Effects of a Learning-Strategy Instruction Intervention on Growth Mindset and Self-Regulation in Introductory Mathematics Courses

Joint Mathematics Meetings
January 08, 2025

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Outline

- Background
  - Math growth mindset
  - Self-regulated learning (SRL)
  - Learning strategies
- Research Framework & Questions
- Learning-Strategy Instruction in Gateway Math Courses
  - Implementation
- Year-2 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).

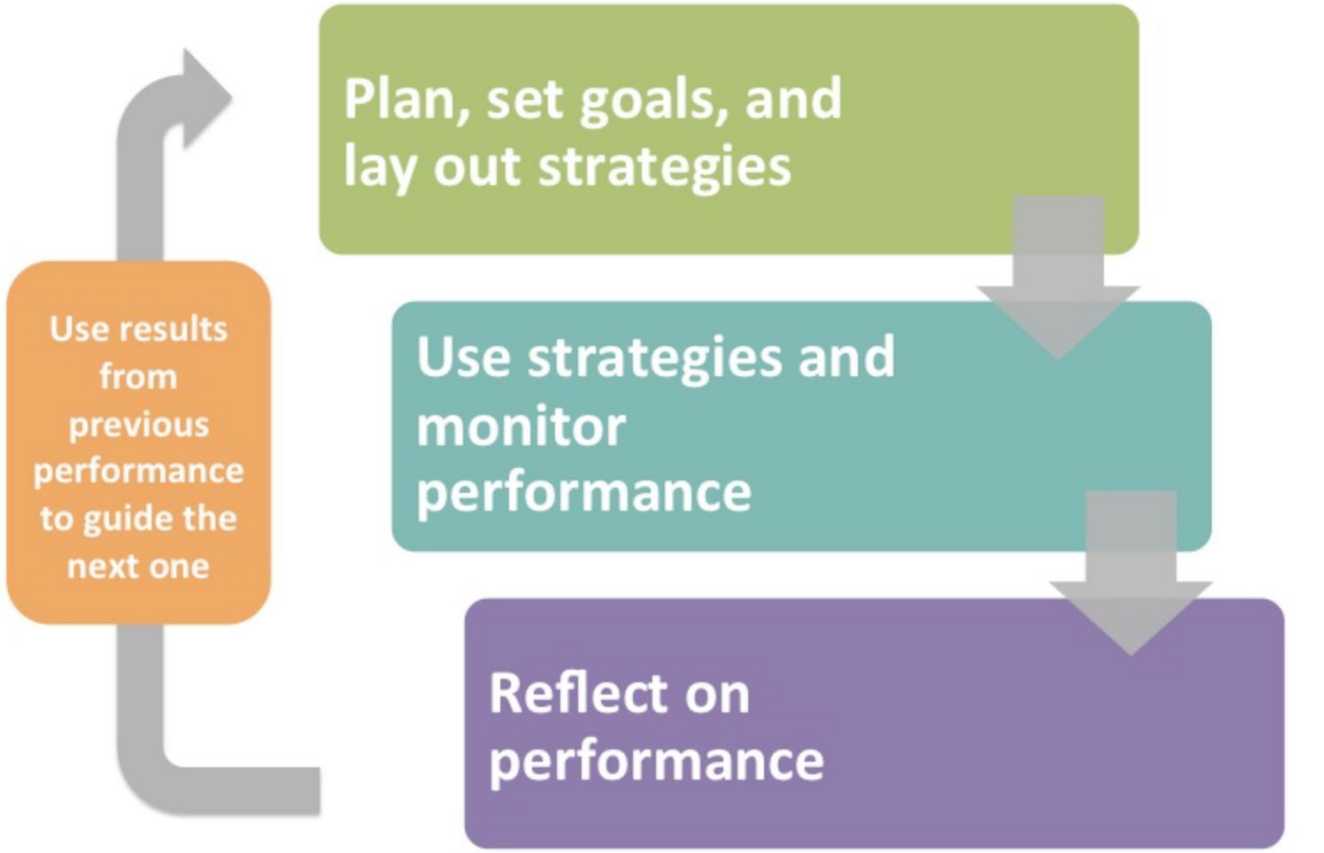
- Students who have a growth mindset are more likely to use new strategies and change their approach when hitting a roadblock, which is vital for success in the math classroom (Dweck, 2008).

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

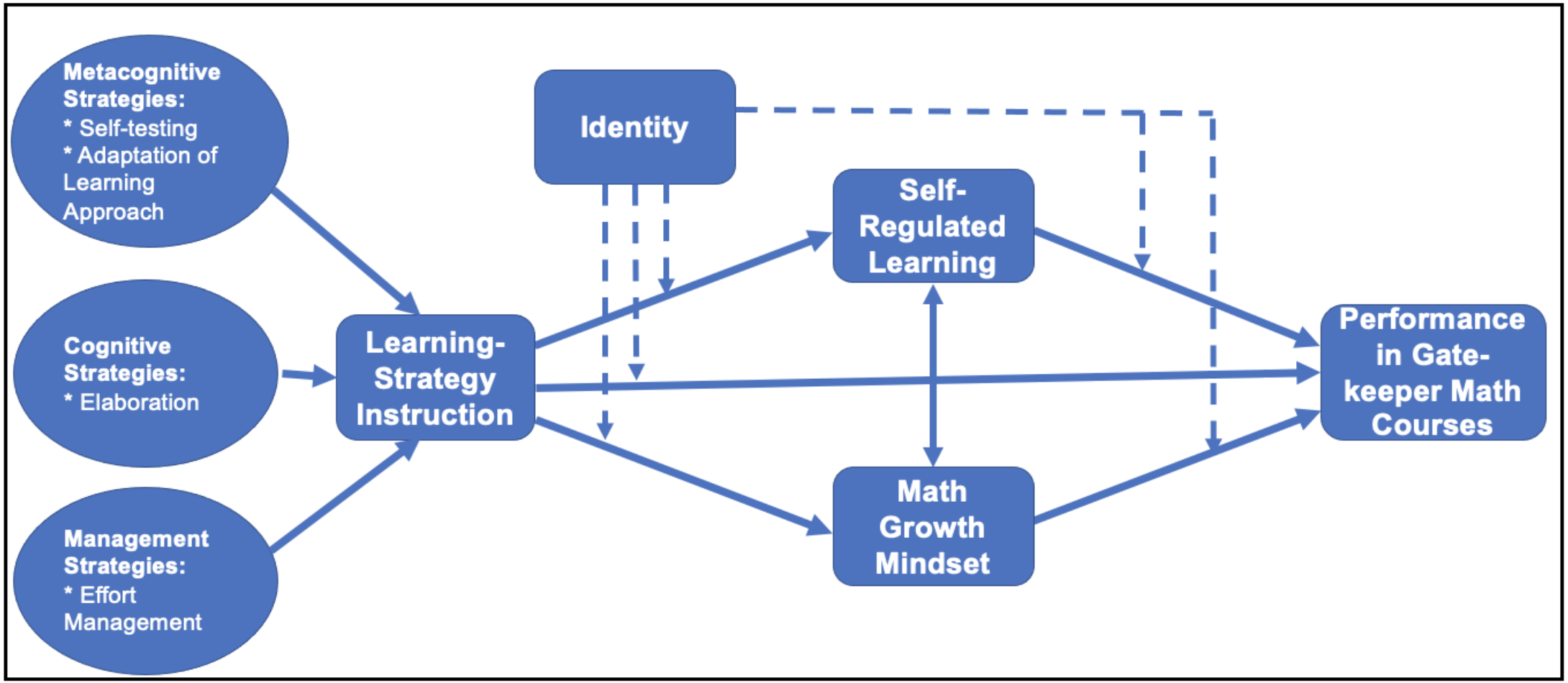


Learning Strategies

- **Types of Learning Strategies**:
  - Cognitive Strategies
  - Metacognitive Strategies
  - Management 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?

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

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 Surveys**
  - **<u>One survey</u>: Math Mindset, Self-Regulated Learning, and Math, Gender and Racial Identities**
  - **Regular Pre-Post Approach:** Student completed pre-survey at the beginning of semester and post-survey at the end of semester
  - **Retrospective Pre-Post Approach:** Student responded to 2 statements of each question; one of the statements reflected on the pre-semester attitude and the other reflected on the end of semester attitude
    - Accounts for the fact that students may tend to overestimate their math growth mindset, SRL, and math identity
- **Students' demographics (gender, PELL status, and residency) and academic profile (STEM status, classification, and GPA) – from institutional records**

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.

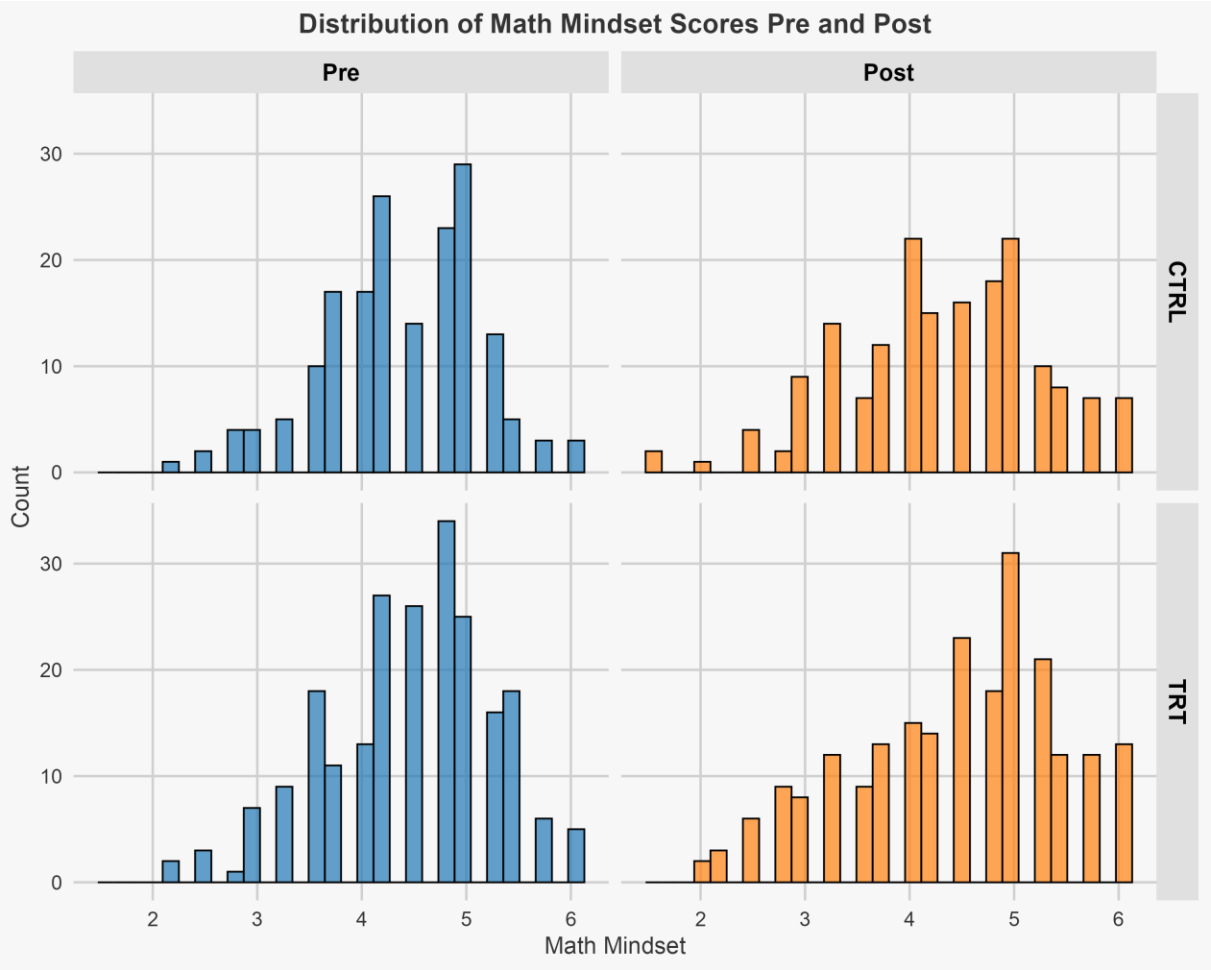
Results

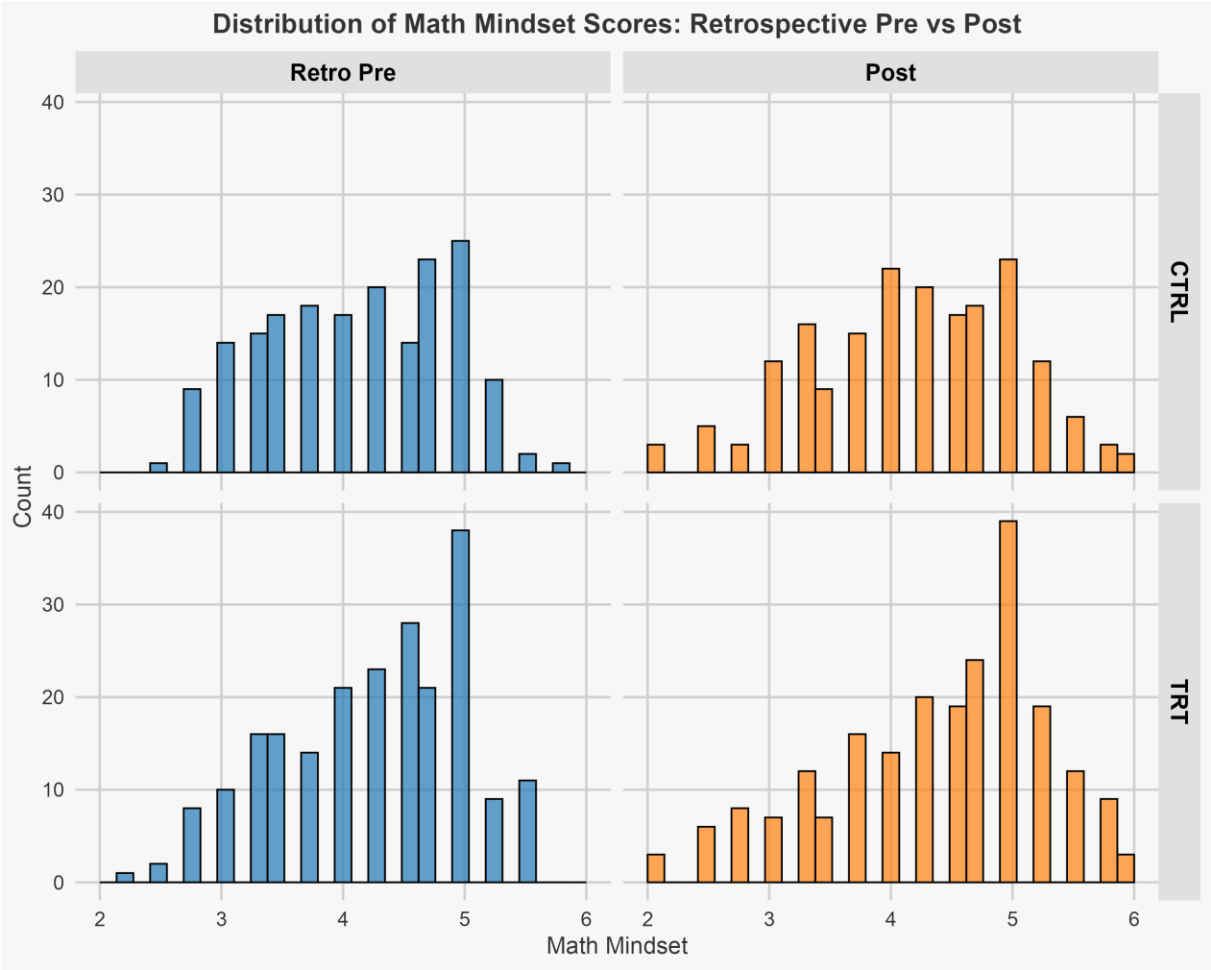
- Data collected in Fall 2023–Spring 2024
- The data comes from 34 sections (17 treatment and 17 control) spanning 4 math courses
  - **512** students (220 control and 292 treatment) completed the pre- and post-attitude surveys
  - In Fall 2023 we had one additional instructor in Calc I.

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

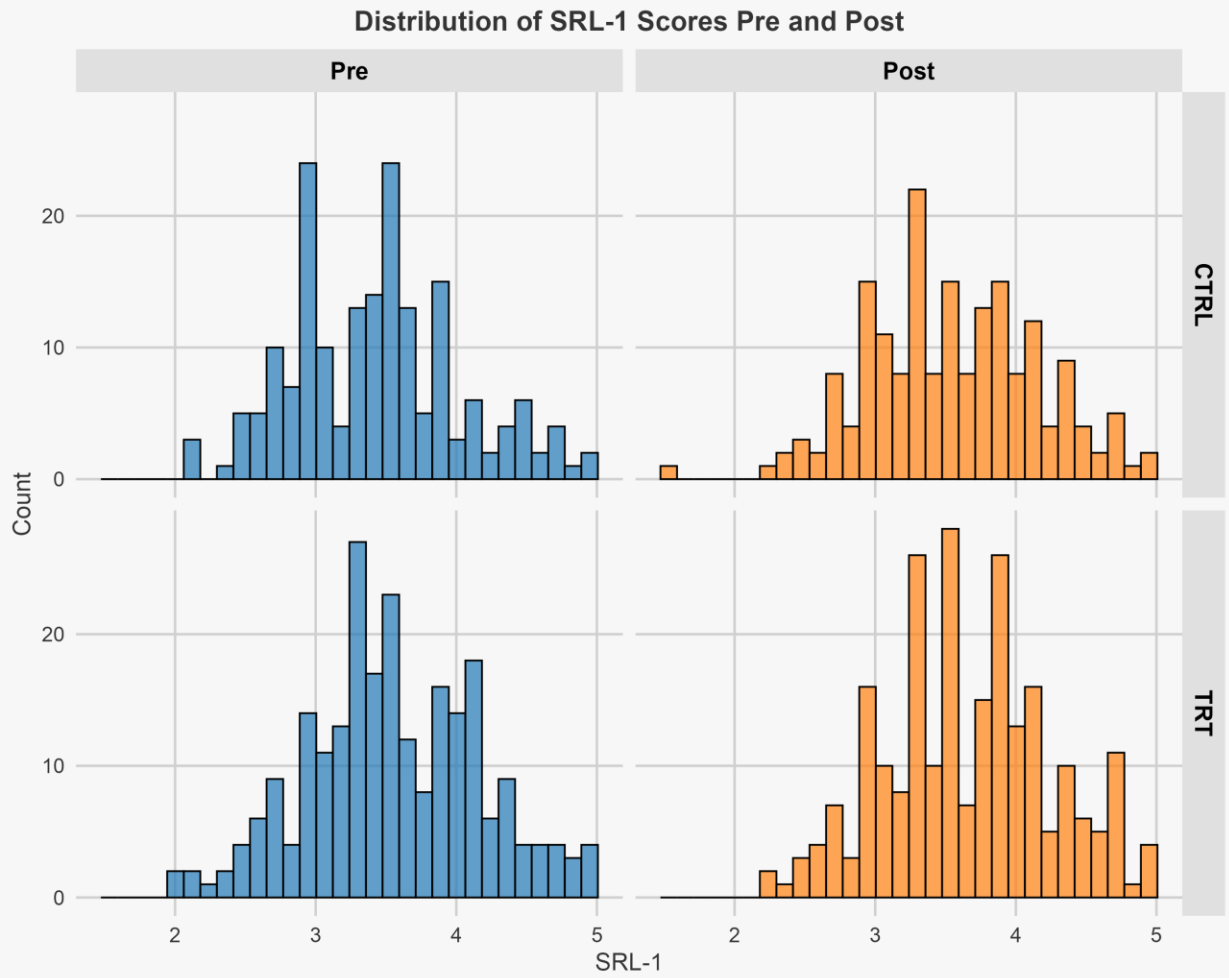
Variable	Control: n (%)	Treatment: n (%)
Gender: Female	123 (55.91%)	182 (62.33%)
STEM: Yes	140 (63.64%)	156 (53.42%)
PELL: Yes	100 (45.45%)	127 (43.49%)
Residency: Out-of-State	105 (47.73%)	122 (41.78%)
GPA: >= 3.00	74 (73.27%)	118 (64.84%)
Classification: Sophomore	63 (29.17%)	86 (30.28%)
Classification: Junior	14 (6.48%)	23 (8.10%)
Classification: Senior	1 (0.46%)	4 (1.41%)

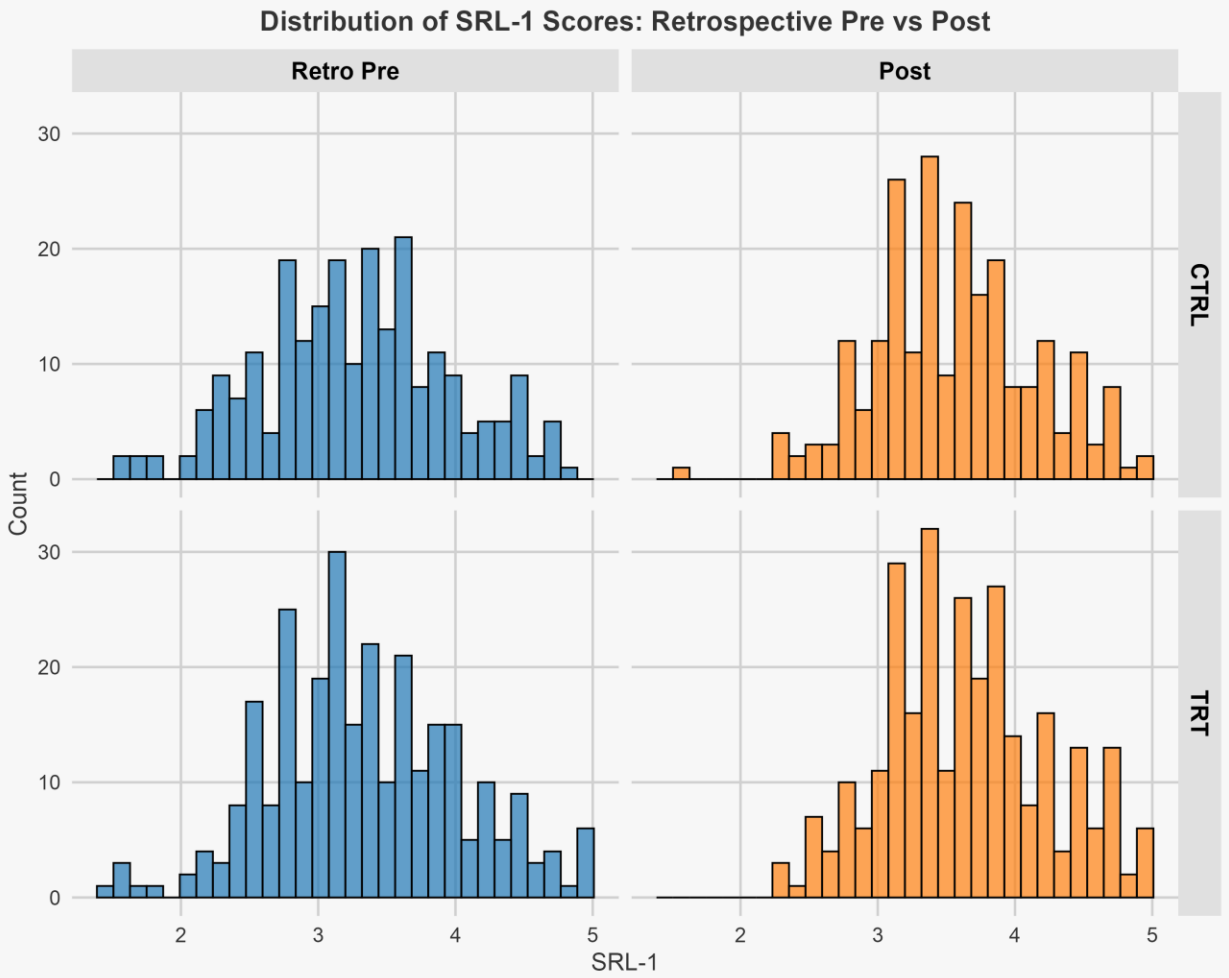
Mindset Distribution



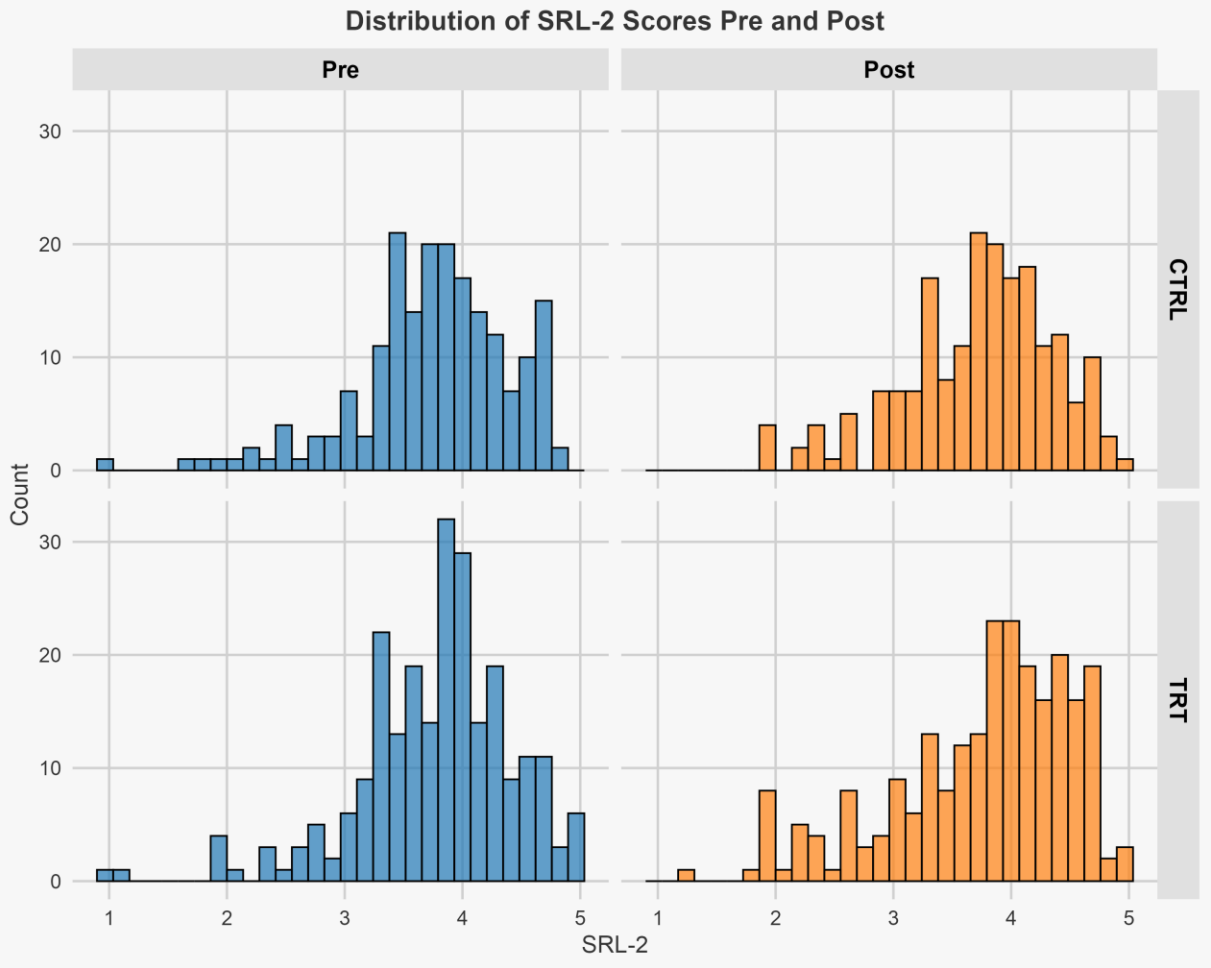


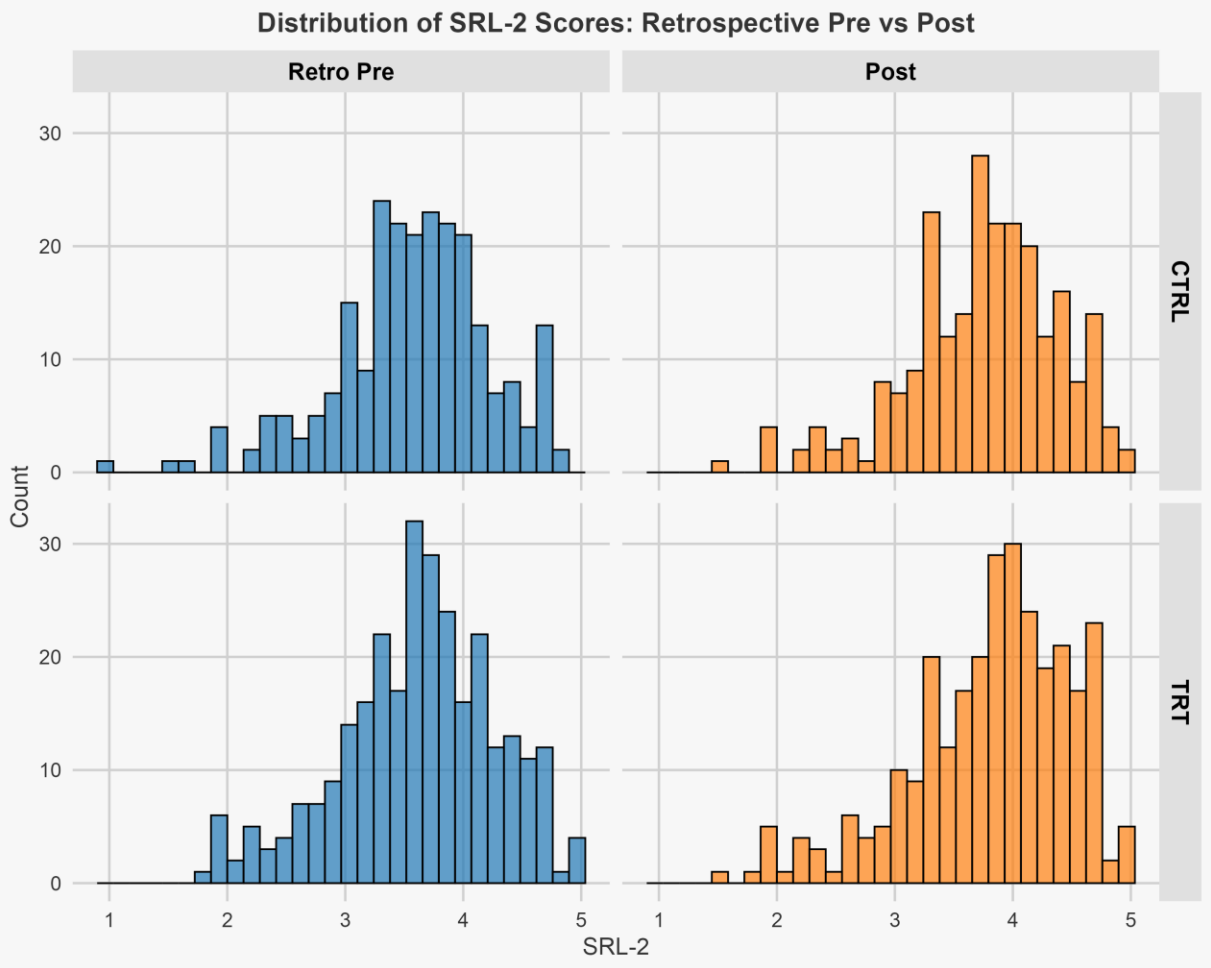
SRL-1 Distribution





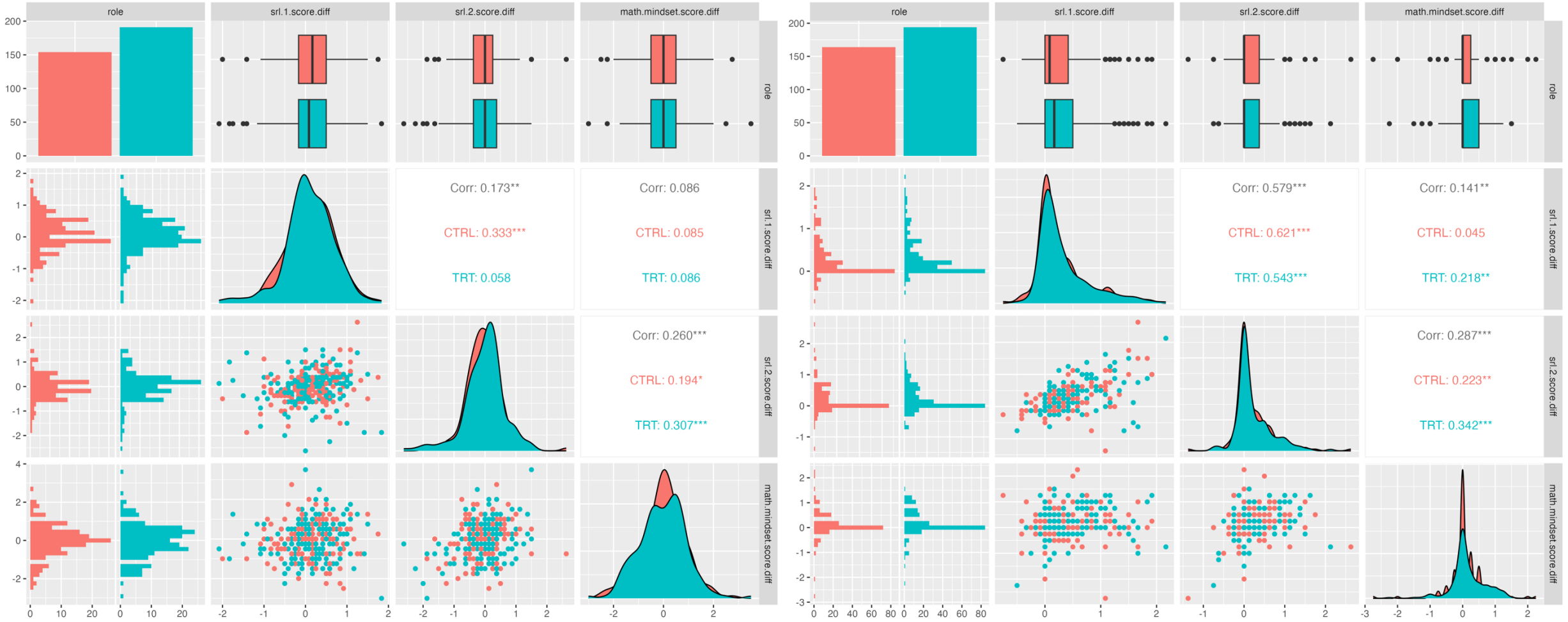
SLR-2 Distribution





Regular

Retrospective



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. = 0.80, $p < 0.001$
    - SRL-1: cor. = 0.71, $p < 0.001$
    - SRL-2: cor. = 0.75, $p < 0.001$
  - students' post-semester mindset score **was positively correlated** with their initial SRL-2 scores (cor. = 0.31, $p < 0.001$) but not their initial SRL-1 score.

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. = 0.018, p = 0.4980; SRL-2: coef. = 0.035, p = 0.2340) given their pre-semester SRL score.
  - students' initial SRL score **was not predictive** of their end-of-semester math mindset (SRL-1: coef. = 0.028, p = 0.5127: SRL-2: coef. = 0.047, p = 0.3210) given their pre-semester math mindset.
  - The above results hold regardless of the condition (CTRL, TRT)

Results

* SRL-1 = Managing Environment and Behavior

* SRL-2 = Maladaptive Regulatory Behaviors

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

Explanatory Variable	Mindset Post	SRL-1 Post	SRL-2 Post
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Role: Treatment	-0.027 (0.125)	-0.021 (0.082)	-0.120 (0.079)
Mindset Score Pre	0.915 (0.094) ***	-0.069 (0.06)	0.060 (0.056)
SRL-1 Score Pre	-0.264 (0.124) *	0.549 (0.076) ***	–
SRL-2 Score Pre	-0.008 (0.136)	0.148 (0.075) .	0.885 (0.072) ***
MIBI Gender: Reflection	0.080 (0.055)	0.008 (0.035)	-0.025 (0.033)
MIBI Gender: Centrality	-0.008 (0.066)	-0.015 (0.041)	-0.079 (0.037) *
MIBI Racial: Score	0.046 (0.089)	0.067 (0.056)	0.008 (0.054)
Math Iden: Competency	0.418 (0.119) ***	0.242 (0.075) **	0.144 (0.072) .
Math Iden: Recognition	-0.083 (0.078)	-0.060 (0.050)	-0.080 (0.047) .
Math Iden: Interest	0.058 (0.079)	0.046 (0.053)	0.013 (0.05)
Gender: Male	-0.049 (0.147)	-0.003 (0.095)	-0.011 (0.094)
STEM: Yes	0.379 (0.158) *	0.070 (0.101)	0.077 (0.094)
GPA	-0.027 (0.148)	0.011 (0.093)	-0.018 (0.088)
PELL: Yes	-0.181 (0.129)	-0.009 (0.082)	-0.185 (0.079) *
Residency: Out-of-State	-0.109 (0.13)	-0.062 (0.082)	-0.001 (0.084)
Class: Sophomore	0.118 (0.239)	0.209 (0.15)	-0.038 (0.134)
Class: Junior	0.093 (0.28)	0.150 (0.173)	-0.119 (0.161)
Class: Senior	-0.011 (0.575)	0.378 (0.362)	-0.229 (0.363)
Intsructor: C	-0.370 (0.684)	-0.997 (0.421) *	-0.682 (0.406) .
Intsructor: D	0.023 (0.404)	-0.436 (0.259) .	-0.339 (0.224)
Intsructor: E	-0.255 (0.453)	-0.487 (0.283) .	-0.305 (0.245)
Intsructor: F	-0.217 (0.647)	-0.892 (0.406) *	-0.543 (0.398)
Intsructor: G	-0.325 (0.511)	-0.618 (0.323) .	-0.307 (0.298)
Intsructor: H	-0.342 (0.427)	-0.566 (0.265) *	-0.461 (0.226) *
Intsructor: J	-0.236 (0.424)	-0.551 (0.266) *	-0.236 (0.232)
Intsructor: K	-0.131 (0.435)	-0.203 (0.271)	-0.286 (0.238)
Adjusted R^2	0.723	0.726	0.706

Note: Reference category is “Control” for Role, “Female” for Gender, “No” for STEM and PELL, “In−State” Residency, “Freshman” for Classification, "A" for Instructor.
Significance code ′***′ ≡ P−value < 0.001; ′**′ ≡ P−value < 0.01; ′*′ ≡ P−value < 0.05; ′.′ ≡ P−value

Results

- Accounting for students' pre-course math mindset score, SRL scores, identities, background characteristics, and instructor, learning-strategy instruction (LSI) **was not significantly associated with post-course math mindset score** (coef. = -0.027, p-value = 0.8311).
- Accounting for students' pre-course math mindset score, SRL scores, identities, background characteristics, and instructor, LSI **was not significantly associated with post-course SRL scores** (SRL-1: coef. = -0.021, p-value = 0.7958; SRL-2: coef. = -0.120, p-value = 0.1350).
- Instructor effect: relative to the baseline instructor, negative or non-significant coefficients indicate LSI has less or no improvement when compared to the reference instructor.

Next Steps

- **Investigate the impact of intervention on the learning strategy instruction of students' course performance**
  - Year-2: Fall 2023/Spring 2024
- **Qualitative data (Focus Groups) analysis for Year-2**
- **Evaluate if/how students use learning strategies in future STEM courses**

Acknowledgements

- **Funding**: work is part of a Broadening Participation Research Project supported by a National Science Foundation Grant No. 2107285.
  - For more info, see the project's website: https://mathlsincat.github.io

- **Collaborators**: We would like to thank other members of the PI team (Drs. Kalynda Smith, Nicholas Luke, and Sayed Mostafa) and course instructors who implemented the LSI project in their course sections.

A. Managing environment and behavior (Factor I)

1. I make sure no one disturbs me when I study
8. I make a schedule to help me organize my study time
28. I finish all of my studying before I play video games or with my friends
2. I try to study in a quiet place
27. I think about how best to study before I begin studying
16. I try to study in a place that has no distractions (e.g., noise, people talking)
7. I quiz myself to see how much I am learning during studying
6. I study hard even when there are more fun things to do at home
24. I tell myself to keep trying when I can't learn a topic or idea
9. I use binders or folders to organize my science study materials
21. I tell myself exactly what I want to accomplish during studying
25. I carefully organize my study materials so I don't lose them

C. Maladaptive regulatory behavior (Factor III)

20. I forget to bring home my science materials when I need to study
11. I avoid going to extra-help sessions in science
10. I lose important science dittos or materials
19. I give up or quit when I do not understand something
26. I let my friends interrupt me when I am studying
23. I avoid asking questions in class about things I don't understand
12. I wait to the last minute to study for science tests
13. I try to forget about the topics that I have trouble learning

B. Seeking and learning information (Factor II)

17. I ask my teacher questions when I do not understand something
14. I try to see how my notes from science class relates to things I already know
18. I make pictures or drawings to help me learn science concepts
22. I look over my homework assignments if I don't understand something
3. I think about the types of questions that might be on a test
4. I ask my science teacher about the topics that will be on upcoming tests
5. I rely on my science class notes to study
15. I try to identify the format of upcoming science tests

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!