On Learning and Development in Mathematics: Leveraging a Decade of Longitudinal Cohort Research to Identify and Characterize Psychoeducational Characteristics Specific to Mathematics

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Back to the Start

- Our work in this area began in the early 2000's in response to a pressing need to address students who were not thriving in college, and in mathematics courses in particular
- We realized that the data we had (e.g., demographic information, measures of crystallized learning, unchangeable past academic experiences) did not inform which actions we should take
- Realizing there are no “quick fixes" in education, we launched longitudinal cohort studies to measure students inherently incremental learning and development

Learning and Development in College Students

- Through our longitudinal cohort research, we have extensively investigated the academic paths and trajectories of tens of thousands ($n \geq 17,000$) of college students over the course of the last decade, contributing to a robust explanatory framework for learning and development

  (Ben-Avie 2008, 2018; Ben-Avie et al., 2003a, 2003b, 2012; Ben-Avie & Polka, 2006; Ben-Avie & Darrow, 2018, 2019, 2023; Darrow, 2016, 2020, 2023a, 2023b, 2023c)

Learning and Development in College Students

- We developed instruments to pursue the "hard-to-measure" psychoeducational facets of student profiles, including
  - Future Orientation
  - Academic Habits of Mind
  - Obstacles to Academic Success
  - Self-limiting Beliefs
  - Interpersonal Relationships
  - Connectedness with Faculty (including coping with hesitancy to approach professors and performance anxiety)
  - Sense of Belonging
  - Engagement with Learning

Example Items: Hesitancy to Engage with Faculty

- I fear that if I ask for help, my professor will think less of me.
- I am hesitant to raise my hand in class even though I know the answer.
- I tell my professor when I don't understand something from math class.

Some Major Findings

- The “Hard-to-measure" components of students’ profiles provided the missing piece for a robust explanatory framework for academic outcomes (e.g., grades/GPA, retention, graduation)

- Malleable characteristics (those that can be influenced after college enrollment) are stronger, more consistent, and better explain students’ persistence and academic achievement than immutable ones (unchangeable characteristics such as demographics, socioeconomic status, past academic experiences, etc.)

Shifting the Focus to Mathematics

- In previous work (Darrow, 2016, 2020), we identified that these domain-general psychoeducational measures are not sufficient to measure individual differences with respect to learning and development in mathematics

- Therefore, we developed and administered psychoedcuational instruments to measure specific learning and developmental attributes in mathematics

Shifting the Focus to Mathematics

- Darrow (2023) and Darrow & Ben-Avie (2023) further developed and refined these instruments and administered them to 130 students at a public university and 390 students at a private university

- Two mathematics-specific facets emerged as distinct from all other domain-general facets under measure: one measuring present-oriented, task-focused beliefs and the other measuring future-oriented, global beliefs

- Responses to these scales indicated their utility in measuring individual differences with respect to learning and development in mathematics

Examples of Present-Oriented, Task-Focused Beliefs Items

- I often "freeze up" when solving math problems.
- The wording of math problems confuses me.
- I push math assinments and do them last.
- I can explain how I reach the correct answer on a math test
- I am just not good at math.

Examples of Future-Oriented Beliefs Items

- I want to be good at math.
- It is worth if for me to spend more time on math.
- No one in my future career will care if I am good at math.

Some Results

- Preliminary analyses suggest that the future-oriented scale better explains students' choice of major and long-term progression through mathematics course sequences
- In contrast, preliminary analyses also suggest that present-oriented, task-focused beliefs better explain outcome measures such as mathematics course grades (particularly in students' first year) and yearly cumulative GPA
- The focus remains on amenable characteristics and that which is amenable to change

The Next Generation of Researchers

- Last year, I began mentoring Luke Brown and Kinshu Gupta, exceptionally capable research assistants at QU, in this work
- We represent two generations of research and mentorship under Dr. Michael Ben-Avie
- I encouraged them to authentically explore our data, leveraging their perspective as students

Current Study Methodology

- To extend this work, we invited all first year students a private university to complete a new psychoeducational survey built upon the work of Ben-Avie and Darrow

- After subgroup and demographic questions, 87 psychoeducational survey items, consisting of both domain-general and mathematics-specifc items were administered to 1330 students

- The psychoeducational items were all coded on the same 5-point Likert scale (1 =Strongly Disagree, 2 =Disagree, 3 =Neutral, 4 =Agree, 5 =Strongly Agree)

There's More to the Story

- Again, the two aforementioned matheamtics-specific scales emerged as distinct
- Our work involved exploring the nature of the relationship between the anxiety scale and mathematics-specific belief scales
- We found a significant correlation between scales measuring present-oriented math and level of anxiety $(r = 0.444, p < 0.001)$, indicating the need for further investigation

Cluster Analysis Methodology

- Performed an exploratory K-Means clustering analysis within scales measuring present-oriented math and level of anxiety with $k \in \{1, 2, 3, \ldots, 30\}$, applying the elbow method in conjunction with our initial hypothesis to identify the optimal number of clusters.

- Utilized the *Greedy k-means++* algorithm for centroid initialization in all clustering analyses.

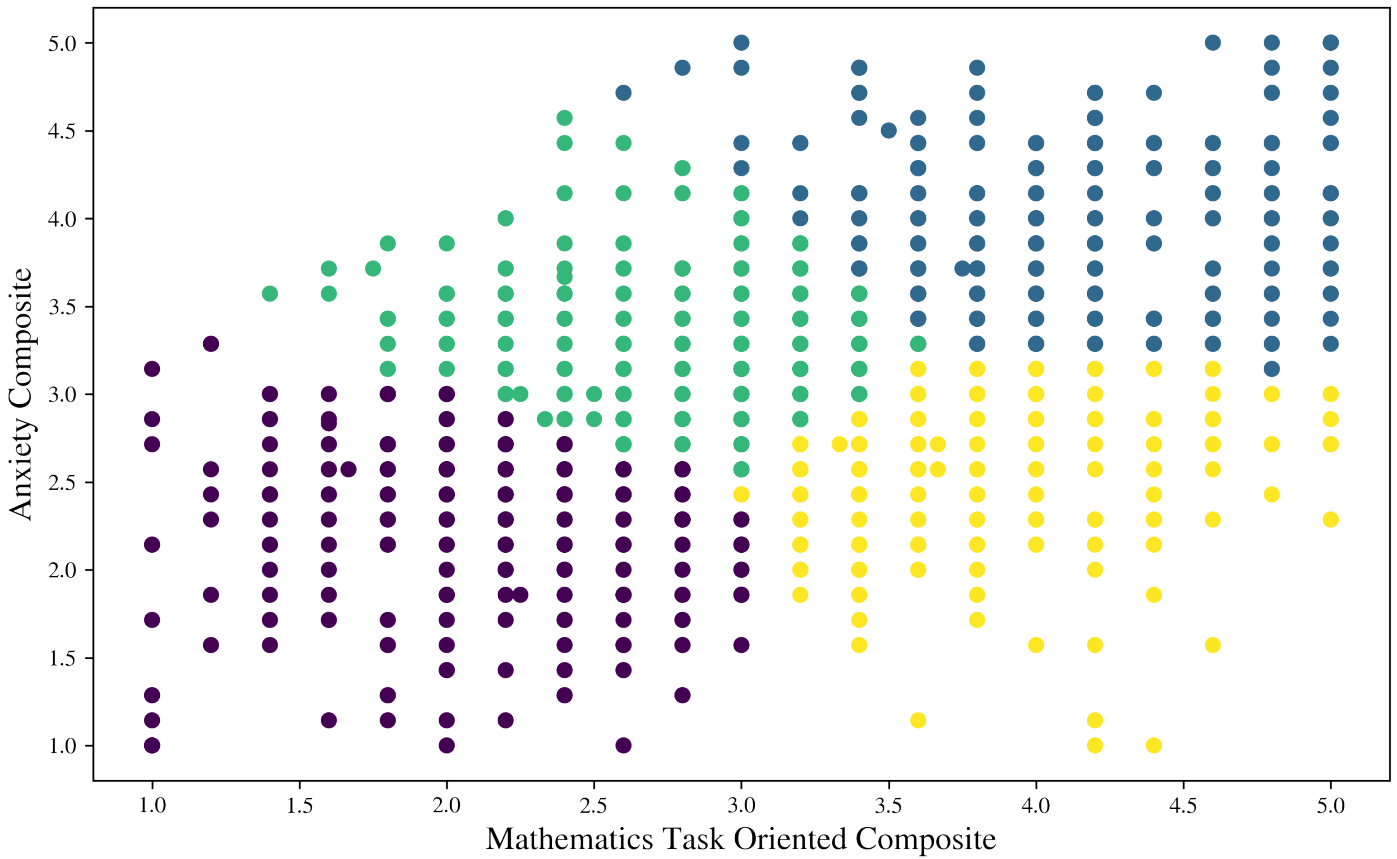
- Conducted the final K-Means clustering analysis with $k = 4$, resulting in the formation of distinct quadrants, aligning with the proposed hypothesis.

Cluster Analysis Preliminary Results

- Each cluster represents a unique relationship between present-oriented beliefs and anxiety measures:

  1. Desirable present-oriented beliefs in mathematics, and desirable responses to anxiety items
  2. Desirable present-oriented beliefs in mathematics, and less desirable responses to anxiety items
  3. Less desirable present-oriented beliefs in mathematics, and desirable responses to anxiety items
  4. Less desirable present-oriented beliefs in mathematics, and less desirable responses to anxiety items

Math-Anxiety Clusters



One Size Does Not Fit All

- With respect to considering how to intervene, the results suggest “one size does not fit all"
- The results provide insights to enhance academic outcomes for different student subgroups
- Just focusing on mathematical context is not enough for many students

One Size Does Not Fit All

- We still need to focus on malleable characteristics, i.e., that which is amenable to change (Ben-Avie & Darrow, 2018), indicated by responses on each scale
- Certain subgroups may need more targeted intervention with respect to mathematics belief systems
- Others may require additional support, since focusing solely on mathematics content will not get the job done
- Designing interventions with these insights in mind may better help meet the needs of students

Does Self-Limitation Lead to Self-Selection?

- Statistically significant differences were found across students' mathematics placement scores with respect to their responses on items measuring self-limiting beliefs

- There were statistically significant differences across math placement scores with respect to the item "I'm just not good at math." $(H(4) = 228.537, p < .001)$

Does Self-Limitation Lead to Self-Selection?

- Statistically significant differences were also found across student major subgroups with respect to their responses on future-oriented items

- There were statistically significant differences across major subgroups with respect to the item "It is worth it for me to spend more time on math." $(F(5, 1242) = 11.140, p =< .001)$

- There were statistically significant differences across major subgroups with respect to the item "No one in my future career will care if I'm good at math."
$(F(5, 1232) = 47.855, p =< .001)$

Does Self-Limitation Lead to Self-Selection?

- Results from Darrow & Ben-Avie's previous work (2023) also indicate that major subgroups of junior and senior students differ significantly with respect to their responses on each of these sets of items

- Taken together, these results suggest more work is needed to determine the link between self-limiting beliefs, major selection, and eventual career attainment

Influence on Major/Career Selection

- Preliminary indications suggest that students' self-limiting beliefs in mathematics may influence their (often unconscious) view of themselves in the future, influencing degree and major selection
- Students may have narrowed their career path too quickly
- This raises the question of how to influence students' academic self-concept and broaden their view of potential career paths
- What is clear is a great deal more work is needed in this area

Onward

- In the Spring 2024 semester, all sophomores and juniors at the private university will be invited to take the same survey
- Our team will continue to analyze these first-year student survey results as we collect more data on this cohort:
- We will analyze our survey responses in relation to longitudinal data, such as course completion, credits earned, GPA, etc.

Onward

- These results are preliminary in nature
- A lot more work is needed to refine these instruments and better understand exactly what they measure, and how this can contribute to discussions of mathematics education
- Our team's work is only a modest contribution to an area already being extensively investigated by other researchers

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