeper understanding of the extent to which the components of an andragogical system can be refined via regulated and personalized learning methods.

References

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Mathematical Modeling of Student Learning Network

MONTCLAIR STATE UNIVERSITY

John O'Meara, Cristina Flores, and Vlad Nita
Advisor: Ashwin Vaidya

Department of Mathematics
Montclair State University
1 Normal Avenue, Montclair, NJ 07043

Introduction

This synthesis employs a network theory mediated analysis to investigate the affordances of curriculum and, in particular, its alignment with student learning processes. Via the utilization of various lenses of network theory, 'connected curriculum' design (Fung, 2017), and modern learning curve theory (Thurstone, 1918; MacLellan et al, 2015), we collectively postulate that education is inherently a complex system at various scales and stages of the learning and teaching process. A network perspective of precalculus curricula (O'Meara and Vaidya, 2021) proves helpful in identifying and motivating key features of the subject as they appear in course texts. Of these, hubs and time-series developments of relevant computed metrics have been particularly useful in mapping the alignment between the preset goals of the precalculus course, as identified in previous literature, and its execution. At the same time, this analysis has also been valuable in identifying the trajectory of the textbook curricula in adequately preparing precalculus students for success in calculus and beyond.

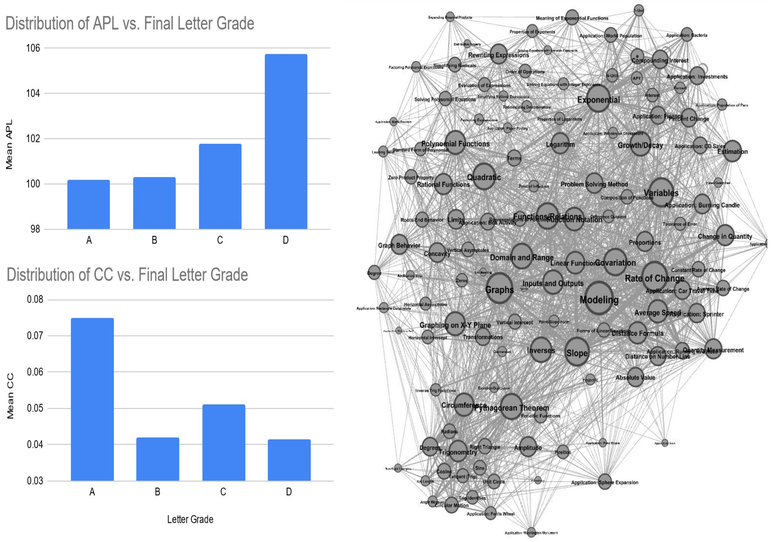

Figure 1: Aggregate results of student concept maps / self-reported networks in which individual perceived connections are formed amongst course topics. Pictured above are histograms displaying relevant network metrics with respect to final grade distribution (left), and the union of all student networks with node size adjusted for degree/span of connectivity (right).

Research Questions

(1) How does the development of connections between topics within a specific precalculus course's curricular materials (textbook and online learning platform) over the course of a semester influence and/or align with the development of students' connections?
(2) How does the development of connections between precalculus topics as perceived by students with respect to average path length (APL), clustering coefficient (CC), and the distribution of highly connected topics (Hubs) correlate with their performance in the course?
(3) What affordances do the alignment between research-based curricular taxonomy and course materials provide? How do observations in precalculus influence the transition for students into calculus and beyond?
(4) To what extent do equitable and identity-based curricular supplements (having students provide specific personal connections to the material, as well as draft problem sessions based on student interests) have an impact on student performance and/or perceived connectivity of precalculus topics?

Research Design

Students are administered an IRB-approved survey (FY21-22-2488) on a biweekly basis in which they are provided with sets of topics covered in the course up to a given point. They are then asked to form any connections they see fit, and these self-reported connections are stored as undirected networks whose properties and relevant metrics are analyzed upon each submission period through the end of the semester to gain insight into student learning trajectories. This acts as an intervention and predictive analytical tools that instructors can make use of in order to identify which students are likely to struggle in the course, and with what particular topics they are failing to fully comprehend. Such an extension is mitigated by a qualitative analysis of identity-based surveys and collaboratively constructed problem sets where the presence of personal connections in this medium are compared and correlated to the students' connected network structures and their overall performance in the course.

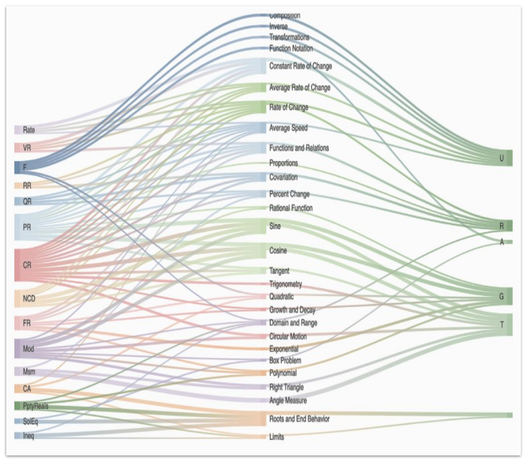

Figure 2: Representation of prominent precalculus topics as an informational exchange between precalculus taxonomy, course textbook, and calculus taxonomy principles.

Findings

Highly successful texts have been found to display a power law with respect to frequency distribution of connected topic inclusion (α = 0.05), among consideration of other theoretical distributions, to assess whether or not meaningful learning patterns retain consistent underlying patterns and/or distributions. The most well-connected topics (Hubs) are regarded as necessary markers of classroom discourse, and the extent to which they are considered in taxonomical goals was measured with respect to the empirical distributions of both the intended curriculum and enacted curriculum.

The results of this study aim to not only provide a deeper understanding of how intended and enacted curriculums interact with each other, but also considers to what extent the components of an andragogical system can be refined via the magnitude of their presence in both course materials and feedback provided directly by active participants in the learning environment.

Keywords

network theory, curriculum, identity, complexity science, connectivity, precalculus

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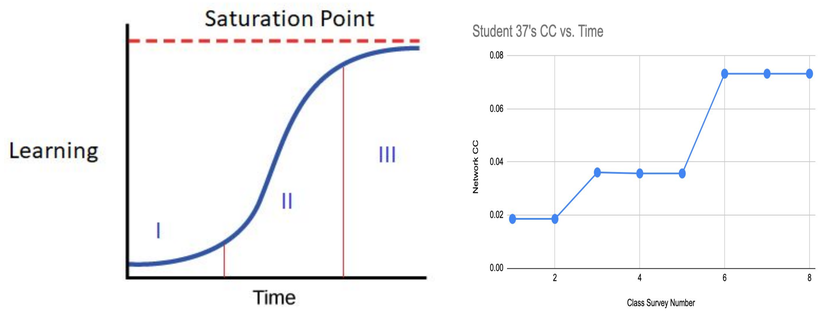

Figure 3: A schematic of the logistic learning curve (left), in which I indicates the phase of slow growth until critical knowledge is reached, II is the phase of rapid learning phase, and III is the phase at which saturation of knowledge is approached, with critical transition points between phases. This is accompanied by a model of an anonymous student's clustering of precalculus concepts over time (right).