Modeling Competitions and Gender Equity

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Background

Someone once said that there is no history, only memory. In order to set a historical context for this paper I need to take a trip down memory lane and talk about the beginning of the Mathematical Contest in Modeling (MCM™). In late 1984, Ben Fusaro came to me with the idea for a modeling competition. I no longer remember the original formulation of the idea, but the basics were there: a team competition for undergraduates who would work on an open-ended problem for an extended period of time and be allowed to use any inanimate resources, assuming they were appropriately cited. In other words, you just couldn't ask a non-team member how to solve the problem.

COMAP succeeded in obtaining funding from the US Department of Education, which led to the first MCM, held in 1985. Ninety 3-person teams worked over a 4-day weekend, coming from seventy US colleges and universities. In those early years there were two contest problems, one of which was meant to be modeled by discrete mathematics and the other by continuous. As teams chose only one problem each, we in effect ran two separate contests. We decided from the beginning that we wouldn't have straight ordinal ranking. Instead, teams were designated as Successful Participants, Honorable Mention, Meritorious, and Outstanding, with no predetermined percentages in any one category.

There are many anecdotal stories that influenced the way the contest has evolved over time. The first of these occurred during the third year of the contest. The grading of the contest is completely blind. None of the judges see the names of the participating schools until after the designations have been determined. In year 3 when the envelope was opened, we learned that one of the Outstanding teams was from the North Carolina School of Science and Mathematics (NCSSM), which is a high school. There was a very heated discussion following this revelation, with several judges arguing that they were not eligible and should be disqualified. This may be the only time in my professional life that I acted in a Solomonic manner. I decided that high school was indeed under graduate and hence high schools were perfectly acceptable participants. In fact NCSSM has had more Outstanding teams over the years than any other institution, undergraduate or secondary school.

There is another anecdote about the NC team that year that is illustrative. The problem they worked on involved determining an optimal search pattern for a helicopter trying to locate a boat off the Florida coast that was suspected of running drugs. The high school team was the only team that realized that you need not simply search for the boat, but you can look for the wake of the boat and follow it to the ship. This observation did not require any sophisticated mathematical technique, but it made a significant difference in the problem's solution. In many ways this was important, because we have always tried to devise problems where it is more important to use sophisticated mathematical reasoning than to employ an advanced mathematical method.

After the grant funding ran out, COMAP needed to charge a registration fee in order to support the contest. Modeling problems require graders with a good deal of experience. And as the contest grew in size we needed to add a triage phase where every paper is read by at least two people and then there is a weekend final grading session once the top papers have been identified. The contest itself has also expanded. In 1999 we added a set of interdisciplinary problems, i.e., problems in which significant knowledge of a non-mathematical discipline is necessary

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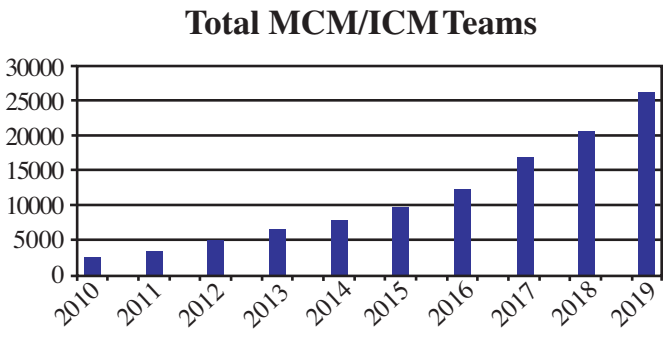
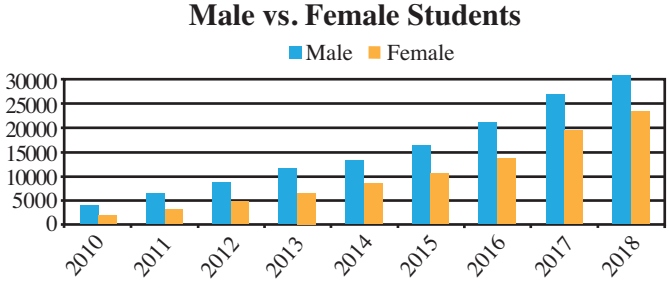
to do the modeling. And so the Interdisciplinary Contest in Modeling (ICM™) was born. This contest was quickly merged with the MCM, so that now we hold the MCM/ICM contest each year. Two years ago we added a data-based problem to MCM, so that MCM/ICM now consists of six problems (graded as six separate contests). MCM has a continuous, a discrete, and a data-based problem, while ICM has a network problem, an environmental problem, and a policy problem.

The contest has grown dramatically in participating teams as well. In the late 1990s, teams from China began to enter. In recent years Chinese participation has grown at an exponential rate. For example, in the past ten years the number of teams from mainland China has increased ten-fold. The graph below shows those dramatic increases. The number of teams from the US and other countries/regions (around twenty) has grown to a little over a thousand in that same time.



Over the last several years we began to notice another growth phenomenon, namely, the number of women who participate in the contest and the number of women on the Outstanding teams. Below is a graph depicting the gender data through 2018. In 2018 43 percent of the participants (both US and Chinese) were women, and the percentage of women members on the Outstanding teams was also 43 percent. Considering how small similar percentages are in other mathematics competitions at both the college and high school levels, these numbers truly stand out. And so the natural question to ask is why. What is it about MCM/ICM that makes it more attractive to female participation?



This question is beyond my area of expertise, and while I was happy to speculate, I wanted results from a respected mathematics education researcher. And so, last year I asked Prof. Jo Boaler of Stanford University if she and her team would undertake this project. Some of their main results are published in [1].

The purpose of this article is to further expand on some of the key results and think about ways we might use the information gathered to increase female participation in other valued mathematics activities.

There were two surveys sent out, one to students and one to faculty advisers. The student survey collected 1,327 results from a pool of approximately 58,000 students. The faculty survey collected data from 37 US team advisers out of a little more than 400. Throughout the next sections, in order to better capture the flavor of the open response questions we will present a set of typical comments.

Student Survey

The first question asked students to explain why they participated in MCM/ICM. There were two typical types of responses:

a. This is an important, well-recognized international contest, and doing well in it will be good for my future; e.g.:

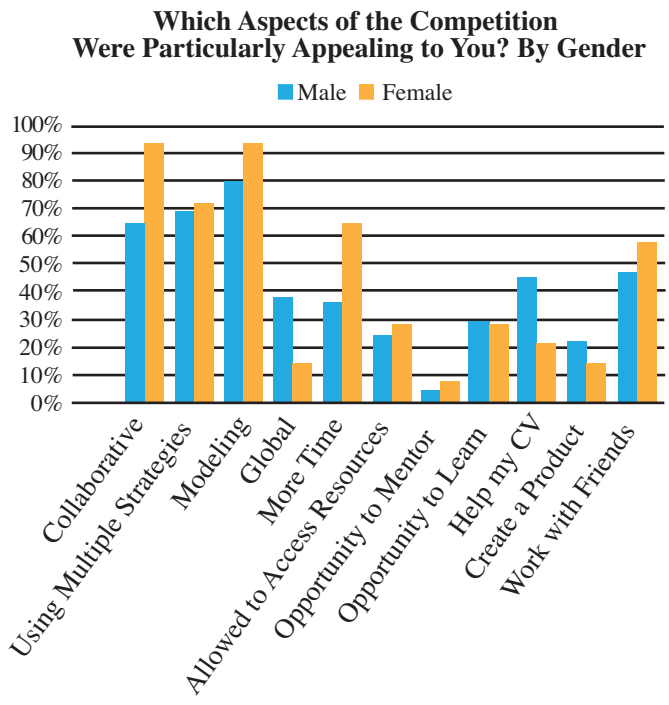
> The longer time frame and collaboration with teammates simulates real-world challenges that most students will face after graduation. I thought it was a great professional development experience that no other competition or event provided.
>
> Its global aspect makes the competition more fierce. Therefore, if our team can receive a good result, it may be persuasive in proving our modelling ability and team spirit.
>
> Our college pays great attention to this competition. If I can get a good award in this competition, it will be very helpful for attending graduate school.

b. The problems are about the real world and working on them will help prepare me for future school and work; e.g.:

> We really appreciate MCM for bringing us an international perspective. It provides us the chance to tackle comprehensive problems we have never thought about before and helps us to see the world from a completely different aspect. The contest is not just about math, but a combination of knowledge and vision.

> MCM is a more comprehensive competition than other competitions. As a participant, we need to do every kind of thing from collecting data to programming, just like solving a problem in our real lives.
>
> Other math contests focus more on theoretical mathematics, such as calculate integral and so on. They made me feel that maths are very difficult. But the MCM/ICM taught me how to use maths to solve problems; it's an unforgettable experience for me.

The second question asked about which aspects of the competition students found most valuable.



We note that comparison of answers from males and females show that while both groups highly value working collaboratively, women value this aspect of the contest significantly more.

The third and fourth questions asked about whether participating in the contest had any positive effect on students taking more courses or changing career paths. While most of the students believed that they knew exactly what courses and careers were in their futures, there were a number of answers where students with an interest in a discipline such as economics or biology or chemistry stated that they would now study or work through a more computational approach to that discipline.

The fifth question asked students if they would have competed in MCM/ICM had it been an individual vs. a team contest and why or why not. The answers get to the heart of the contest; e.g.:

> I believe working with a team can surely make the work more effective. And teamwork should be a better experience than individual work because we participants may improve our math knowledge and skills through exchanging ideas with our teammates.
>
> In my opinion, learning how to cooperate with partners is also a precious gift I got in this competition. And the power of brainstorm is very amazing!
>
> I think the math competition is a good chance for me to mentor new participants and enjoy the math time with my new MCM/ICM friends. Actually, with this competition's development, we developed too. In my opinion, participating in a competition is the quickest way to improve your ability.

Faculty Survey

While only a relatively small number of faculty returned the survey, the responses are instructive. When asked their opinion of the contests and why they felt it appears to appeal more to women than other mathematics competitions, these were the typical responses:

> I'm a woman in math, so I work hard to be a role model and personally connect with women in my class, and support them through outreach. I also find some students, but women more commonly, initially worry that they are not strong enough students for the contest. By emphasizing the teamwork aspect, the ways everyone can contribute, and working to have a final product, I can help assuage some of their concerns.
>
> We have a huge group of math majors at my university, and I think the gender proportions are quite balanced. I usually have the competition be advertised to all math majors; without fail, there will always be a lot more male students registering. I then contact individual female students and students from other underrepresented groups who took/are taking my course and encourage them to participate. The female students I reach out to are usually excited to participate, and would form all-women or majority-women teams.

First I believe the collaboration with a team is essential. This makes the competition partly social in nature. Secondly, there is a final product other than just a mathematical proof. Finally, the extended timeline alleviates the stress that other competitions impose.

MCM/ICM is a different kind of experience compared to math competitions like the Putnam. In my opinion, it is a more accurate reflection of what professional and academic mathematicians do (reading, writing, working in a team, exchanging mathematical ideas, attacking problems that are not initially well-defined, spending time on a problem instead of having a shorter time period, etc.). Among other reasons, I recommend this competition for students who want to get a taste of what math 'research' is like, and I recommend it to students who want to go to industry jobs directly after graduation.

Conclusions

What are the major takeaways from this research? One is that the participation and success of women is likely due to the collaborative and multidimensional nature of the challenges. The results of this study suggest that gender equity in mathematics competitions is related to the type of working environment offered by the competition.

We see that women value the collaborative nature of the MCM/ICM more than men, although both report a high level of enjoyment from the team experience. Interestingly, when one asks students about the best part of the modeling contest they will invariably mention the teamwork. When you ask them about the hardest part, they will also answer that it is the teamwork, which I would argue is exactly as it should be.

Of course, there is a question about whether the collaborative aspect of MCM/ICM is solely responsible for the relatively high percentage of women participants. I think that an honest answer is, not entirely. MCM/ICM has a great deal of prestige, especially in China, as does the study of mathematics. Students often commented on the importance of success in the contest to their future educational and career opportunities. In fact a number of students answered the question of why they thought such a high percentage of women entered the contest by saying things to the effect: "Math is important. Studying math will help me get a better job and a better life. This is something we believe."

So, yes, I strongly believe in teaching mathematics through modeling, and, yes, I believe that if the mathematics contests in the US had more of a team aspect they would attract a higher percentage of women. But I also believe that in order to continue to match these results, work in the mathematical sciences has to be valued more highly than is currently the case. Modeling, teamwork, and realistic open-ended problems are all extremely important. And incorporating them into our mathematics teaching at all levels will certainly help. But answers also lie in the rewards and respect we as a society give to all students who succeed in mathematics.

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References

[1] Boaler J, Cordero M, Dieckmann J. Pursuing Gender Equity in Mathematics Competitions: A Case of Mathematical Freedom, *FOCUS*, Feb/March 2019, 18–21.

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Credits

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