Teaching Modeling and Advising a Team

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Introduction

The two authors of this article have been highly successful ICM advisors: Daniel Teague at the high school level and Gary Olson at the university level. This article presents the courses, events, preparations, and support provided to the ICM teams at their respective schools.

High School Modeling Course

The NC School of Science and Mathematics (NCSSM) has been teaching a curriculum focused on mathematical modeling since 1985. As a part of that curriculum, we offer a formal course in mathematical modeling to seniors. There were three major influences leading to our decision to focus on modeling. The most important was the good fortune to have Henry Pollak, then director of the Mathematics and Statistics Research Center at Bell Labs, on our Board of Trustees. Henry spent many hours with the mathematics department encouraging us to consider mathematical modeling as a fundamental component of the mathematics program. The second and third came simultaneously at the Joint Meetings of the AMS and MAA. Frank Giordano and Maury Weir gave a minicourse on mathematical modeling and a winning MCM team gave a presentation of their paper at that meeting. I [Daniel Teague] attended both and came away with the idea that "my kids would enjoy the MCM challenge" and I thought they could do reasonably well in the competition.

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All students competing in the MCM/ICM challenge at NCSSM take the modeling course during the fall term. These students are concurrently taking calculus or have completed calculus prior to enrolling, but none of the assigned problems require the use of calculus or differential equations. This one-term course is almost entirely problem-based, with very little new content being taught. The only formal mathematical instruction is comprised of one week each on

- methods of data analysis,
- Markov processes, and
- an introduction to agent-based models.

The goal of the modeling course is not learning new mathematical content, but to learn how to use profitably whatever mathematics the student already knows (though students will obviously learn some new mathematics from their partners as they develop their models).

Students will obviously learn some new mathematical ideas from their partners. However, the course is not primarily focused on learning new mathematical content, but on using profitably whatever mathematics they know. Students in the course are concurrently taking calculus or have completed calculus prior to enrolling, but none of the problems that they are given require the use of calculus or differential equations.

Problems in the course are of varying lengths. Short problems may take one or two class periods, including a short presentation of their ideas to the class. For example, we might consider the problem of redistricting the state of North Carolina based on the most current census. State law requires that all districts be as compact as possible. So, the students might be asked to develop a metric to measure compactness. This activity represents one of the steps that students would need to take in a larger problem.

A medium problem might take two to three days and have some modified form of presentation. An example is the driving-for-gas problem. In some areas, local radio stations report on the location of the gas station with the lowest price per gallon for regular gas. Of course, that station may be across town from where you are driving. Is it worth the drive out of your way for less expensive gas? If you know the locations and the prices at all gasoline stations, at which station should you buy your gas? Develop a model that can be used in an app that will tell drivers how far they should be willing to drive based on the specifications of their car. Turn in four Powerpoint slides, one with the essential assumptions used in your model, one with the mathematical model, and two showing potential screenshots from a smartphone app based on your model. The first screenshot requests essential information from the user and the second is the app's response to that information. In this problem, rather than taking the time to write a formal paper, the students present both their model and their idea for how it could be used in a mobile app.

The long problems typically take a week to 10 days for students to work. They typically require a formal paper written in MCM/ICM format. Past MCM/ICM problems are often used for these assignments. The groups will receive extensive feedback on both their modeling and their written presentation of their work. Most of the feedback is on the clarity of their presentation including their explanation of what they have done and why they believe their work captures important features of the process or phenomenon being modeled.

Other Preparations for the Contest

Following the modeling course, most students take a course in Complex Systems, which extends the agent-based modeling approach and introduces dynamical systems. They also work together on projects in all of their science classes, so they are very comfortable with open-ended problems and negotiating the team-work aspects of the MCM/ICM challenge. As high school students, there are many disadvantages NCSSM teams face in the MCM/ICM competition. Primary among them is a very limited mathematical base to use in their modeling. However, their lack of mathematical firepower can be an advantage, since the focus of their work must be on using simple mathematics in a creative way. It is the modeling, not the mathematics, that stands out in their work. Another advantage is the opportunity to compete in the HiMCM competition prior to MCM/ICM. In addition to the experience for the students, this gives their coach an opportunity to select teams based on their HiMCM performance. Over the years since 1985, the MCM/ICM competition has been the highlight of their high school experience for many NCSSM students. Whether their work was deemed Outstanding, Finalist, Meritorious, Honorable Mention, or Successful, the richness and intensity of the MCM/ICM experience has been life-changing for some, and memorable for all.

Choosing Teams at the University Level

One of the most important elements for constructing a successful competition team is to start planning and generating excitement and interest about the competition early on. I [Gary Olson] am a great cheerleader for the competition with our students, but I can only reach a small subset of those at our university who might be interested. Therefore, it is important for me to reach out to other faculty in our department and other departments and colleges at our university to help in recruitment. Through email, phone calls, and office visits, I solicit names of students whom faculty think might be a good fit for the competition and also target specific classes to visit and give a brief five-minute introduction to the competition. Once

I have identified interested students I often use them to help recruit their friends and classmates who might be interested. Through these efforts I am usually able to generate a large list of potential students to recruit.

Once the groups of interested students are identified, I hold an informational meeting early on to help the students learn more about the competition and to help me learn more about the students. During this session, I give out a survey that helps me identify the different skill sets for each student. In particular, I'm interested in what mathematical backgrounds they have, what familiarity they have with programming languages, which students are confident in their writing abilities, and if any students have colleagues they prefer working with. I also make time for a small conference with each student to determine more about their particular interests and skills. This information helps me identify which students would potentially complement each other for the contest. In terms of team composition, I generally strive to match up one student who is confident and experienced with programming with one student who is confident they can lead the writing effort for the team and a third student who can fill in different roles and complement the skills of the others.

Preparing the Team

Once the teams have been formed, the competition preparations begin. I prefer to have my teams solidified in the fall so that they can begin meeting together as a team for the competition training sessions. At our university, we do not focus on mathematical preparations during our training but rather on interpersonal skills, community building, competition time management, and brainstorming sessions for previous problems. Some of the trainings are done as a large group with all of the teams participating, but the majority of the training is work done by the team itself. Once we have identified the teams, we have an informational meeting where we first introduce all of the students and start getting to know one another. Once we are all on a first name basis, I begin by giving them more information about the competition (background information and history of the contest, more information about each of the different problems and information about the different types of interdisciplinary problems that are possible).

After the initial meeting, I encourage the teams to meet together as a group in a nonmathematical setting (i.e., it cannot be on campus!). Many of the students who compete do not know some of their teammates when we start, so we want to encourage them to get to know one another, become comfortable conversing with one another and sharing ideas and thoughts, and to some extent help them to start building a friendship. After the teams have met outside of the department for community building (coffee shop, library, baseball game, etc.), we bring them together again for a training session that details how to handle interpersonal relationships during the competition and potential conflict. I feel that for many teams the biggest pitfalls during the contest occur because of interpersonal conflict. We focus a large amount of our training sessions on how to work with one another in a group, how to respectfully listen and disagree, and what steps can be taken to recover when a conflict has occurred.

The next phase of our training involves allowing teams the opportunity to practice brainstorming and working together. I have them choose two or three sessions where they can meet together for a two-hour time block and I give them all of the contest problems from a given year. Their task is first to practice the process of going through and choosing a problem and then to begin work on the initial brainstorming of ideas for the contest problem. In-depth models cannot be developed in a two-hour time frame; however, it allows the team to start working together early and develop a familiarity and comfort level with one another that will ultimately benefit their actual competition experience.

Guiding the Teams' Experiences

To kick off the competition, we hold a pizza party in the department an hour before the contest problems go live. This allows the teams to have a chance to settle into their rooms a bit and for me to give any last-minute advice/preparations before the clock starts to tick. Once the problems go live, the teams separate into their respective rooms and the work begins. We reserve separate rooms in our department for each team for the entirety of the 96 hours to give them privacy, a central location, and space to work. While the teams are brainstorming and choosing a problem, I go and stock the kitchen with all sorts of food to fuel them throughout the weekend. While the students are allowed to request specific items, the competition mainstay items are fruit, Oreos, a plethora of junk food, and lots and lots of caffeine. During the competition we also arrange for team dinners on Friday, Saturday, and Sunday night. These dinners are provided by faculty in our department and allow each team a chance to take a break from the problem and get out of the department for a change of scenery. It also allows them the opportunity to get to know some of the faculty members in our department on a more personal level than what would previously be possible. Faculty members have also commented that it is a fun way for them to get to know our undergraduates while also providing support for the competition.

Reference

Olson, Gary. 2015. Competing and coaching. In *The Interdisciplinary Contest in Modeling: Culturing Interdisciplinary Problem Solving*, edited by Chris Arney and Paul J. Campbell, 33–36. Bedford, MA: COMAP.

About the Authors

Dan Teague has been teaching mathematics at the North Carolina School of Science and Mathematics since 1982 and mathematical modeling since 1985. Under his mentorship, North Carolina School of Science and Mathematics teams have earned six Outstanding rankings in the ICM, including two in 2016, in the Water Scarcity Problem and the Refugee Immigration Policies Problem. Dan has served as the Second Vice-President of the Mathematical Association of America, as Chair of the MAA SIGMAA on Teaching Advanced High School Mathematics, and twice as the MAA Governor-at-Large for High Schools. Dan has also served on the AP Statistics Test Development Committee and two terms on the US National Commission on Mathematics Education.

Gary Olson is a senior instructor in the Dept. of Mathematical and Statistical Sciences at the University of Colorado Denver. He serves as the director of service courses in mathematics and teaches both mathematics courses for undergraduates and professional development courses for in-service middle school teachers. He is interested in inquiry-based learning, teaching-assistant training and models, and online learning strategies for mathematics. He is also actively involved with the MCM and ICM mathematical modeling competitions and undergraduate student activities. As an undergraduate, he received an Outstanding ranking in the ICM as a student team member at Carroll College, Montana. In 2016, a team that he advised at the University of Colorado Denver was an Outstanding team in the Water Scarcity Problem.