Advocacy Corner: The Case for Ohio's Mathematical Modeling and Reasoning Course

Steve Miller, *Summit Educational Service Center*

Jennifer Walls, *Firestone High School CLC, Akron Public Schools*

Abstract: *College algebra and calculus are barriers that too often prevent students from pursuing STEM degrees. The authors describe an innovative curricular response conceived by the Ohio Mathematics Initiative (OMI) that will offer secondary-level students new courses designed to better prepare them for college mathematics. In this paper, the authors describe one such offering—namely,* Mathematical Modeling and Reasoning.

Keywords: *Quantitative reasoning, mathematical modeling, pilot study*

Introduction

Curricular Barriers

College algebra and calculus are barriers that too often prevent students from pursuing STEM degrees. Twenty-five percent of college calculus students earn a D or an F (Bressoud & Rasmussen, 2015, p. 144), with 50% of college algebra students earning a D or an F (Saxe & Braddy, 2015, p.3). In 2019, 20.2% of college students in Ohio were enrolled in a remedial math course (Ohio Department of Education & Ohio Department of Higher Education, 2020). In 2015, just 22% of bachelor degrees awarded in Ohio were in STEM careers (ODE & ODHE, 2020).

A New Curriculum for Today's Students

In response to this issue, the Ohio Mathematics Initiative (OMI) was formed in May 2013 to explore ways to better align mathematics coursework to college and career goals of Ohio's students. The initiative was designed to address many issues including a high failure rate of students in college mathematics. With the support of the Ohio Department of Education (ODE) and the Ohio Department of Higher Education (ODHE), OMI identified and developed a number of alternative curricular pathways to better prepare college students for various non-STEM-related majors and careers. An important feature of OMI's recommendations was the development of a more engaging, rigorous secondary mathematics curriculum—one focusing on real-world applications and topics of interest to high school students. By helping learners see mathematics as a tool that can help them communicate ideas and solve problems of personal relevance, it is thought that more high school mathematics students will experience greater success and learn more, with a smaller portion requiring remediation in college.

A Response to Remedial Mathematics Courses

As previously noted, a significant portion of Ohio college students enroll in remedial mathematics coursework. These courses are expensive—in many instances, students enroll in the same courses repeatedly while earning no credit towards graduation. Obtaining a "remediation free" score on a college entrance exam (e.g., ACT math score of 22; SAT math score of 530) saves students time and money, and improves the chances that they will eventually graduate with a STEM degree.

With such observations in mind, OMI created Subgroup 5 and tasked its members with developing a plan to "improv(e) student success in college-level mathematics courses by aligning postsecondary expectations and high school practice" (ODHE, 2021). In response, Subgroup 5—together with ODE and ODHE—developed *Mathematical Modeling and Reasoning* (MMR), a new course for high school students (ODE, 2020). In the remainder of this paper, we discuss the ongoing development and implementation of the course. In particular, we explore findings from a recent pilot study.

1 Building the *Mathematical Modeling and Reasoning* (MMR) Course

As plans to create the MMR course took shape, two groups were formed—an *Advisory Group* and a *Planning Team*.

- The *Advisory Group* consisted of college faculty, high school teachers, and administrators. The aim of this group was to provide guidance in the development of a new high school transition to post-secondary mathematics course. The *Advisory Group* noted that failure rates under traditional lecturing are 55% higher than rates observed under more active approaches to instruction (Saxe & Braddy, 2015, p. 3).
- A *Planning Team* was assembled composed of high school teachers and post-secondary faculty with the charge of identifying lessons to meet the expectations outlined by the *Advisory Group*.

Together, the groups agreed upon a number of general principles and aims for new course offerings. These included the following.

1. In an effort to provide students an active learning environment the *Planning Team* agreed that the approach of this course should promote reasoning, problem-solving and modeling.
2. The *Planning Team* wanted the MMR course to be inquiry-driven. They agreed that the *Standards for Mathematical Practice* as outlined in *Ohio's Learning Standards* (ODE, 2017) were more important outcomes than specific mathematical content. As students engage in the study of Number and Quantities, Functions, Geometry, Statistics and Probability, they are also learning to make sense of problems, reason, construct arguments and critique the reasoning of others, model, use tools, be precise, use structures and generalize.
3. The *Planning Team* envisioned students engaged in mathematical situations that would require them to pose questions, then plan and implement methods for answering them—with many questions engaging students in data collection and analysis. For example, in a popular lesson, *Bungee Drop*, students might investigate questions such as "Where should we drop Barbie to ensure the most thrilling (yet safe) ride possible?" The mathematical skills needed to explore this question are addressed as students engage in the exploration rather than before hand.
4. Moreover, the *Planning Team* agreed that the course structure should provide for students to apply mathematics skills in real-world contexts to make decisions relevant to daily life, such as building an ADA compliant ramp, stocking a trout pond, or designing a logo—reducing the likelihood of questions such as "when are we ever going to use this?"

5. The structure of MMR assumes that students will develop mathematical habits of mind such as perseverance, reasoning, and constructing justifications. These habits are promoted by the National Council of Teachers of Mathematics in *Principles and Standards for School Mathematics* (NCTM, 2000) and the National Research Council in *Adding It Up* (NRC, 2001).

6. Lastly, the *Planning Team* agreed that MMR requires students to develop successful communication skills—in both written and oral forms. As students have opportunities to work in small groups, they develop confidence in crafting their own answers to questions of personal significance. As they build confidence in their approaches, they learn to communicate their findings through the use of precise mathematical language.

Piloting and Revising the Course

First Steps

In May 2018, the *Planning Team* came together. Informed by the principles they had previously crafted, the team began the process of collecting lessons that would engage students in the *Mathematical Practices*. Lessons were designed for multi-day interaction. The lessons centered learning around a context with the *Planning Team* referring to each activity as a Context. Three of the high school teachers on the team agreed to implement Contexts as they were developed to aid the group's understanding of how to write them successfully.

Contexts

Each Context started with the teacher posing a situation or condition—for instance, a plate of Double Stuf Oreo cookies. The teacher asks students what they know about the context as well as "things they'd like to know." For instance, one might ask, "Is a Double Stuf Oreo is really double stuffed?" Teachers guide students in their explorations, linking activities and findings to grade level indicators as appropriate. A focus on *Ohio's Learning Standards Mathematical Practices* led the *Planning Team* to arrange the Contexts by the mathematical content most likely to be explored, i.e., their "theme." For instance, *Theme 6: Statistics* includes the contexts "Misusing Statistics," "M&M's Sampling Distribution," and "What Does a Normal Distribution Sound Like?"

Initial Revisions Based on early Pilot Feedback

Pre-pilot teachers (i.e., those teachers who agreed to test early versions of the Contexts with their students) identified statistics as content that was most engaging for students. As a result, the course initially included a Statistics theme early in the curriculum. However, the first group of pilot teachers didn't have the same experience with statistics. The pilot teachers found more engagement with the Functions theme. So the *Planning Team* used this feedback and moved the Algebra and Functions Theme to the first semester and the Statistics and Probability Theme to the second semester.

The *Planning Team* continues to use feedback from the pilot to refine and improve each Context. For instance, the Functions theme was moved earlier in the year and the Statistics Theme was restructured by reordering activities to allow for better continuity for students and teachers. In addition, the team created a set of introductory lessons that build problem solving and structured routines for students in a way that prepares them for MMR's new approach to instruction. In one example, students estimate the number of square inches of pizza that would be needed to feed everyone in their school. Students also work together to create the tallest tower out of marshmallows and spaghetti as well learn routines around 3-act tasks and number talks.

Professional Development

Overall Aims

Implementing a different approach to instruction is a challenge for teachers and their students. Not only did the MMR Pilot teachers need to become familiar with the Context portions of the course; they needed to replace their teacher-centered instructional approaches with ones that were more student centered. MMR was designed to assist college bound students not having yet received a remediation-free score. More lecture and more worksheets is not the solution. In order to reach these students, teachers need to implement instructional approaches that may be largely unfamiliar (or uncomfortable)—methods that replace instructor-led *teaching* with student-centered *learning*.

Initial Summer Training

Pilot teachers gathered for a four-day summer training. The facilitators engaged participants in various MMR Contexts as learners. For example, teams of teachers were asked to determine if an energy efficient washing machine would save more water in a year than a typical individual would drink in a lifetime. Since MMR bridges secondary- and postsecondary-level content, pilot teachers were paired with faculty from various Ohio postsecondary institutions. Pairs collaborated throughout the school year in an effort to orient high school students to higher education. For instance, pilot teachers and higher education collaborators engaged in lesson planning, explored mathematical connections across their courses, and discussed various MMR Contexts. An administrator from each participating district attended the first day of the summer training. The administrators strengthened their understanding of the curriculum and instructional expectations of MMR as they engaged in a series of mathematics activities with their teachers. The sessions helped administrators understand the aims of inquiry-based teaching and recognize basic features its implementation—for instance, productive struggle, small group collaboration, and student-led conversation and proof. Background knowledge of the MMR curriculum empowers administrators to more fully support student-centered instruction in their conversations and evaluations of faculty and students.

NCTM's *Effective Mathematical Teaching Practices*

In the training, teachers learned about instructional moves that promote student engagement in the Mathematical Practices. Through study of NCTM's eight *Effective Mathematical Teaching Practices* (NCTM, 2014), the teachers discussed and practiced techniques for facilitating productive mathematical discourse and posing purposeful student questions. Throughout the workshop, teachers were encouraged to ask questions that assess learners' background knowledge and advance thinking with respect to lesson goals.

Ongoing Development Throughout the School Year

Although participants engaged in a variety of engaging activities during the four-day training, the event organizers recognized that a week-long workshop did not provide pilot teachers with adequate support on its own. They realized that pilot teachers would need ongoing support once the upcoming school year began. For this reason, weekly virtual meetings were scheduled throughout the first few months of the school year, with monthly meetings continuing until year's end. A variety of times was provided to accommodate teachers' busy schedules. In addition, quarterly in-person professional development meetings were arranged to continue the learning by teachers of the student-centered approach.

Pilot Results

An evaluation of the project was conducted by Miami University's Discovery Center. Students were given a pre-assessment, a mindset survey and the *Accuplacer*, an online software tool provided by the College Board "to help colleges assess student readiness for introductory credit-bearing courses and make reliable placement decisions" (College Board, 2021). Teachers and higher education collaborators were also surveyed. Unfortunately, the evaluation effort was thwarted by the COVID pandemic. Much of the post-course data was not collected. Fortunately, teachers were surveyed at the end of the year. Some of the highlights of that data include the following.

- As the MMR course progressed, students learned problem solving, displayed perseverance and grit through difficult content, and actively worked to figure things out before asking questions of the teacher. Students also were able to present and explain their mathematical reasoning and began applying lessons learned in MMR to real-world scenarios.
- 57% of teachers reported large gains in their students' ability to model with mathematics as a result of the implementation of MMR with 48% of teachers reporting large gains in students' ability to make sense of problems and persevere in solving.
- 70% of teachers reported large gains in their ability to connect important mathematics concepts to real-world contexts as a result of MMR implementation, with 65% of teachers reporting large gains in their ability to understand how students think about/learn mathematics.
- 75% of post-secondary collaborators reported large gains in MMR teachers' abilities to teach mathematical modeling, facilitate student discussions about mathematics and their reasoning, and connect important mathematics concepts to real-world contexts. Moreover, post-secondary collaborators reported MMR teachers' increased use of student- and inquiry-directed learning, as well as their incorporation of active learning and hands-on activities.
- MMR teachers positively responded to all forms of professional learning implemented to support the MMR Course Pilot. Teachers' responses suggested that the weekly Zoom meetings and other professional learning support was well-aligned to their needs during the school year.
- One MMR teacher reported 1–to–3-point gains by her students on the October ACT.

Feedback from pilot teachers has been positive. One high school mathematics teacher commented "the Mathematical Modeling and Reasoning course is more engaging for my students than the previous course that they have taken. The students' confidence in their ability to do math increases steadily throughout the course as they experience problem solving and explain their reasoning."

A second pilot teacher reported that the MMR "class creates a new way for students to think about math and relates it to things they do in their lives or will do in future careers. My students have repeatedly told me that it does not feel like they are in a math class and are surprised when they learn mathematical concepts with ease. The students love this class and I enjoy teaching it as much as they enjoy being in it."

Another pilot teacher remarked that the MMR course "has been a great experience to teach this year. It has challenged my teaching into a hands-on, collaborative approach. While there were challenges because of teaching virtually the students were still expected to work as a group for much of the class and developed their critical thinking skills. It is a highly engaging and relevant class. The students seemed to really enjoy the challenges of the class and you could see their growth."

Future Needs and Next Steps

Work with the MMR course is ongoing. This upcoming school year, the Ohio Department of Education will identify a researcher to continue evaluating the implementation of the course. By the 2021-2022 school year, 11% of public high schools will have adopted the curriculum. To encourage equitable offerings and equitable preparation for college mathematics, more schools need to adopt the course. School administrators and school guidance counselors need to be aware of the existence of MMR and understand the aims of the course and the benefit that it promises current secondary-level mathematics teachers and students. In addition, counselors need to be informed about the placement of students in the course and how the course will help prepare them for college mathematics. Finally, students should be encouraged to take the class. They need to know about the benefits of the course and how MMR will prepare them for future career and academic goals.

References

Bressoud, D. & Rasmussen, C. (2015). Seven Characteristics of Successful Calculus Programs. *Notices of the American Mathematical Society (AMS) 62*(2), 144.

College Board (2021). *Accuplacer* [Software]. Available on-line at https://accuplacer.collegeboard.org/.

Saxe, K. & Braddy, L. (2015). *A Common Vision for Undergraduate Mathematical Sciences Programs in 2025*. Washington, DC: Mathematical Association of America. Available on-line at https://www.maa.org/sites/default/files/pdf/CommonVisionFinal.pdf.

Ohio Department of Higher Education (ODHE) (2021). Ohio Mathematics Initiative (OMI). Columbus, OH: Author. Available on-line at https://www.ohiohighered.org/math.

Ohio Department of Education (ODE) & Ohio Department of Higher Education (ODHE) (2020). *Educational Attainment: Ohio by the Numbers*. Columbus, OH: Authors. Available on-line at https://development.ohio.gov/files/research/P7006.pdf.

Ohio Department of Education (ODE) (2017). *Ohio's Learning Standards for Mathematics*. Columbus, OH: Author. Available on-line at http://education.ohio.gov/Topics/Learning-in-Ohio/Mathematics/Ohio-s-Learning-Standards-in-Mathematics.

Ohio Department of Education (ODE) (2020). Mathematical Modeling and Reasoning Course Pilot. Columbus, OH: Author. Available on-line at https://education.ohio.gov/Topics/Learning-in-Ohio/Mathematics/Resources-for-Mathematics/Mathematics-Modeling-and-Reasoning-Course-Pilot.

National Council of Teachers of Mathematics (NCTM) (2000). *Principles and Standards for School Mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (NCTM) (2014). *Principles to Actions: Ensuring Mathematical Success for All* Reston, VA: Author.

National Research Council (2001). *Adding it up: Helping children learn mathematics* (Edited by Jeremy Kilpatrick, Jane Swafford, and Bradford Findell). Washington, DC: Author.

Steve Miller is in his 43rd year in education and sixth year as the Mathematics Content Consultant for the Summit Educational Service Center. Steve spent 35 years in the Akron Public Schools, which included teaching at three levels as well as district level technology and coaching positions. He is one of the authors of NCTM's new series "Taking Action: Implementing Effective Mathematics Teaching Practices." He is a current member of the ODE's Network of Regional Leaders for mathematics and the Ohio Mathematics Leadership Council (OMELC).

Jennifer Walls teaches mathematics at Firestone CLC in Akron Public Schools. Jenny was recognized as Akron Public Schools Teacher of the Year for 2016. She was also recognized by the Ohio Council of Teachers of Mathematics as the recipient of the state secondary Buck Martin Award in 2020. As one colleague noted, "Jenny truly teaches from her heart and is known as a student advocate who strives to find ways to connect learning to students on a personal, individualized basis." Jennifer is a member of the Ohio Mathematics Leadership Council (OMELC).