Integration of Learning Strategies in Math Courses: Impact on Students Math Mindset, Self-Regulated Learning and Performance

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Outline

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  - Math growth mindset
  - Self-regulated learning (SRL)
  - Learning strategies
- Research Framework & Questions
- Learning-Strategy Instruction in Gateway Math Courses
  - Implementation
- Preliminary Results
- Next Steps

Motivation

- Introductory math courses are gateway (or gate-keeper) courses for STEM disciplines.
- Performance in gateway math courses profoundly impacts students' transitions from high school to college, their ability to remain enrolled, make progress, and ultimately graduate (Carver et al., 2017).
- Enhancing students' learning experiences and performance in these gateway courses poses a persistent challenge for higher ed. institutions.
- Several interventions have been proposed and studied to tackle this challenge.

Growth Mindset

- Growth mindset is the belief that intelligence is pliable; "intelligence is portrayed as something that can be increased through one's efforts" (Dweck, 2000, p.3).

- Students who have a growth mindset are more likely to use new strategies and change their approach when hitting a roadblock, which is vital for success in the math classroom (Dweck, 2008).

Mathematical Growth Mindset

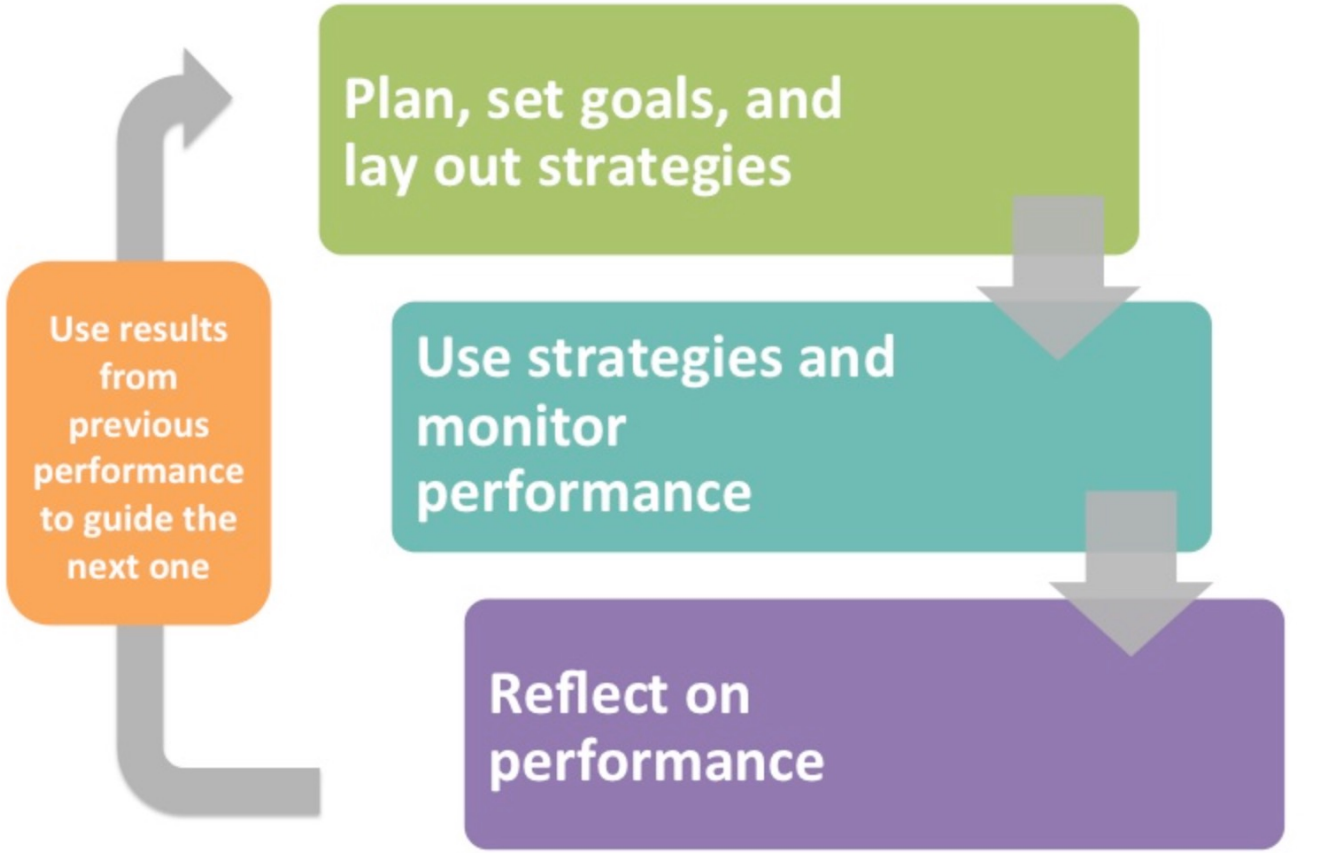
- An approach to teaching mathematics with the belief that ***mindset is more important than initial ability*** in determining the progress made by students in their mathematical understanding.
- **Faculty** who present material in a ***growth mindset framework can help protect against stereotype threat***—the perception that certain students, especially females, and minorities cannot do math.
- Research showed that ***students developed more growth mindsets when teachers presented mathematics as a subject with more opportunities for growth and learning*** (Sun, 2015).

Self-Regulated Learning (SRL)

Self-regulated learners

- are characterized by their **ability to be metacognitively, motivationally, and behaviorally active participants in their learning process** (Zimmerman, 1986).

- are actively involved in maximizing their opportunities and abilities to learn.



Self-Regulated Learning (SRL)

Self-regulated learners

- can critically evaluate and intentionally alter how their thoughts, attitudes, behaviors, and working environments contribute to their learning outcomes (Darr & Fisher, 2015).

- are capable of applying domain-relevant ***learning strategies*** to support their learning processes (e.g., Donker et al., 2014).

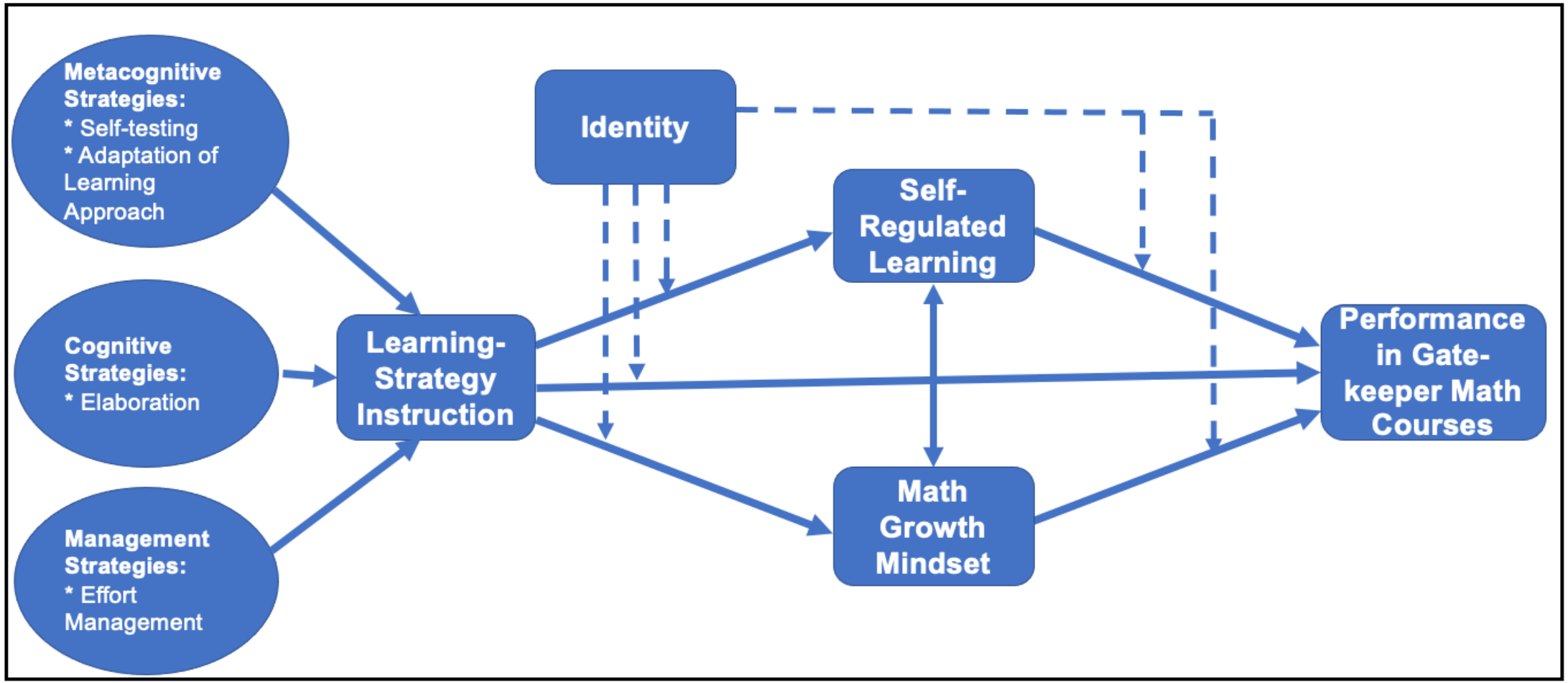
Learning Strategies

- Pressley et al. (1989) define learning strategies as "processes (or sequence of processes) that, when matched to the requirements of tasks, facilitate performance".
- These strategies encompass students' ***thoughts, behaviors, or beliefs*** that facilitate the acquisition, comprehension, or practical application of new knowledge and skills (Weinstein et al., 2000).
- **Types of Learning Strategies**:
  - Cognitive Strategies
  - Metacognitive Strategies
  - Management Strategies

Learning Strategies

- The literature on math growth mindset and SRL suggest that ***students' knowledge and use of learning strategies can be a common facilitator of both constructs of math growth mindset and SRL***, which would in turn lead to improvements in students' performance in math.

Research Framework/Hypotheses



Research Questions

Accounting for gender, racial, and math identities,

- **RQ1**: Does integrating learning-strategy instruction within gateway math courses promote math growth mindset?
- **RQ2**: Does integrating learning-strategy instruction within gateway math courses promote SRL?
- **RQ3**: What is the nature of the association between students' math mindset and SRL?
  - ✓ When and how is math growth mindset consequential for SRL and vice versa?
- **RQ4**: Do learning-strategy instruction, math growth mindset, and SRL predict students' performance in gateway math courses?

Learning-Strategy Instruction (LSI) in Math Courses

Implementation:

- We sought to integrate LSI in four gateway math courses at NCA&T:
  - College Algebra I (MATH103) and II (MATH104)
  - Calculus I (MATH131) and II (MATH132)
- We focused on four key learning strategies:
  - Elaboration (cognitive)
  - Self-testing and Adaptation of Learning Approach (metacognitive)
  - Effort Management (management)

Learning-Strategy Instruction (LSI) in Math Courses

We focused on four key learning strategies:

- **Elaboration (cognitive)**:
  - Elaboration strategies can be effective for learning math as they help students form internal connections between existing knowledge and new material (Donker et al., 2014).
  - Instructors can train students to use elaboration strategies by encouraging student explanation, sense-making, and justification using class discussions and discussion board assignments.
  - Such discussions allow students to form a math growth mindset (e.g., Sun, 2015, p.37) and directly connect to the self-reflection phase of the SRL model.

Learning-Strategy Instruction (LSI) in Math Courses

We focused on four key learning strategies:

- **Self-testing and Adaptation of Learning Approach (metacognitive)**:
  - By frequently encouraging self-testing and allowing for multiple attempts, instructors can
    - help students develop a math growth mindset (e.g., Sun, 2015) and
    - allow them to practice self-monitoring (the performance phase of SRL).
  - Presenting mathematical tasks that allow for multiple solutions sends growth mindset messages and motivates students to adjust their learning strategies for better task performance (the self-reflection phase of SRL).

Learning-Strategy Instruction (LSI) in Math Courses

We focused on four key learning strategies:

- **Effort Management & Test-Taking (management)**:
  - Instructors who frequently make effort attributions about math tasks encourage students to practice effort management strategies (forethought phase of SRL) and promote math growth mindset
  - Test-taking strategies are crucial for achieving on a math test.

Learning-Strategy Instruction (LSI) in Math Courses

Implementation:

- We used a robust combination of activities to ***inherently*** integrate LSI in the target math courses
  - Discussion board assignments (posts and replies)
  - In-class discussions and reflections
  - Peer tutor presentations

Learning-Strategy Instruction (LSI) in Math Courses

- **Discussion board (DB) assignments**
  - » #1- What do top students do differently?
    - Top Students Learning Habits: TEDx Talk by Douglas Barton of Elevate Education
  - » #2- Introduction to the study cycle (preview, attend, review, study, and check)
    - Watch a study cycle video by the LSU Center for Academic Success
  - » #3- Time Management
    - Students take an online time management quiz and reflect on scores in DB
    - Students are provided with a sample study calendar and are asked to create their own study calendar for the math course
  - » #4- Test-taking strategies
    - » Watch a math test-taking strategies video by the EKU Student Success Center

Learning-Strategy Instruction (LSI) in Math Courses

- **In-class discussions and reflections**
  - Class discussion starts with a brief summary of the key takeaway points from the DB assignment (~5 slides provided to instructors)
  - The remainder of the discussion is integrated within the MATH problem(s) covered during the class session.
    - Course-specific example class scripts were developed for instructors to use as starters.

Learning-Strategy Instruction (LSI) in Math Courses

- **Peer tutor presentations**
  - ~5-minute pre-recorded videos created by peer tutors
  - Peer tutors are students who have recently completed the MATH course with outstanding performance
  - Peer tutors discuss the learning strategies they used to succeed in the MATH course
  - Instructors play the video in class and/or post it in the LMS as a discussion board assignment

Research Design

- The study utilizes a **repeated-measures between-subjects** design and a **mixed methods** sequential (two-phase) approach
- **4 sections** in each of the 4 target math courses (College Algebra I/II and Calculus I/II)
  - a treatment group (2 sections) or
  - a control group (2 sections)
- ***Treatment*** students are taught about effective math learning strategies including elaboration, self-testing, effort and time management, and test-taking strategies.
- ***Control*** students, on the other hand, are taught the same course content without any instruction on learning strategies.

Data Collection

- Qualtrics Pre- and Post-Surveys
  - One survey: Math Mindset, Self-Regulated Learning, and Math, Gender and Racial Identities
- Content Knowledge Pre- and Post-Tests
- Students' demographics (gender, PELL status, and residency) and academic profile (STEM status, classification, and GPA) – from institutional records
- Focus Groups

Scales

- Hocker's (2017) modified math mindset scale was used for measuring math mindset.
- Cleary's (2006) Self-Regulation Strategy Inventory–Self-Report (SRSI–SR) was used for measuring SRL.
  - Original SRL scale, validated on a sample of high school students, had three subscales:
    - Managing Environment and Behavior (SRL-1),
    - Maladaptive Regulatory Behaviors (SRL-2), and
    - Seeking and Learning Information (SRL-3).
- Racial identity was measured using Sellers et al.'s (1997) Multidimensional Inventory of Black Identity (MIBI) for Black students and Brown et al.'s (2014) Multigroup Ethnic Identity Measure (MEIM) for non-Black students.
- Gender identity was measured using a modified version of the MIBI scale.
- Math identity was measured using Lock et al.'s (2013) math identity scale.

Preliminary Results

- Data collected in Fall 2022–Spring 2023
- The data comes from 32 sections (16 treatment and 16 control) spanning 4 math courses
  - **551** students (278 control and 273 treatment) completed both the pre- and post-content tests and the pre- and post-attitude surveys

Table 1. *Characteristics of the sample participants by their role in the study.*

Variable	Control: n (%)	Treatment: n (%)
Gender: Female	152 (65.52%)	162 (71.78%)
STEM: Yes	128 (55.17%)	100 (44.25%)
PELL: Yes	208 (89.66%)	199 (88.05%)
Residency: Out-of-State	121 (52.16%)	105 (46.46%)
GPA: >=3.00	93 (56.71%)	107 (68.15%)

Preliminary Results

* SRL-1 = Managing Environment and Behavior

* SRL-2 = Maladaptive Regulatory Behaviors

Table 2. *Estimates of regression coefficients (standard errors) from four regression models with the* response variable shown in the column and explanatory variables shown in the rows.

Explanatory Variable	Mindset Diff	SRL-1Diff	SRL-2 Diff	Performance Diff
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Role: Treatment	0.180 (0.106) ·	0.023 (0.058)	-0.083 (0.074)	-3.924 (2.418)
Mindset Difference	-	-0.003 (0.032)	0.155 (0.040) ***	2.834 (1.348) *
SRL-1 Difference	-0.010 (0.107)	-	0.172 (0.074) *	3.281 (2.414)
SRL-2 Difference	0.319 (0.082) ***	0.107 (0.046) *	-	4.438 (1.891) *
Gen Identity Reflection	-0.100 (0.046) *	0.058 (0.025) *	-0.003 (0.032)	0.588 (1.070)
Gen Identity Centrality	0.069 (0.045)	-0.008 (0.025)	0.042 (0.032)	0.503 (1.028)
Racial Identity	0.173 (0.073) *	-0.028 (0.040)	-0.050 (0.051)	-1.932 (1.665)
Math Iden: Competency	0.063 (0.115)	-0.068 (0.063)	-0.121 (0.080)	3.265 (2.619)
Math Iden: Recognition	0.148 (0.072) *	0.013 (0.400)	-0.023 (0.050)	1.524 (1.171)
Math Iden: Interest	-0.178 (0.016) **	0.000 (0.034)	0.093 (0.043) *	-1.450 (1.429)
Gender: Male	0.136 (0.126)	0.046 (0.069)	-0.042 (0.088)	-5.338 (2.880) ·
STEM: Yes	-0.120 (0.125)	-0.053 (0.069)	-0.040 (0.087)	-1.983 (2.861)
GPA	0.014 (0.089)	0.034 (0.049)	-0.009 (0.062)	1.456 (2.003)
PELL: Yes	0.243 (0.178)	0.165 (0.098) ·	-0.090 (0.124)	1.462 (3.665)
Residency: Out-of-State	0.052 (0.110)	-0.031 (0.060)	0.059 (0.076)	-0.699 (2.498)
Class: Sophomore	-0.012 (0.116)	0.004 (0.064)	-0.118 (0.081)	-0.432 (2.646)
Class: Junior	-0.282 (0.242)	0.062 (0.133)	0.166 (0.169)	-4.430 (5.683)
Class: Senior	-0.506 (0.940)	-1.115 (0.513) *	-0.360 (0.655)	-7.612 (20.76)
Course: Algebra II	-0.111 (0.138)	0.021 (0.076)	0.043 (0.096)	8.757 (3.097) **
Course: Calc I	0.081 (0.166)	0.102 (0.091)	0.003 (0.115)	-8.352 (3.765) *
Course: Calc II	-0.003 (0.181)	0.040 (0.099)	0.313 (0.125) *	18.017 (4.166) ***
Adjusted R^2	0.078	0.014	0.088	0.212

Note: Reference category is "Control" for Role, "Female" for Gender, "No" for STEM and PELL, "In-State" for Residency, "Freshman" for Classification, and "Algebra I" for Course.
Significance codes: '***' ≡ P-value <0.001; '**' ≡ P-value <0.01; '*' ≡ P-value <0.05; '·' ≡ P-value <0.1

Preliminary Results

- Accounting for students' SRL, identities, background characteristics, and course, learning-strategy instruction (LSI) **was associated with positive**, yet marginal (coef. = 0.18, p-value = 0.0903), improvement in math growth mindset.

Preliminary Results

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- Accounting for students' math mindset, identities, background characteristics, and course, LSI **was not significantly** associated with changes in SRL.

Preliminary Results

- Accounting for students' SRL, identities, background characteristics, and course, learning-strategy instruction (LSI) **was associated with positive**, yet marginal (coef. = 0.18, p-value = 0.0903), improvement in math growth mindset.
- Accounting for students' math mindset, identities, background characteristics, and course, LSI **was not significantly** associated with changes in SRL.
- Both gains in math mindset and gains in SRL-2 **were positively associated** with gains in students' performance on the content tests (Mindset: coef. = 2.83, p=0.0364; SRL-2: coef. 4.44, p=0.0197)
  - but LSI **was not significantly associated** with performance gains.

Preliminary Results

- Correlation analyses were conducted to test the bidirectional association in **RQ3**.
- **Bivariate Pearson correlation analysis** between students' math mindset scores and SRL scores showed that
  - students' initial mindset and SRL scores **were positively correlated** with their post-semester mindset and SRL scores
    - mindset: cor. = 0.53, $p < 0.001$
    - SRL-1: cor. = 0.69, $p < 0.001$
    - SRL-2: cor. = 0.50, $p < 0.001$
  - students' post-semester mindset score **was positively correlated** with their initial SRL-2 scores (cor. = 0.36, $p < 0.001$) but not their initial SRL-1 score.

Preliminary Results

- Correlation analyses were conducted to test the bidirectional association in **RQ3**.
- **Cross-lagged correlation analysis** revealed that
  - students' initial math mindset **was not predictive** of their end-of-semester SRL (SRL-1: coef. = 0.004, p = 0.8720; SRL-2: coef. = 0.041, p = 0.1750) given their pre-semester SRL score.
  - only students' initial SRL-2 **was predictive** of their end-of-semester math mindset (coef. = 0.291, p <0.0001) given their pre-semester math mindset.

Next Steps

- **Qualitative data (Focus Groups) analysis**
- **Retrospective pretest-posttest approach**
  - Fall 2023/Spring 2024
  - Accounts for the fact that students may tend to overestimate their math growth mindset, SRL, and math identity
- **Explore additional factors**
  - Instructor, attendance, participation in DB and class reflections, etc.
- **Evaluate if/how students use learning strategies in future STEM courses**

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References I

Brown, S.D., Unger Hu, K.A., Mevi, A.A., Hedderson, M.M., Shan, J., Quesenberry, C.P., & Ferrara, A. (2014). The Multigroup Ethnic Identity Measure–Revised: Measurement invariance across racial and ethnic groups. *Journal of Counseling Psychology*, 61(1), 154.

Carver, S.D., Sickle, J.V., Holcomb, J.P., Jackson, D.K., Resnick, A., Duffy, S.F., Sridhar, N., & Marquard, A. (2017). Operation STEM: increasing success and improving retention among mathematically underprepared students in STEM. *Journal of STEM Education*, 18(3):30-39.

Cleary, T. (2006). The development and validation of the self-regulation strategy inventory–self-report. *Journal of School Psychology*, 44(4):307-322.

Donker, A.S., de Boer, H., Kostons, D., Dignath van Ewijk, C.C., & van der Werf, M.P. (2014). Effectiveness of learning strategy instruction on academic performance: A meta-analysis. *Educational Research Review*, 11:1–26.

Dweck C.S. (2000). *Self-theories: Their roles in motivation, personality and development*. Psychology Press, New York.

Hocker, T. (2017). A study of perceptions of math growth mindset, math anxiety, and view of math by young adults. PhD Thesis, Southeastern University.

References II

Lock, R.M., Hazari, Z., & Potvin, G. (2013). Physics career intentions: The effect of physics identity, math identity, and gender. *AIP Conf. Proc.,* 1513: 262–265

Pressley, M., Goodchild, F., Fleet, J., & Zajchowski, R. (1989). The challenges of classroom strategy instruction. *Elementary School Journal*, 89:301–342.

Sellers, R.M., Rowley, S.A., Chavous, T.M., Shelton, J.N., & Smith, M.A. (1997). Multidimensional Inventory of Black Identity: A preliminary investigation of reliability and construct validity. *Journal of personality and social psychology*, 73(4), 805.

Sun, K.L. (2015). There's no limit: Mathematics teaching for a growth mindset. PhD Thesis, Stanford University.

Weinstein, C.E., Husman, J., & Dierking, D.R. (2000). Self-regulation interventions with a focus on learning strategies. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), Handbook of Self-regulation: Theory, research, and applications, 727-747. Academic Press, San Diego, CA.

Zimmerman, B.J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), Handbook of self-regulation,13-39. Academic Press, San Diego, CA.

THANK YOU!