STUDENTS' EXPECTED GAINS FROM A MODELING COMPETITION

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This study is a post-hoc analysis of pre- and post- survey data from two rounds of a mathematical modeling competition comprised of high school and undergraduate students (n=107). The purpose of this study is to describe the expectations students held going into the competition and how those expectations compare to those held by researchers and designers of modeling competitions. Additionally, this study examines students' satisfaction with the competition in terms of their anticipated gains. Results show that students, researchers, and designers held differing expectations. We explore implications of this finding for broadening participation.

When unpacking the extent to which mathematics competitions are impactful, there are three perspectives to consider: the researcher, the designer, and the participant. For example, designers might promote networking opportunities, while researchers may examine benefits of solving equations outside of the classroom. Participants may sign up for competitions expecting to get resumé lines or develop critical thinking skills. While there is overlap in these expectations, any disconnect among the three perspectives may offer insight into how to increase participation in these events.

Broadly, studies of the benefits of mathematics competitions have found that they provide a venue for gifted and talented students to distinguish themselves (Bicknell & Riley, 2012; Gleason 2008). In the general population, mathematics competitions help motivate participants, steer them toward STEM fields, provide an avenue for recognition, garner prestige for institutions, engage participants in mathematics outside the classroom, and encourage teamwork (Kenderov, 2006; Thrasher, 2008). Even competitions tightly focused on one aspect of mathematics, like mathematical modeling, positively influence self-efficacy (Czocher, Melhuish, & Kandesamy, 2019). Design-based competitions, such as those common in engineering, promote soft skills like teamwork and leadership skills, as well as promote hands-on learning, interest, motivation and further involvement (Wankat, 2005; Gadola & Chindamo, 2019). Thus, from a researcher's perspective, participation in competitions promotes confidence, interest, soft skills, and more.

Designers of mathematical modeling competitions promote additional benefits. According to Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations (SIMIODE), the MCM/ICM Contest, the MathWorks Math Modeling Challenge, and the AoCMM Math Modeling Competitions' websites, designers of mathematical modeling competitions anticipate gains in modeling experience, modeling proficiency, and confidence. Additionally, they expect participants to gain a general appreciation of modeling. Designers also promote academic recognition, teamwork and communication skills, resume development, and professional networking.

Given the (anticipated) benefits of participation, the next goal for competition sponsors should be broadening participation in these competitions. Doing so successfully would require accounting for the participants' expectations to market the benefits enticingly. Additionally, competition designers who incorporate participants' needs into their competitions give researchers dimensions to evaluate impact. Within this context, the purpose of this study is to understand the experience of participants in a mathematical modeling competition using the SIMIODE Challenge Using Differential Equations Modeling (SCUDEM) as an example, with the intention of uncovering the extent to which their experiences and self-reported gains align with those of researchers and competition designers

METHODS

We conducted a post-hoc analysis on survey data collected before and after two rounds of SCUDEM: SCUDEM II in April 2018 and SCUDEM III in October 2018. In the SCUDEM competitions, teams of three participants were given a week to write an executive summary of their solution to their choice of modeling problem. At the competition site, teams were given an additional modeling issue related to their chosen problem to address briefly in their presentation as well as substantive critiques of their efforts. The teams then gave a ten-minute presentation of their findings to their original problem and the new modeling issue, which were judged by the faculty coaches. Teams were also provided immediate oral and written feedback.

A total of 399 and 228 students from secondary and post-secondary institutions participated in the SCUDEM II and III competitions, respectively. Of those, only a fraction responded to the relevant items on both the pre- and the post-competition surveys (n=107). In the pre-/post-competition surveys, the participants were asked "In a few words, please tell us what you expect to gain from participating in the competition?"; and in the post-competition survey, the participants were asked "In a few words, please tell us the main thing you learned about mathematical modeling from competing." Additionally, we analyzed responses to the question "Would you recommend this competition to a friend?" However, this question was only present on the SCUDEM II survey (n=66). As well, the question "Please describe some positive aspects of the SCUDEM experience for you. Why were they positive?" was included but was only on the SCUDEM III survey (n=36).

We used in vivo coding techniques to analyze pre-competition survey responses (King, 2008). We identified categories such as 'confidence', or 'applying differential equations to the real world'. We applied the method of constant comparison to develop stable evidence-based definitions for higher-level categories of like codes (Corbin & Strauss, 2015). For example, the code 'experience in modeling' was assigned to explicit statements about experience in modeling, or from phrases such as 'applying/using differential equations to the real world'. The union of benefits from competition designers' websites, research reports, and the participants' expectations became the basis of descriptive statistics to report student responses. Codes were not mutually exclusive; one response could have multiple codes. Next, we compared the pre-/post- responses to examine whether students gained what they expected from competing.

RESULTS

Researchers and designers promoted appreciation of modeling and a chance at recognition. However, those benefits were not widely recognized by the participants (0% and 0.93% respectively). Participants and designers promoted experience in modeling (71% of participants), proficiency in modeling (16.82%), and practice teamwork (13.08%) and communication (9.35%) skills. Only 8.41% of participants mentioned mathematics outside of the classroom, a benefit reported by researchers. Participants held some expectations that neither the designers nor the researchers promoted. Participants expected to practice solving differential equations (16.82%), problem-solving (5.61%), and critical thinking (0.93%) in addition to career building (7.48%). Researchers and designers promoted gains in confidence to do modeling, a benefit not recognized by most participants (2.08%) Overall, these results suggest that participants' expectations mostly aligned with those of the researchers and designers, but there were expectations participants held that were not present in the literature.

Comparing pre-/post- responses showed that the most common expectation among participants, "experience in modeling," was the most commonly reported gain (56.07%), implying that most of the participants' primary expectations were met. Additionally, the top three most important skills/experiences participants reported gaining were experience in modeling (71%), improved proficiency in modeling (26.32%), and teamwork skills (17.75%). Many participants reported gaining something from the competition (37.28%) and a majority reported their expectations were at least partially met (52.33%). We took responses to the question "would you recommend to a friend" (SCUDEM II) to indicate general satisfaction with the competition. Most (57 of 66) stated they would recommend this competition to a friend. Of the remaining nine, seven reported their expectations were mostly or completely unmet. SCUDEM III participants reported teamwork (10 of 36) and learning new strategies from others (6 of 36) as the most positive aspects of the competition.

DISCUSSION

Based on our review of the literature, designers' promotional material, and our analysis of participants' perspectives, we conclude that participants, designers, and researchers hold differing, though not incompatible, perceptions of the benefits of mathematical modeling competitions. Specifically, participants hold expectations not identified by either the designers or the researchers. We conjecture that participants may feel dissatisfied due to these unmet expectations, possibly leading to lower future participation. Results from analysis of SCUDEM II data showed participants who would not recommend to a friend (ie. felt dissatisfied with the competition) also seemed to have unmet expectations. Indicating our conjecture may be valid, however, it is unclear to what extent participants' unmet expectations influence their decision to no longer participate. Many participants did report gaining something from the competition even when their expectations went unmet. Only 2.08% of participants reported gaining confidence in modeling post competition which contrasts results of a research study measuring gains in self-efficacy for this same sample (Czocher, Melhuish, Kandasamy, 2019). We interpret this result as indicating that participants gained more form the competition then they realized, were able to articulate, or perhaps even valued. We infer there might be aspects of the competition participants value over their original expectations. There are limitations to this study. There is a disconnect between observed gains versus participants' reported gains. For example, many participants did not state they got experience with mathematics outside of the classroom; however, by nature of this competition they did have this experience. Additionally, only 17% of participants responded to the pre- and post- survey. Despite the limitations, this study suggests that designers and researchers could better attend to the student perspective when promoting and evaluating the effectiveness of competitions. For when participants leave the competition with unmet expectations, or unaware of the benefits they have acquired, the participant could feel dissatisfied with the competition and no longer participate or advocate for others to participate. SUCDEM IV (to take place in October, 2019) provides another opportunity to explore lingering questions. Using SCUDEM IV data at ICME-2020, we anticipate answering and reporting on the extent to which unmet expectations influence future participation, and aspects of the competition that students identify as the most important. Additionally, we plan to corroborate our previous results, and we plan to explore the extent to which previous participation changed the students' incoming expectations.

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