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Titan Mathematics Apprentice Program (TMAP)

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Abstract. The Titan Mathematics Apprentice Program (TMAP) was created to support the commitment at California State University, Fullerton (CSUF) to providing students with work-related experiences. Dr. Ichinose, who also coordinates the Single Subject Mathematics Credential at CSUF, designed TMAP so students can gain experience in teaching mathematics through lesson planning, classroom delivery, and mentorship. The program gradually increases apprentices' responsibilities, helping them develop essential teaching skills such as classroom management and student assessment. TMAP also fosters professional interactions and encourages reflection on teaching practices, building confidence and practical skills for future mathematics educators. Over 200 students have participated in TMAP since it began in 2017, with the 2024-2025 academic year consisting of 46 apprentices. The program follows a traditional apprentice model, incorporating elements of supplemental instruction and embedded tutoring to enhance learning by doing, mentorship, and gradual skill development.

Introduction

The idea of an apprentice or apprentice program is not new. For years the term "apprentice" included craft/trade apprenticeships, medical school students, technical apprenticeships, and graduate apprenticeships (Hawkins, 2008). The Titan Mathematics Apprentice Program (TMAP) follows similar approaches with the major focus on learning by doing, mentorship, and gradual skill development. These have been noted as essential characteristics of any effective apprenticeship, including those in trade, medical and educational settings (Billett, 2010; Fuller & Unwin, 2003; Raelin, 2008).

TMAP Builds on Learning Assistant Models

Apprenticing in the TMAP program at California State University Fullerton (CSUF) is based on ideas typical of undergraduate learning assistant roles. Colleges and universities are increasingly using learning assistants (LA) to support students in developmental courses with high failure rates (e.g., high proportions of D, F, or W grades). These include bottleneck courses, which have high enrollment but also high failure rates, and are obstacles that delay students' academic progress. Developmental mathematics courses are courses which are designed to help students develop foundational skills necessary for success in college-level coursework. For mathematics courses, learning assistants are undergraduates, typically those majoring in science, technology, engineering, or mathematics (STEM), who work with faculty to help students succeed academically. The type of LA necessary is influenced by factors such as the course's delivery

methods (e.g., synchronous or asynchronous, traditional lecture, or flipped classroom), faculty needs, and LA availability (Chaves et al., 2013). Most learning assistant roles take the form of Supplemental Instruction or Embedded Tutoring.

Supplemental Instruction (SI) Program. Supplemental Instruction (SI) was developed by the University of Kansas City in 1973 to enhance student success in traditionally lower-performing classes. Key participants in such a program are SI leaders and students. SI leaders are typically high-achieving students who have successfully completed the associated course (with a grade of B or better) and possess strong communication skills and a desire to help others succeed (Anfuso et al., 2022; Bowman et al., 2023). Typically, SI leaders attend all associated classes, take notes, complete homework, and read the text (Hurley et al., 2006), often adopting a more passive role during class time.

Outside of class, SI leaders conduct special sessions that students can attend, voluntarily. These sessions incorporate active learning-style work designed to reinforce the content delivered previously by the instructor (Hurley, Jacobs, & Gilbert, 2006). Unlike traditional tutoring models, SI leaders do not provide rote answers to student's questions; instead, they redirect and reframe questions resulting in more interactive lessons that promote rich content discourse among students (Anfuso et al., 2022, Bowman, Preschel, & Martinez, 2023).

Embedded Tutoring. Embedded tutoring shares principles with Supplemental Instruction (SI) but differs in key ways. Embedded tutors actively participate in class, posing questions and providing just-in-time remediation, while SI leaders engage with students only outside of class. Embedded tutors collaborate closely with their associated instructor, whereas SI leaders operate more independently, creating SI sessions based on the instructor's plan. Both roles model ideal student behaviors, but embedded tutors emphasize asking rich questions and play an active role in facilitating group discussions during class (Channing & Okada, 2020; Chaves et al., 2013). Embedded tutoring offers a major advantage by integrating student support directly into the classroom, reducing the need for students to seek help outside of class. Students may see visiting a tutoring center or finding extra time for sessions as barriers to be overcome (Duffy & Burkander, 2024).

With the huge shift to online learning post-COVID, embedded tutors have become essential in scaffolding active learning in online college mathematics classes. With synchronous courses, embedded tutors facilitate chat discussions and work with students in breakout rooms for individual and group activities. With asynchronous courses, embedded tutors' model effective online engagement, such as crafting well-composed posts and interacting with peers, while also offering both synchronous and asynchronous tutoring (Channing & Okada, 2020).

Like SI, embedded tutors do provide support outside of class in both online and face-to-face settings. However, this support is usually more flexible and resembles traditional tutoring, yet it still fosters deeper engagement with the course content presented during class (Channing & Okada, 2020; Chaves et al., 2013).

In some ways the apprenticing in the TMAP program is similar to the above supplemental and embedded tutoring forms of learning assistantships. However, in the TMAP program, the work of apprentices differs in that they gradually take on the responsibilities of an instructor. The program is designed to give pre-service secondary teachers and graduate students the opportunity

to engage in teaching practices before officially entering the profession. Apprentices integrate into an active learning classroom—both online and face-to-face—at their own pace, working alongside a mentor faculty member. Depending on the mentor's planning and the apprentice's skills, the apprentice's duties may include taking attendance, creating warm-ups and icebreakers, planning and delivering mathematics lessons, sending emails and announcements, facilitating group work, modeling effective classroom interactions, completing observation logs, holding office hours, and light grading (see Table 1).

Table 1. Titan Mathematics Apprentice Program (TMAP) Overview

Timeline	**Program Components**	**Apprentice Participation**
Recruitment Phase	Host informational webinars, in-class announcements, orientation events.	Attend recruitment events and apply for the program.
Selection Phase	Review applications based on GPA, letters of recommendation, statement of interest, and group interview.	Participate in the application and interview process.
Training Phase	Pair apprentices with mentor faculty members.	Begin participating in classroom activities, such as taking attendance and planning lessons.
Initial Engagement	Introduce apprentices to classroom activities and responsibilities.	Meet and work with assigned mentor faculty.
Active Participation	Monitor and support apprentices as they gradually take on more teaching responsibilities.	Engage in teaching practices, including delivering lessons and facilitating group work.
Feedback and Reflection	Conduct regular feedback sessions and professional development activities.	Receive feedback and reflect on teaching experiences to improve skills.
Ongoing Support	Provide continuous mentorship and access to teaching resources.	Utilize available resources and support for teaching activities.
Completion Phase	Assist apprentices in transitioning to student teaching.	Complete the program and prepare for student teaching.

Recruitment and Selection Process. Potential apprentices are recruited from a pool of undergraduate and graduate students studying mathematics who are interested in teaching at the secondary or college/university level. Throughout the year at CSUF, several recruitment activities occur including informational webinars, targeted in-class announcements, and pre-semester orientation events. Faculty will often nominate potential candidates, and students who have had an apprentice in their classes frequently inquire about how they can participate. Applicants are selected based on their undergraduate GPA, letters of recommendation, statement of interest, and performance in a group interview.

Recruitment and retention are also often dependent on securing funding. Duffy and Burkander (2024) suggest:

> Colleges need to develop strategies and incentives to encourage faculty to recruit tutors and provide ongoing support for embedded tutors. They further need to allocate funding to provide competitive compensation and make tutoring positions desirable (p. 9).

At CSUF we are active in our pursuit to secure funding. TMAP is supported by the Mathematics Department, CSU Chancellors' Mathematics and Science Teacher Initiative, and the National Science Foundation (NSF DUE No. 2243558) Noyce Scholarship program, *Recruiting and Transitioning Math Majors into Teaching* (TMMT 2.0).

Mentorship Through Professional Development

The TMAP program offers apprentices a wide range of professional development activities each year. These activities occur both informally and formally. Informally, apprentices participate in professional learning communities and weekly check-ins. Formally, they engage in weekly meetings with their mentor instructors, which can range from discussing plans for the week to co-planning lessons. All apprentices are invited to attend monthly Zoom webinars and are required to attend a summer/intersession training workshop.

Dr. Cherie Ichinose, the director of TMAP, brings to the work her experience in secondary education, including expertise in mathematics education, mentorship, and teacher development. While Dr. Ichinose plays a significant role in facilitating professional development, she is supported by mentor instructors who are CSUF faculty from both the mathematics department and the College of Education. Dr. Ichinose reviews professional development activities and updates them regularly, typically on an annual basis, to incorporate feedback from apprentices, mentor instructors, and the current literature. These updates ensure the activities remain relevant and effective. The professional learning activities are hosted on the university's learning management system (Canvas), facilitating easy updates, collaboration, and accessibility for all apprentices.

TMAP has monthly webinars that focus on issues related to equitable mathematics teaching. These include the series *5 Strides on the Path to Math Equity* (https://equitablemath.org/). In 2024, Dr. Antonette Linton, co-PI on TMMT 2.0, began a series focused on Just, Equitable, and Inclusive Education (JEIE) with a particular emphasis on epistemic practices in mathematics teaching. Among these practices is mathematics literacy, and how it can be translated to social media literacy, with an emphasis on creating classrooms that are socially and academically safe for learning.

In the Fall 2024 semester, six of the senior apprentices, along with Dr. Ichinose, examined the Thoughtful Classroom Teacher Effectiveness Framework, which covers effective teaching, instruction, and professional practice (Silver et al., 2010). Using this framework, they engaged in a quasi-lesson study. Four apprentices were placed in College Algebra and two in a Calculus co-requisite course. Collaboratively, each group developed and executed their designed lesson. After the students executed the lesson, they solicited feedback from their mentor instructor and students. Then the apprentices together reviewed the lessons and feedback and made suggestions for future revision and delivery.

Weekly Zoom check-ins throughout the year are informal, allowing apprentices to guide the discussions with questions on topics such as classroom management, grading, and student engagement. These check-ins sometimes lead to targeted advisement for the apprentices. Additionally, summer and intersession workshops focus on pedagogies that support active learning in both face-to-face and online settings. For example, during the *Be Present—Not Perfect* Summer Virtual Workshop, apprentices were trained on using learning management system communication tools, threaded discussion boards, VoiceThread, and Zoom breakout rooms.

Mentor Matching of Apprentices with Instructors and Courses

Mentor instructor willingness to take on an apprentice and the nature of their classroom environment are the foundation of mentor selection. TMAP specifically targets active learning classes, particularly those that use the flipped class model, where most class time is dedicated to discussion and group work. This approach aligns with the goals of providing apprentices with a dynamic and interactive teaching experience. In these active learning environments, apprentices can observe and practice effective teaching strategies that promote student engagement and collaboration. This hands-on experience is crucial for developing their skills in classroom management, lesson planning, and facilitating group activities, ultimately preparing them to become effective teachers. TMAP supports both face-to-face and large online courses that use the flipped classroom model. With the addition of apprentices, instructors can provide students with one-on-one and differentiated instruction, even in larger sections. The flipped classroom allows apprentices to offer additional support to students who benefit from extra guidance.

Mentor-apprentice matches are based on recommendations from instructors, the availability of classes, students' course schedules, and interest in specific topics (e.g., algebra, calculus, statistics). Instructors may decline requests and may opt-out of participation in the program. Often, mentor instructors will request specific apprentices. Chaves et al. (2013) suggest that apprentice-mentor instructor pairings are often more successful when the apprentice and mentor instructor already know each other, and the apprentice is familiar with the course.

Apprentice Experiences in the Workforce

The success of the apprentice program can be measured by employment records and apprentices' reported perceptions of being better prepared for their student teaching. The mathematics department tracks our students, this includes out apprentices, as they participate in the credential program and throughout their induction program. We maintain regular contact via email and invite them to participate in induction activities such as Math Teacher Circle Webinars. All apprentices, to date, have secured a teaching position within six months of completing their credential and/or master's program. Furthermore, all have expressed that their participation in the Titan Mathematics Apprentice Program significantly contributed to their success. One note: several former apprentices have become mentor teachers for the credential program, further demonstrating the program's impact and success.

Testimonials

The success of TMAP largely depends on the contributions of faculty and students at CSUF. Their voices are central in the ongoing professional conversation that is the program. Participating mentor instructors and apprentices are surveyed to gather their thoughts and experiences. Their insights are crucial in documenting the impact and success of TMAP.

Faculty Testimony.

> *I wanted to take a second to let you know that* ***Apprentice A*** *is absolutely amazing. She has gone above and beyond during these last 12 weeks-I am so thankful for her assistance with everything. She has been such a huge help during our Zoom meetings and announcements all while staying professional and courteous with me and our students. . . . I know how tempting it can be to just explain everything yourself but she let the students be the star. She is going to become a phenomenal educator one day.* —**Faculty A**

Thank you so much for allowing me to work with our amazing future math teachers. Not only did they attend class twice a week, we met weekly for an hour to discuss the upcoming week, supported me with grading assignments, quizzes, and several exam problems – learning about applying rubrics fairly to written student work as well as student Flipgrid videos. They often stepped into the teacher role during class, asking great questions, modeling to students what mathematical reasoning looks like. They learned what collaboration among teachers can look like by forming our Professional Learning Community together. The students were all so expressed, acknowledging how great it was to have a fellow CSUF Titan in class. —**Faculty B**

My apprentices are a dream come true! They are basically my team of consultants for all things student-centered. The apprentices provide me with invaluable feedback on what works best for students. They helped me to clarify tasks. They helped me to organize my Canvas page in a way that is student-friendly. They keep me in check with deadlines and expectations. They truly feel like colleagues and I am so grateful for their contribution. Without a doubt, I am a better teacher as a result of working with them. —**Faculty C**

As the instructor of a large section, I greatly value the presence of the Apprentices. I strongly believe that their contributions are essential to the success of the course. The apprentices interaction with students in small groups of 30 allows for more personalized attention and deeper engagement with the material, especially in a virtual environment. By facilitating the daily group activities (via breakout rooms), the apprentices help foster a collaborative learning environment. The additional office hours they offer are invaluable, providing students with extra support and opportunities to clarify their understanding outside of class hours. The apprentices also plays a crucial role in lesson planning and classroom management, and their assistance in answering questions—whether in person or in the Zoom chat—ensures that all students feel heard and supported. Their presence significantly enhances the overall learning experience for both the students and myself as the instructor. —**Faculty D**

Apprentice Testimony.

I learned that teaching is something that requires a lot of patience and excitement towards the material. ***Faculty E*** *always tried to make learning math a fun process. She always came to class smiling, she made sure that anyone's questions are always welcomed. Working in groups with the students and helping them helped me grow as a math educator. It's important for me to have tutoring opportunities and* ***Faculty E*** *shadowing for my mathematics educator growth. I have tutored before, but it was a part of AVID where students come with questions however, being an embedded tutor was much more beneficial. I don't really know what more opportunities to get when being a mathematics tutor. I really liked what I did this semester!* —**Apprentice A**

I learned a lot of pedagogy and classroom skills, especially when working with students who have a negative view on math. I feel I gained a lot of insight and new perspectives through our monthly webinars. —**Apprentice B**

TMAP influenced how I thought about teaching. I was always a Math major with a concentration in teaching but apprenticing ***Faculty F*** *gave me great practice with working with university students. Working alongside* ***Faculty F*** *in planning on how instruction will be presented gave me an experience that still has an influence with how I run things in the classroom that I currently student teach in.* —**Apprentice C**

This semester I was an apprentice for our introductory statistics class. This opportunity helped me better prepare for my future classroom. I plan on teaching statistics for high school students, so apprenticing for college statistics is perfect practice. I loved the students this semester too. ***Faculty G*** *gave me plenty of free reign on my responsibilities in the class.* —**Apprentice D**

Before joining the program, I didn't have any teacher role models in my life . . . my parents aren't teachers (and) the only teachers I saw in my life were the ones that were teaching me as a student, and that the TMAP program provided me valuable examples of how to be an effective teacher. —**Apprentice E**

This semester, I learned a lot about how to best challenge and help students with their problem-solving skills. ***Faculty H*** *did a great job of asking the students questions about their work, particularly asking them to give reasoning for the steps they make in the problem-solving process. This inspired me to ask the students similar questions, often asking them "Why did you do that?" when they would explain their reasoning to me. One insight I gained this semester is that sometimes students do not know why they are taking certain steps in the problem-solving process, yet they do it without asking the instructor why. I realized that we, as instructors, need to ask our students "why" to challenge them to think more critically about what they are doing and grow in their conceptual understanding of the material.* —**Apprentice F**

Conclusion

The Titan Mathematics Apprentice Program (TMAP) at CSUF has successfully prepared future mathematics educators with practical experience, mentorship, and professional skill development. Key recommendations for similar programs include establishing a clear recruitment and selection process through webinars, announcements, and a thorough application, interview, and review process. Further, providing comprehensive training and ongoing professional development via workshops, webinars, and regular check-ins is also crucial. Another important aspect is the matching of apprentices with mentor instructors in active learning environments. Securing funding from institutional and external sources is vital for sustaining the program. This funding is primarily allocated for course release for the director, summer salaries for the principal investigator and co-principal investigator for the Noyce program, TMMT 2.0, and much of the funding is dedicated to the salaries of the apprentices. Finally, maintaining contact with former

apprentices, tracking their progress, and inviting them to ongoing professional development activities helps ensure their long-term success as educators.

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About the Author

Cherie Ichinose is a Professor of Mathematics at California State University, Fullerton, where she coordinates the Single Subject Credential Program in Mathematics and directs the Titan Mathematics Apprentice Program. Her research examines the role of emerging pedagogies and technology in mathematics education, including flipped classrooms and online learning. Currently, her work focuses on how Project-Based Learning (PBL) shapes future secondary teachers' perceptions of teaching Statistics and Data Science. She has actively contributed to CSU-wide initiatives, presenting at Professional Learning Community meetings, Summer Learning Institutes, and system-level gatherings with Presidents and Trustees.