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Charles A. Dana Center

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Accelerating Underprepared Students' Completion in Quantitative Reasoning Through Holistic Developmental Mathematics Reform

This summary is part of the Charles A. Dana Center's "Notes from the Field" series, which highlights examples of innovative practices from colleges, universities, and systems.

Helping underprepared students complete their introductory college-level mathematics course within the first year of enrollment is key to removing a major barrier to degree completion, especially for traditionally underserved student populations. National data show that only 40 percent of students at universities enroll and complete a gateway mathematics course in their first year.[1] For students identified as underprepared, that number drops to 36 percent in two years.

Just-in-time support, combined with redesigned curricular and pedagogical approaches, for underprepared students results in improved and sustained student success rates.

To address this issue, institutions across the nation are implementing one-semester co-requisite models, which refer to the practice of placing students directly into college-level courses regardless of preparation and providing them with supports for just-in-time instruction.[2] Although there is evidence showing how the implementation and scale of co-requisite models are improving student outcomes, less is known about effective curricular and pedagogical approaches that influence students' completion and success in co-requisite and college-level math courses.

This brief describes how mathematics faculty at California State University, Fresno (Fresno State) used different strategies to better support their underprepared students. After recognizing that past efforts were not producing impactful results, the faculty chose to simultaneously redesign developmental mathematics structures, curriculum, and pedagogical strategies. Promising results from Fresno State's one-semester co-requisite support pilot in Fall 2018 led to fully scaled co-requisite supports for underprepared students.

Background

The California State University (CSU) system is one of the largest higher education systems in the country with 23 campuses and eight off-campus centers. In 2018, the CSU campuses enrolled over 481,000 students, representing the most ethnically, economically, and academically diverse student body in the United States.[3]

Fresno State is located in the city of Fresno in central California, with an approximate student enrollment of 24,139 in Fall 2019. The university's majority–minority student population reflects the diversity of its service region: The three largest student groups are Hispanic (53%), White (18.9%), and Asian American (12.6%). Of new undergraduates, 67.9 percent are first-generation students and 61.2 percent are Pell grant-eligible students.[4]

Challenges

For many years, Fresno State struggled with how best to help its students, particularly first-generation and underrepresented student populations, complete their entry-level mathematics courses for their programs of study. As early as 2014, Fresno State mathematics faculty recognized that remedial mathematics courses offered to students, who arrived as underprepared freshmen for entry-level mathematics, were not working well. Between 2012 and 2016, non-STEM students averaged 71 percent success rates in remedial courses that led to quantitative reasoning coursework. Yet, the multiplicative effect of successive semesters as well as attrition resulted in low numbers of these students' successful completion of their required remedial coursework or entry-level mathematics course.

Dr. Rajee Amarasinghe, the chair of Fresno State's Department of Mathematics, theorized that pedagogical issues could be a contributing factor to these student success rates. He noted, "Remediation used to be lecture-based and, clearly, this was not the best way to prepare our [underprepared] students."[5]

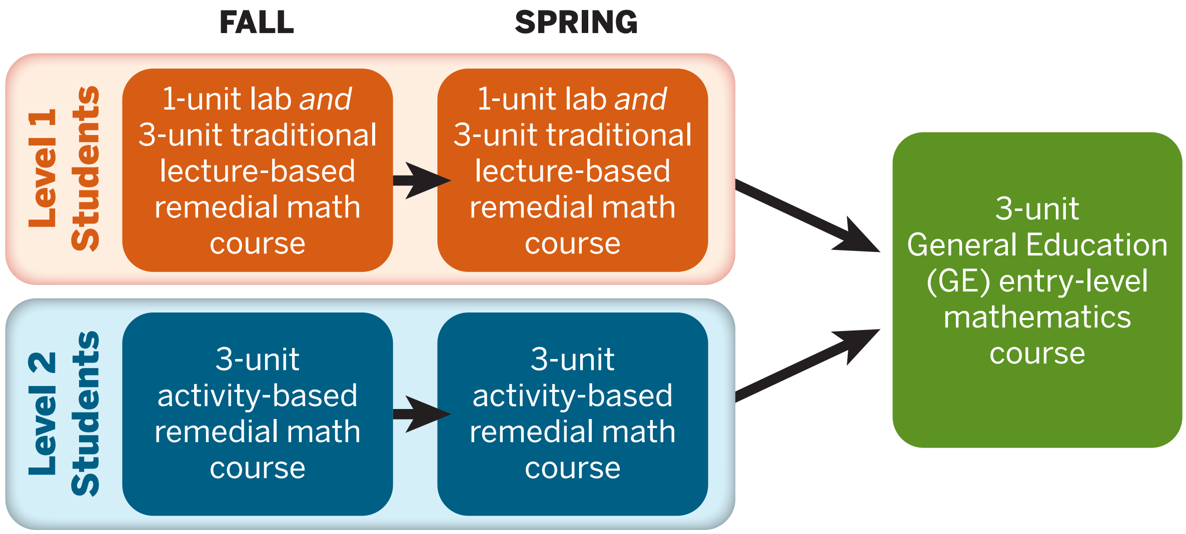
Taking Action

To improve student success for underprepared students, Amarasinghe began trying different remediation strategies, paying special attention to curriculum and pedagogy. In 2014, both STEM and non-STEM underprepared students were most often placed in one of two levels of remedial mathematics based on their placement test scores (see Figure 1). For students placed in the higher level remedial mathematics course (Level 1), a 1-unit[6] lab component was added to the 3-unit traditional lecture-based course. These Level 1 students were required to pass two one-semester remedial mathematics courses before being eligible, in their second year, to take their 3-unit general education (GE) entry-level mathematics course.

Underprepared students who needed significant academic support—identified as Level 2 students—were enrolled in two one-semester, 3-unit remedial mathematics courses that were an activity-based curriculum. These courses relied heavily on small group work delivered by teaching assistants who received training on effective pedagogical practices for facilitating this type of curriculum. Unit credit for both levels of remedial mathematics coursework were not applicable toward Fresno State degree requirements.

Figure 1

Levels 1 and 2 of Remedial Mathematics Coursework Applied Across STEM and non-STEM Programs of Study Students



Favorable student outcomes for the Level 2 activity-based curriculum inspired Fresno State mathematics faculty to collapse the department's multiple levels of remedial coursework for non-STEM students into a yearlong mathematics pathway. This refinement led to the following model: 1 one-semester, 3-unit remedial mathematics course and 1 one-semester credit-bearing, entry-level quantitative reasoning mathematics course called "Math 45–What Is Mathematics?" that was supported by a 1-unit supplemental instruction (SI) support called "Problem-Solving Labs" for underprepared students (see Figure 2). Math 45 is the primary entry-level mathematics course requirement for non-STEM majors.

Figure 2

Refinement of Remedial Mathematics Coursework Applied Only to Non-STEM Programs of Study Students

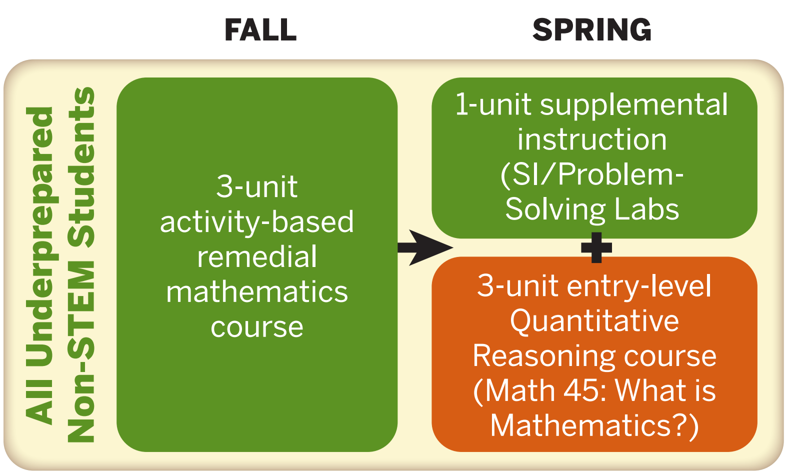


Table 1 shows the remedial course success rates before and after the implementation of problem-solving labs as part of the yearlong mathematics pathway for non-STEM underprepared students.

Table 1

Remedial Course Success Rates for Underprepared Students, 2012–2017

Academic Year	Number of Enrolled Students	Lab/SI Session	Course Success Rates	DFW, NC Average
Spring 2012–Spring 2015	4,813	Problem-Solving Labs not implemented	71.7%	28.3%
Fall 2015–Spring 2016	1,762	Problem-Solving Labs as "optional" resource implemented	70.6%	29.4%
Fall 2016–Fall 2017	1,889	Problem-Solving Labs as required 1-unit of mandatory lab implemented	**77.9%**	**22.1%**

Note. Adapted from Amarasinghe, R. (2019, September 20). Math 4R "Transition to College Mathematics" course gains using Problem-Solving Labs as innovative curricular and pedagogical strategy.

The problem-solving labs emphasized three distinct cognitive and non-cognitive skill areas: requiring practice in basic skills to improve mathematical fluency, providing problem-solving challenges that require deep thinking about mathematics, and improving students' mindsets about mathematics while also improving their study skills.

New Opportunities Shift Fresno State's Focus. As Fresno State shifted its curricular and pedagogical redesign to problem-solving labs, two timely opportunities further shifted the institution's work to support its underprepared students. First, in Summer 2017, California State University Chancellor Timothy White issued an executive order (**EO 1110**) mandating that all first-year students needing academic support be enrolled in a credit-bearing mathematics/quantitative reasoning course with a maximum 1-unit supportive course model (e.g., co-requisite) beginning in Fall 2018. Although the short timeline for implementation presented a host of challenges, Fresno State was optimally positioned to meet this mandate, as the institution had already spent several years planning, implementing, and continuously improving remedial course supports for underprepared students. Second, in June 2017, the university's innovative curricular and pedagogical approach to support underprepared students garnered national attention. Fresno State received a Collaborative Opportunity Grant[7] from the Association of Public and Land-Grant Universities. The $50,000 award supported the continued development and refinement of Math 45 problem-solving labs as part of a yearlong mathematics pathway into a one-semester, 1-unit co-requisite support course, which met the EO 1110 mandate.

The curricular content for problem-solving challenges were developed through a unique collaborative effort among mathematics faculty and teachers from Fresno State and the main feeder community colleges and high schools. A team of 11 educators from across these sectors met regularly during the 2017–18 academic year to design the problem-solving labs. Involving high school faculty established strong K–16 partnerships and ensured that labs would align in structure to the Common Core Performance Tasks familiar to California high school students. This curricular familiarity positioned newly graduated high school students to be more academically prepared to engage with problem-solving challenges that required deeper thinking and reflection about quantitative mathematical concepts.

Fresno State mathematics faculty member Jim Ryan acknowledged the invaluable contributions of high school and community college mathematics faculty in this curricular and pedagogical approach. This collaboration helped create the performance tasks for the problem-solving labs. Ryan also credited the use of a lesson study cycle[8]—a training protocol of cooperative planning, observations, and reflections for teacher development —to train Fresno State mathematics faculty implementing the problem-solving lab curriculum and pedagogical practices.

Through the collaborative effort, many of the community colleges that feed into Fresno State offer the same entry-level quantitative reasoning course (Math 45) and co-requisite support as Fresno State, thus promoting seamless transferability of the mathematics course across higher education institutions.

One-Semester Problem-Solving Lab Co-Requisite Support Findings. In Fall 2018, Fresno State piloted the new one-semester Problem-Solving Lab (PSL) co-requisite support for Math 45 to serve non-STEM underprepared students. The curricular content of the labs comprised performance tasks, worksheet practice, and online computer modules. In presenting the pilot findings, Ryan emphasized the importance of students' becoming comfortable with vocabulary, participating in group discussions, and gaining an understanding of grading rubrics. This comfort level could not be achieved solely through disconnected worksheets drilling concepts without context. Rather, the problem-solving lab curriculum offered performance tasks that encouraged deeper thinking through open-ended problems, requiring students to justify and reflect on their solutions in a group setting.

The Fall 2018 data showed encouraging results for student completion of an entry-level mathematics course in one semester in sections that were taught by instructors who had received training in the new approach. All incoming students had the option to enroll in the PSL co-requisite support course for Math 45 or to complete the course without support. Those who chose to enroll in Math 45 with co-requisite support from a PSL-trained instructor had a course completion rate above 70 percent. Students who enrolled in other Math 45 sections without a PSL-trained instructor, and who did not have co-requisite support, achieved a 63-percent completion rate. In other words, students who received co-requisite support from a trained instructor were able to outperform students who did not have a trained instructor and received no co-requisite support. Students who enrolled in Math 45 without co-requisite support, but who had a trained instructor, achieved an 87.3-percent pass rate. See Table 2 for Fall 2018 pilot results of Math 45 with co-requisite supports.

Table 2

Fall 2018 Pilot of Math 45 With and Without Problem-Solving Lab (PSL) Co-Requisite Support

Fall 2018 Pilot of two sections of Math 45 with and without support				
	Trained Instructor		Non-Trained Instructors	
	Math 45 With PSL co-requisite support	**Math 45** No co-requisite support	**Math 45** Other sections – no co-requisite support	**Total/Average**
Average HS GPA	3.20	3.43	3.42	3.38
#of Sections	1	1	3	5
# of Students Enrolled	208	256	527	991
Completion Rate (%)	**70.7%**	**87.3%**	**63.1%**	**71%**
Average Course Grade	2.15	2.88	2.00	2.26

Note. Adapted from Ryan, J. (2018). Fresno State University Quantitative Reasoning Corequisites presentation [PowerPoint slides].

Data from Fall 2018 to Fall 2019 continued to show positive results. For two out of the three semesters, students with lower GPAs who were enrolled in Math 45 sections with PSL co-requisite support had a pass rate similar to that of students with higher GPAs enrolled in Math 45 sections without PSL co-requisite support. In the remaining third semester, students with lower GPAs enrolled in Math 45 sections with support had a pass rate just 4 percent below that of students with higher GPAs.

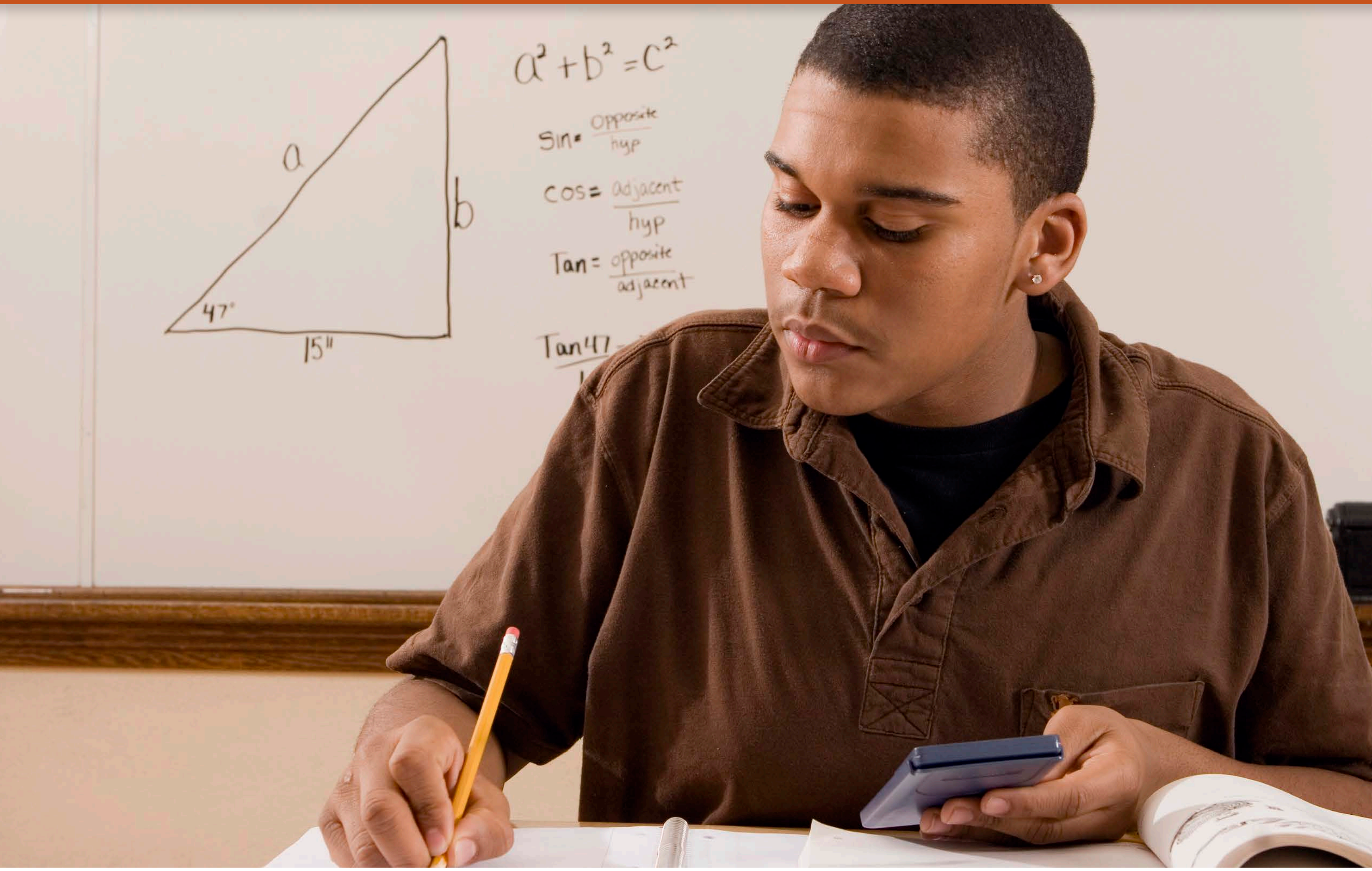
Disaggregated course completion data for Math 45 with and without co-requisite support yielded promising results, although additional work remains. In Fall 2018 and Spring 2019, first-generation students had good pass rates, but a gap remained compared to continuing-generation students. In Fall 2019, first-generation students in sections of Math 45 with support succeeded at higher rates than continuing-generation students. The gap had narrowed between first-generation and continuing-generation students in sections of Math 45 without support. Finally, existing data results underscore that it is still too early to formulate claims about underrepresented minority students and students from low-income backgrounds. A multiyear longitudinal study is needed to illuminate patterns and drivers that shift equity gaps before drawing conclusions and to identify appropriate recommendations. See overall Math 45 completion rate trends for Fall 2018, Spring 2019 and Fall 2019 in Table 3.

Table 3

Fall 2018 – Fall 2019 Overall Math 45 Completion Rates including Completion Rates Disaggregated by First-Generation Status, Race/Ethnicity, and Pell Grant-Eligible Status

		Fall 2018 Math 45 Completion Rates		Spring 2019 Math 45 Completion Rates		Fall 2019 Math 45 Completion Rates	
		With PSL Co-Requisite Support	Without PSL Co-Requisite Support	With PSL Co-Requisite Support	Without PSL Co-Requisite Support	With PSL Co-Requisite Support	Without PSL Co-Requisite Support
All Students	Average HS GPA	3.21	3.42	3.19	3.39	3.28	3.56
	# of students enrolled	208	783	169	358	226	564
	Course passing rate (%)	**71.5%**	**70.3%**	**70.8%**	**74.5%**	**72.1%**	**73.5%**
First-Generation Status							
First-generation students	# of students enrolled	149	563	116	243	177	385
	Course passing rate (%)	**71.6%**	**69.9%**	**67.8%**	**71.9%**	**72.3%**	**73.6%**
Continuing-generation students	# of students enrolled	45	176	33	83	42	149
	Course passing rate (%)	77.8%	74.4%	81.8%	75.9%	66.7%	76.5%
Race/Ethnicity							
African American	# of students enrolled	11	33	10	15	14	14
	Course passing rate (%)	**81.8%**	**54.5%**	**60.0%**	**64.3%**	**57.1%**	**64.3%**
American Indian	# of students enrolled	NA	2	NA	2	3	3
	Course passing rate (%)	NA	100.0%	NA	50.0%	0%	100%
Asian	# of students enrolled	21	110	15	43	20	75
	Course passing rate (%)	57.1%	67.0%	73.3%	67.4%	60.0%	70.3%
Pacific Islander	# of students enrolled	1	2	1	1	NA	1
	Course passing rate (%)	100.0%	50.0%	0.0%	0.0%	NA	100%
Hispanic	# of students enrolled	133	442	104	214	153	316
	Course passing rate (%)	**70.7%**	**71.1%**	**71.8%**	**76.2%**	**71.2%**	**72.4%**
White	# of students enrolled	21	113	17	43	18	105
	Course passing rate (%)	90.5%	77.7%	70.6%	76.7%	94.4%	78.1%
Non-Resident Alien	# of students enrolled	12	32	15	11	10	23
	Course passing rate (%)	66.7%	71.9%	86.7%	90.9%	100%	78.3%
Other / Unknown	# of students enrolled	9	49	7	29	8	27
	Course passing rate (%)	62.5%	71.4%	42.9%	72.4%	87.5%	73.1%
Pell Grant-Eligible Status							
Pell Grant-eligible	# of students enrolled	66	277	50	110	169	346
	Course passing rate (%)	**78.8%**	**77.0%**	**80.0%**	**77.3%**	**69.8%**	**70.5%**
Not Pell Grant-eligible	# of students enrolled	142	499	118	237	57	215
	Course passing rate (%)	68.1%	67.8%	67.5%	72.9%	78.9%	78.9%

Note. Adapted from Amarasinghe, R. (2020, January 27). Math data follow-up – 20200121 [Excel file].



Next Steps

The PSL co-requisite support for Math 45, the entry-level mathematics course for non-STEM students, are now fully scaled at Fresno State so that all first-year non-STEM students can enroll in their entry-level mathematics course in their first semester. All incoming freshmen identified as non-STEM majors are placed in one of four categories based on multiple measures of readiness.[9] Students who place in Category 3 or Category 4 are required to take the PSL co-requisite support, and those who place in the lowest category (Category 4) are also required to complete an Early Start Program (ESP) mathematics class in the summer before their first semester.

Michael Bishop, an assistant professor of mathematics at Fresno State, is involved in developing the online computer modules component of the PSL co-requisite support, which is aimed at improving basic math competencies. Results from this aspect of the labs have been disappointing, Bishop said, and revisions are ongoing. Bishop and others recognized that there are also challenges aligning the "just-in-time" aspect of lab topics because students are not always studying the same topic in their classes.

The early promise of PSL co-requisite supports to help students in non-STEM majors complete their entry-level mathematics course aligned to their programs of study is certainly good news. However, issues remain with the STEM track. Students pursuing **STEM majors** with Calculus I as the entry-level mathematics course who place in the lower two readiness categories[10] (Category 3 or 4) are required to enroll in a two-semester Calculus I sequence that includes extensive review of algebra and elementary functions as a yearlong stretch-model support strategy.

Additionally, students who place in the lowest category (Category 4) are required to complete an ESP mathematics class in the summer before their first semester at Fresno State.

At present, mathematics faculty are concerned the PSL co-requisite support available to non-STEM majors *might* make STEM degrees less attractive to underprepared students. This topic, among others, remains a priority for continuous improvement efforts to support underprepared students.

Endnotes

[1] https://completecollege.org/strategy/math-pathways/

[2] https://dcmathpathways.org/sites/default/files/resources/2018-02/Co-req%20supports.pdf

[3] https://www2.calstate.edu/csu-system/about-the-csu/facts-about-the-csu/Documents/facts2019.pdf

[4] https://www.fresnostate.edu/academics/oie/quickfacts/index.html

[5] R. Amarasinghe (personal communication, September 20, 2019).

[6] Per Fresno State Academic Regulations in the 2019–20 General Catalog, a "unit" is a credit or semester unit that represents one hour of class work per week for one semester (http://www.fresnostate.edu/catalog/academic-regulations/index.html#key-terms).

[7] http://www.aplu.org/news-and-media/in-the-news/fresno-state-receives-50000-collaborative-opportunity-grant-to-advance-student-success

[8] Fresno State's lesson study cycle was adapted from Lewis, 2008. See Resources.

[9] http://fresnostate.edu/cge/documents/MathSTEMCollegeReadiness.pdf

[10] http://fresnostate.edu/cge/documents/MathSTEMCollegeReadiness.pdf

Resources

The following research guided Fresno State's development of its lesson study cycle:

Lewis, C. (2008). Lesson study: *A handbook of teacher-led instructional improvement*. Philadelphia, PA: Research for Better Schools, Inc.

Lewis, C., & Hurd, J. (2011). *Lesson study step by step: How teacher learning communities improve instruction*. Portsmouth, NH: Heineman.

Lewis, C., & Perry, R. (2015). A randomized trial of lesson study with mathematical resource kits: Analysis of impact on teachers' beliefs and learning community. In E. J. Cai & Middleton (Ed.), *Design, results, and implications of large-scale studies in mathematics education* (pp. 133–155). New York: Springer.

Lewis, J., Fischman, D., Riggs, I., & Wasserman, K. (2013). Teacher learning in lesson study. *The Mathematics Enthusiast*, 10(3), 583–620.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: Summit Books.

Takahashi, A. (2008). Beyond show and tell: Neriage for teaching through problem-solving: Ideas from Japanese problem-solving approaches for teaching mathematics. Paper presented at the 11th International Congress on Mathematical Education, Monterrey, Mexico.

Takahashi, A. (2011). The Japanese approach to developing expertise in using the textbook to teach mathematics. In Y. Li & G. Kaiser (Eds.), *Expertise in mathematics instruction: An international perspective* (pp. 197–219). New York: Springer.

Contact Information

For more information about Fresno State's co-requisite support/Problem-Solving Labs for non-STEM students, please contact:

Dr. Rajee Amarasinghe
Mathematics Department Chair
California State University, Fresno
ramarasi@csufresno.edu

Dr. Gil Harootunian
Executive Director, University Initiatives
California State University, Fresno
gharootunian@csufresno.edu

About the Dana Center

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