

# Relations Among Students' Experience of the Math Error Climate, Math Identity, and Math Problem-Solving Performance



Maegan A. Reinhardt<sup>1</sup>, Isabel Valdivia<sup>1</sup>, Jisun Kim<sup>1</sup>, Tamika L. McElveen<sup>2</sup>, Amanda S. Mayes<sup>3</sup>, Dana Miller-Cotto<sup>4</sup>, Eric D. Wilkey<sup>5</sup>, Andrew D. Ribner<sup>6</sup>, Nydia Prishker<sup>7</sup>, Ma Bernadette Andres-Salgarino<sup>8</sup>, Sarah R. Powell<sup>9</sup>, Sara A. Schmitt<sup>10</sup>, David J. Purpura<sup>3</sup>, & Caroline Byrd Hornburg<sup>1</sup>

<sup>1</sup>Virginia Tech, <sup>2</sup>Miami University, <sup>3</sup>Purdue University, <sup>4</sup>Kent State University, <sup>5</sup>Vanderbilt University, <sup>6</sup>Chatham University, <sup>7</sup>St. Thomas Aquinas College, <sup>8</sup>Santa Clara County Office of Education, <sup>9</sup>The University of Texas at Austin, <sup>10</sup>University of Oregon



## Introduction

- Less than 30% of 4th graders demonstrate math problem-solving proficiency. Scores overall have declined since COVID-19.<sup>1</sup>
- Making errors is a key part of the learning process and a helpful instructional tool, particularly in a math context.<sup>2</sup>
- Error analysis is a helpful instructional tool for teachers to identify where a student is struggling, for example with the mechanics of a particular skill or with mathematical sense-making in general.<sup>4,5</sup>
- Functionality of errors for learning is an aspect of classroom error climate that describes the extent to which errors are used to support learning processes in the classroom.<sup>3</sup>
- Actual teacher responses to student errors vary rather widely.<sup>3</sup> These responses create a climate that may welcome errors and encourage students to learn from them or discourage mistakes as something to be avoided.

## The Present Study

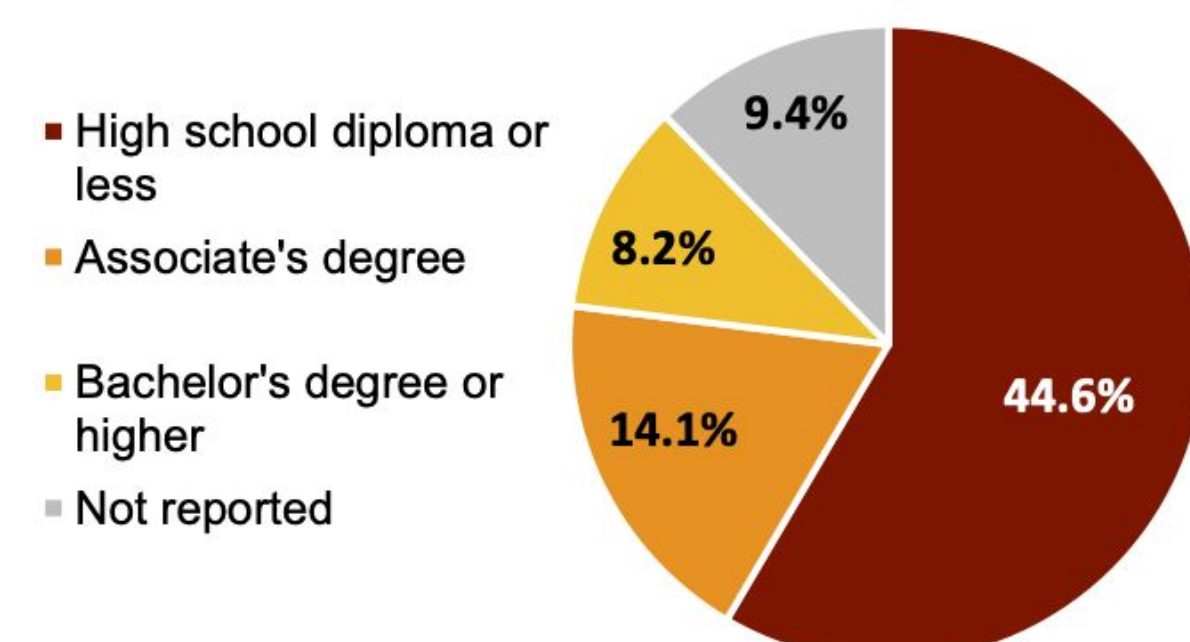
This study examined relations among 3rd-5th grade students' experience of the math error climate, math identity (i.e., self-perceptions of math), and math problem-solving proficiency.

## Method

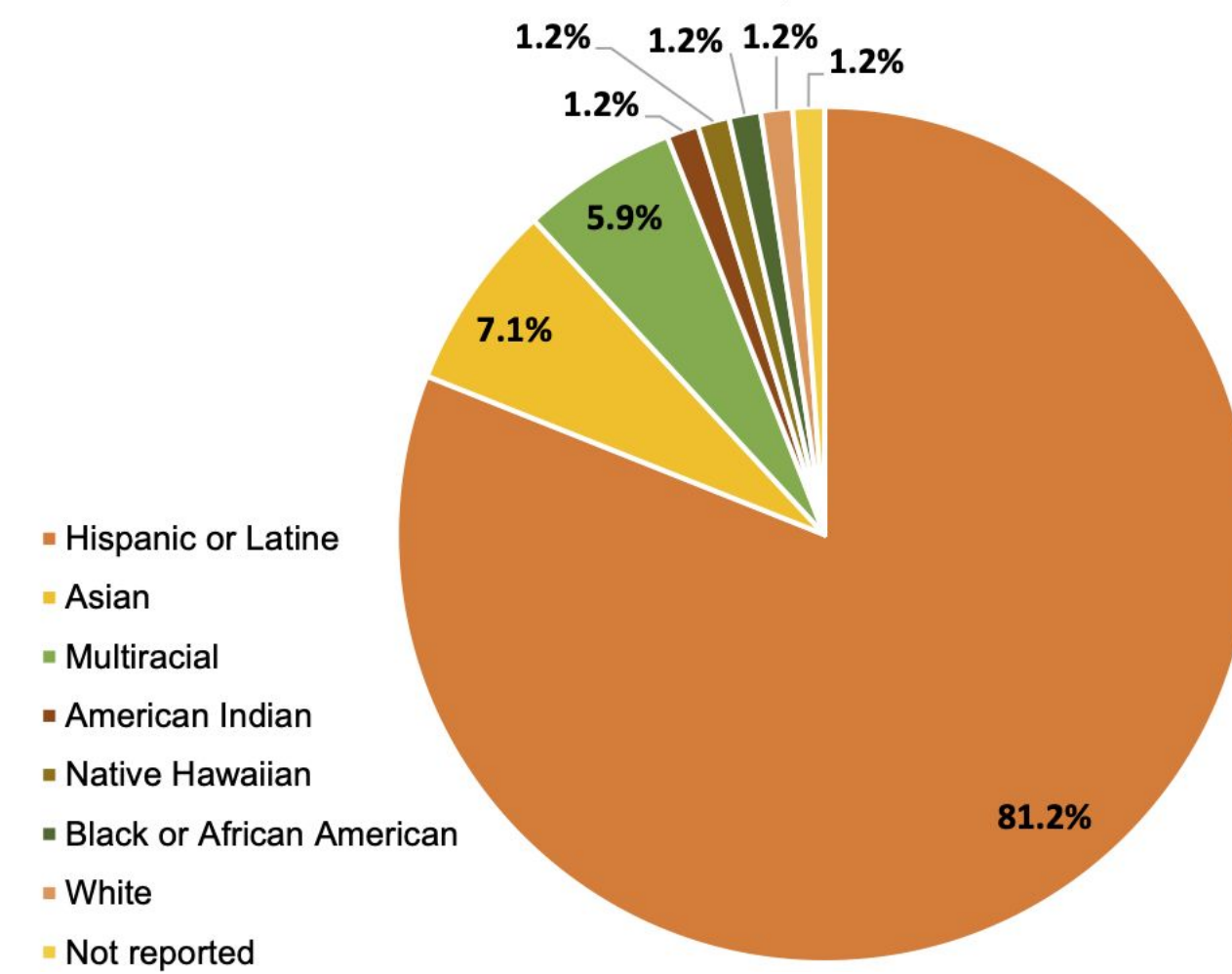
### Participants:

- 85 students from 6 classrooms at one school in California
- 17 3rd graders; 36 4th graders; 32 5th graders
- 36 male; 49 female

### Highest Parent Education



### Participant Race



Researchers administered the measures below in students' classrooms in either November 2022 or February 2023 as pretests for a pilot study of the "Our Mathematical World" program.

### Math Error Climate

- Adapted from the Functionality of Errors for Learning subscale of the Error Climate Measure<sup>6</sup> with 4-point Likert-type responses (No [0], Not Really [1], Kind of [2], Yes [3])
  - Example: In our math class, wrong answers on assignments are used to learn something.

### Math Identity

- Adapted from the Math Identity Measure<sup>7</sup> with 4-point Likert-type responses (as above).
- Subscales included interest, recognition and competence. Example items:
  - I enjoy learning math (interest)
  - My friends see me as a math person (recognition)
  - I can overcome challenges in math (competence)

### Problem Solving

- 6 single-step word problems, adapted from Powell et al. (2020),<sup>8</sup> coded for error type<sup>9</sup>
- Schemas of total ( $N = 2$ ), change ( $N = 1$ ), difference ( $N = 1$ ), equal groups ( $N = 2$ ):
  - **Total:** The animal park has 68 tigers and some giraffes. If the total number of tigers and giraffes is 99, how many giraffes are there?
  - **Change:** Sofia bought 34 beads at the bead store. For a bracelet, she used some of the beads. Now she has 19 beads. How many beads did Sofia use for the bracelet?
  - **Difference:** Kavon rode the roller coaster 44 times. His brother rode the roller coaster 25 times. How many fewer times did Kavon's brother ride the roller coaster?
  - **Equal groups:** Mr. Lopez sold 5 boxes of peaches at the farmer's market. Each box holds 12 peaches. How many peaches did Mr. Lopez sell?

## Results

Relations Among Error Climate, Math Identity, and Problem-Solving Performance

Variable	1	2	3	4	5	N	M	SD	Range
1. Error Climate	-					84	2.39	0.67	0.33-3.00
2. Math Identity (full scale)	.25*	-				85	2.25	0.54	0.93-3.00
3. Math Identity (interest)	.30**	.73***	-			85	2.44	0.55	1.00-3.00
4. Math Identity (recognition)	.11	.88***	.54***	-		85	2.08	0.79	0.00-3.00
5. Math Identity (competence)	.29**	.79***	.46***	.45***	-	85	2.33	0.57	0.67-3.00
6. Problem-Solving Performance	-.08	-.06	-.10	-.15	.09	85	3.20	2.08	0.00-6.00

Note. Controlling for grade.

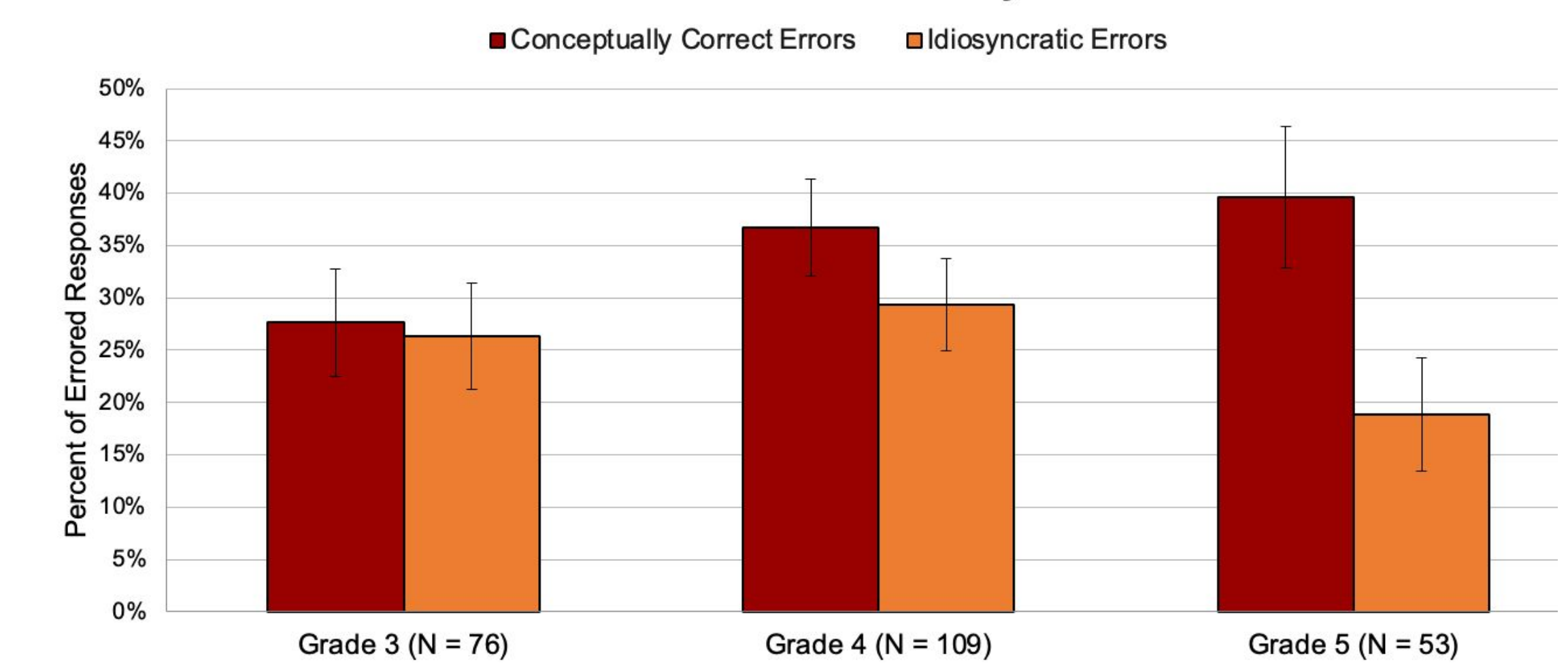
\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

- Students' perception of the error climate was significantly related to their math identity ( $r = .25$ ,  $p = .02$ ), but not problem-solving performance ( $p = .48$ ), controlling for grade.
- Error climate was related to the interest ( $r = .30$ ,  $p = .006$ ) and competence ( $r = .29$ ,  $p = .009$ ) subscales of math identity, but not the recognition subscale ( $r = .11$ ,  $p = .31$ ).

### Error Climate and Problem-Solving Errors

- Examination of students' errors by problem schema and their own positive (vs. negative) error climate revealed no significant associations among these variables.

Error Patterns Across Problems by Grade Level



### Problem-Solving Patterns

- Overall problem-solving performance increased by grade.
- Among incorrect responses, errors indicating correct conceptual understanding (e.g., computation errors) increased by grade, as idiosyncratic errors (i.e., incorrect answers where no work is shown and process cannot be inferred) decreased.

### Limited Variability of Error Climate

- 76% of participants indicated an overall positive error climate (conceptualized as a score of at least 2 on the Error Climate measure).

## Discussion

- Classroom error climate was positively correlated with students' math identity. It seems that an error climate that emphasizes the functionality of errors as part of the learning process is associated with stronger math identity.
  - No relation was found between error climate and problem-solving performance or error types. It may be that no relation exists; however, there was limited variance in error climate, with most students reporting a positive error climate. It may be that an effect would be seen in a sample with more negative error climate.
  - Among subscales of math identity, error climate was positively correlated with interest and competence, but not recognition. This is consistent with normalizing errors as functional,<sup>6</sup> as this relates to interest and competence aspects of motivation. Functionality of errors would not necessarily relate to the recognition of oneself as a "math person."
  - Proportion of errors indicating conceptual understanding increased by grade, as overall error rate decreased, suggesting that these errors may represent part of the learning process.
- ### Limitations and Future Directions
- This study only examined single-step problems at one time point; further research should examine the relation to multi-step problem solving, as well as students' response to interventions, which can inform the use of error climate as a tool in math instruction.
  - There was limited variation in error climate among our participants (ceiling effect). Examining these relations in a sample of students with a more diverse experience of classroom error climate may yield additional findings.

## References

1. National Assessment of Educational Progress (2022). <https://nces.ed.gov/nationsreportcard/>
2. Steuer, G., & Dresel, M. (2015). A constructive error climate as an element of effective learning environments. *Psychological Test and Assessment Modeling*, 57(2), 262-275.
3. Tulis, M. (2013). Error management behavior in classrooms: Teachers' responses to student mistakes. *Teaching and Teacher Education*, 33, 56-68. <https://doi.org/10.1016/j.tate.2013.02.003>
4. Reusser, K. (2000). Success and failure in school mathematics: Effects of instruction and school environment. *European Child & Adolescent Psychiatry*, 9(2), S17-S26. <https://doi.org/10.1007/s007870070006>
5. Soncini, A., Visintin, E. P., Matteucci, M. C., Tomasetto, C., & Butera, F. (2022). Positive error climate promotes learning outcomes through students' adaptive reactions towards errors. *Learning and Instruction*, 80, 101627. <https://doi.org/10.1016/j.learninstruc.2022.101627>
6. Steuer, G., Rosentritt-Brunn, G., & Dresel, M. (2013). Dealing with errors in mathematics classrooms: Structure and relevance of perceived error climate. *Contemporary Educational Psychology*, 38(3), 196-210. <https://doi.org/10.1016/j.cedpsych.2013.03.002>
7. Cribbs, J. D., Hazari, Z., Sonnent, G., & Sadler, P. M. (2015). Establishing an explanatory model for mathematics identity. *Child Development*, 86(4), 1048-1062. <https://doi.org/10.1111/cdev.12363>
8. Powell, S. R., Berry, K. A., & Tran, L. M. (2020). Performance differences on a measure of mathematics vocabulary for English learners and non-English learners with and without mathematics difficulty. *Reading & Writing Quarterly*, 36(2), 124-141. <https://doi.org/10.1080/10573569.2019.1677538>
9. Kingsdorf, S., & Krawec, J. (2014). Error analysis of mathematical word problem solving across students with and without learning disabilities. *Learning Disabilities Research & Practice*, 29(2), 66-74. <https://doi.org/10.1111/ldrp.12029>

## Acknowledgments

Thanks to participating students, parents, teachers, and school staff. The research reported here was supported by the EF+Math Program of the Advanced Education Research and Development Fund (AERDF) through funds provided to Purdue University. The opinions expressed are those of the authors and do not represent views of the EF+Math Program or AERDF.