2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #38096

Board 268: Engineering Connections in Culturally-Responsive Mathematical Modeling Problems

Dr. Corey E. Brady, Vanderbilt University

Corey Brady is assistant professor of the Learning Sciences in the Department of Teaching and Learning at Vanderbilt University. His research focuses on mathematical and computational thinking and modeling, with a particular emphasis on supporting and understanding the collective learning of classroom groups. He partners with teachers and schools to support and understand new forms of STEAM activity that foster the participation of all learners. Prior to entering academia Corey worked in industry, leading the design and development of Texas Instruments' TI-Navigator system (2001-2006). He has also been a classroom teacher, at middle school, high school, and community college levels. Corey holds degrees in Pure Mathematics (MS), English Literature (MA), and Mathematics Education (PhD).

Dr. Hyunyi Jung, University of Florida

Hyunyi Jung is an assistant professor of mathematics education at the University of Florida. Her research focuses on the learning and teaching of mathematics as a humanizing practice. She cares about students' authentic mathematics learning experiences in safe spaces and has devoted her career to working with students and teachers to enact and study mathematical modeling. She currently serves as a Department Editor for one of the National Council of Teachers of Mathematics (NCTM)'s journals, Mathematics Teachers: Learning and Teacher PK-12 in its Ear to the Ground Department. She served as the president of the Graduate Student Education Council at Purdue University (2012-2013) and a director of mathematical modeling summer camps and after-school programs (2018-2020).

JOSE DAVID DE LEON ALEJANDRO, University of Florida
Dr. Chonika C Coleman-King, University of Florida

Dr. Chonika Coleman-King is currently Assistant Professor of Teachers, Schools, and Society at the University of Florida where she also serves as the Coordinator for Curriculum and Research of the new equity-centered elementary teacher education program. She has been named Director of the Collaborative for Equity in Education, a university center that focuses on building collaborations that advance equity-centered initiatives and research endeavors. Dr. Coleman-King's research interests include the development of anti-racist teachers, culturally responsive STEM education, Black mothering, and the experiences of Black immigrant and Black American youth in U.S. schools. Dr. Coleman-King is the author of the book, The (Re-)Making of a Black American: Tracing the Racial and Ethnic Socialization of Caribbean American Youth which documents the complex interplay between race, class, and immigrant status for Afro-Caribbean immigrant youth and the role of schools and families in their identity development.

Zandra de Araujo, University of Florida
Kayla Sutcliffe, University of Florida

Kayla is a doctoral student in the Curriculum and Instruction program specializing in mathematics education at the University of Florida. She has more than eight years of elementary teaching experience and has eight activities published on Teach Engineering, a standards-based classroom tested digital collection of engineering activities and lessons. Her research interests include perspectives on mathematical strategies implemented at the elementary level and mathematical modeling.

Engineering Connections in Culturally-Responsive Mathematical Modeling Problems

This poster presents findings from design and early implementation work of the NSF DRK-12 project, Empowering Students with Choice through Equitable and Interactive Mathematical Modeling (EIM2), which positions 6th and 7th grade students as decision makers in their own learning, integrating culturally responsive mathematical modeling problems into their regular curriculum. We take a socio-critical perspective on modeling, supporting students in using mathematics to understand their life experiences and, when appropriate, to challenge the existing social order (e.g., Aguirre et al., 2019; Jung & Magiera, 2021; Cirillo et al., 2016; Felton-Koestler, 2020). By learning to recognize mathematical dimensions of their emerging identities in classroom settings, we hope to inspire excitement about mathematics and boost students' experiences of mathematical agency (Boaler & Greeno, 2000).

Our approach to task design within mathematical modeling is also grounded in the Models and Modeling Perspective (Lesh & Doerr, 2003), which aims to engage students with problem-settings typical of mathematical work beyond school (Lesh, Hamilton, & Kaput, 2007). Such problems often involve trade-offs or feedback; where goals (e.g., "fair distribution of resources" or "comfortable living space") must be quantified before they can be tackled mathematically; and where one is often interested in optimizing, maximizing, or minimizing these quantities. This approach to modeling connects modeling with engineering (Diefes-Dux et al, 2008; Hamilton et al, 2008) in ways that we explore in the activity we present in this poster.

Research Questions

In this study, we were interested to explore how a culturally-responsive mathematical modeling task can be motivated by engaging students with a significant community issue, and how students may find relevance in such an activity. Our research question was, "How can a modeling activity be designed to engage students in mathematical analysis and construction, so that their mathematical activity is guided by their interpretations of the challenge, the values they articulate, and their design goals?

Materials and Methods

The Homeless Shelter task (Jung & Brand, 2021) invites students to create a design for a personal microshelter for the homeless. Students are introduced to the problem through videos showing how communities across the US have been implementing such shelters; the problem is also situated locally in the particular needs of the homeless population in the communities served by our partner schools. Given the goal to produce many of these microshelters using a fixed budget, students are faced with the challenge of creating a design that optimizes the qualities they believe most important within realistic budgetary constraints (Jung et al, in preparation). Students work in groups of 3-4 to develop a shared design. Each group is given a price sheet with various items they can incorporate—including plywood of different thicknesses, different potential materials for windows, etc. These options can provoke or reinforce students' recognition that while the size (i.e., enclosed volume) of a microshelter is an important consideration, they value additional factors (such as sturdiness, light and ventilation, etc) as well. In addition, we provide physical modeling materials that support student groups in envisioning and communicating their microshelter designs.

We analyzed video data and student-created artifacts from an early implementation of this activity, describing the distinctive ways of thinking that emerged across different groups' work and the strategies for mathematizing and optimizing that they employed. We used discourse analysis (Gee, 2014), defining discourse broadly, to include multimodal communication (Radford, 2014). Below, we describe each group's distinctive approach and the mathematical insights that they produced.

Participants

The 12 participants in the activity were drawn from two schools (pseudonyms used). Eight Black 6^{th} grade students came from St. Teresa Academy (six who presented as female and two as male). Four Hispanic/Latinx students came from the Roper Developmental Research School (one 6^{th} grader who presented as female, one 7^{th} grader who presented as female, and two 7^{th} graders who presented as male).

St. Teresa's Academy is a small, majority-Black private school situated in a historically Black community that has been systemically cut off from the larger community of the surrounding town. Many of the students who attend St. Teresa's live on this side of town, where there is quite a bit of poverty. Most students receive government-funded scholarships to attend the private school, which is owned and run by a Black woman native to the local community. The school serves students pre-K through eighth grade. Roper Developmental Research School is a public school affiliated with a University. The student population is selected by lottery and required to reflect the demographics and socioeconomics of the school-age population of the State.

Participants were recruited and consented through a convenience sampling, by word of mouth through researchers' contacts in the schools and communities. In the 75-minute modeling session, the participants formed four groups. Each group was provided with a written explanation of the problem and construction materials intended to enable them to explore and communicate ideas about shelter designs. They were shown two videos introducing homelessness and existing efforts to support the homeless community. After a whole-group discussion, the teams developed their designs for shelters, working to achieve the goals they identified while meeting cost constraints. Their work was video recorded, and photos were taken of the groups' material productions.

Results and Analysis

When researchers introduced the dilemma to the whole group, students were very engaged and intrigued by the homeless situation in their town. While watching the videos, students took note of relevant details, including the cost of materials and the tools needed to construct the shelters. The debriefing discussion was lively, as students shared what they noticed and what they wondered. In particular, students shared their concerns about homelessness in their town and hypothesized about the reasons people might become homeless. They reflected on the data provided, comparing and contrasting with their hypotheses. On being asked, the students agreed that homeless people deserve a safe home, and they began their design work with enthusiasm.

For each team, we note salient features of their design discussions, focusing on the way they expressed their intentions and values for the shelters in their design decisions.

Team 1. This group began by talking about the walls of the shelter: how to measure them and how to represent them. More generally, they focused on the structural elements of the shelter, using the materials to envision it and the options they had for design. They began early with materials, working to build a model that would take into consideration the real dimensions of the wood panels and wood studs listed in the supply sheet. To them, solid, sturdy walls were important, and they decided that a floor was also important. One student in particular from this group was concerned about the stability and sturdiness of the structure, emphasizing the wooden studs and their placement, to make the shelter safe.

Team 2. This team started by discussing how much space/area was designated for each of the finished microshelters. Once they envisioned this allowed "footprint," they began to explore the materials list to determine what they would need. In terms of representations, this group worked with sketches on paper to capture their emerging thinking. Along with diagrams, they made a list of the materials they would need, which allowed them to calculate costs as they went. (This involved adding, multiplying, and subtracting as their design emerged.) They became concerned about the tools needed to construct the shelters and about materials that could add to the structure's sturdiness. As they took these considerations into account, the budget constraints became salient to them, and they made adjustments to their plans, accordingly.

Team 3. Team 3 first turned their attention to the physical construction materials they had been given to build the model of their microshelter. They measured these components and discussed how these measurements could represent the size of the real structures. That is, they were concerned right away with the scale and scale factor of the model they would build. They noticed the even dimensions—2in, 4in, 6in, and 8in—of the materials and then compared these to the dimensions of the supplies in the supply sheet.

Although they focused initially on the two-dimensional space available for the floor (the "footprint" of the shelter), they were also very concerned about the interior height of the structure. For them it was important that the people could stand up inside their own microshelter. They decided that 8 feet was an appropriate height, and then they worked to maximize the space they could enclose given that height, with the materials they could afford (playing with length and width). Finally, they then started building their model.

Team 4. This group started by drawing a blueprint of the shelter layout together. Like Team 3, they were concerned about the size and nature of the three-dimensional space available *inside* the structure. Beyond the volume enclosed, they were interested in the usability of the shelter, and they were concerned about features like shelving and a closet, as well as ensuring there would be room to move. They designed the shelter from the inside out and made comparisons from that to the available footprint and the cost. As they negotiated these features and began to envision the shelter from the inhabitant's point of view, they began to discuss how the measures in their model related to the measures in real life. This led to debates about whether to use a certain size of building material versus another, juggling between the space constraint and the materials size and cost constraints.

Discussion and Conclusions

In this implementation of the Homeless Shelter task, we aimed to discover whether students were engaged by the idea of designing a shelter and whether they found the activity relevant to their interests and lived experiences. We were also interested to see whether the task was sufficiently open-ended to encourage different groups to bring their unique perspectives and values to their designs, and to see whether these perspectives led them to a diversity of ways of mathematizing their goals for the shelters.

Overall, students were interested and engaged with the task and expressed feelings of investment in their designs. They were excited about using mathematics collaboratively to solve a very real and urgent problem that they saw as affecting them and their community. They humanized the design process, empathizing with the inhabitants and showing concern for how the interior space would be experienced. Beyond the structural elements, many students also expressed their sense that it was important to get electricity to the shelters, and to ensure that the inhabitants had amenities to make them comfortable.

In these ways, the task supported design empathy as well as the foundation for sociocritical perspectives on modeling. They also utilized mathematical knowledge flexibly to interpret the situation, and to advance their intentions and values for the shelter designs. They recognized the need to quantify their goals in order to express those goals in a concrete and feasible design. In the process, they activated a range of mathematical knowledge, including many skills reflected in the state standards as well as many others that went beyond the standards.

For us as researchers, the Homeless Shelter task serves as a prototype for a series of activities, to be developed in the EIM2 project. Our next steps include articulating a set of design principles that can be used to guide our own task development work and our co-design work with participating teachers.

References

Aguirre, J. M., Anhalt, C. O., Cortez, R., Turner, E. E., & Simic-Muller, K. (2019). Engaging teachers in the powerful combination of mathematical modeling and social justice: The Flint Water Task. *Mathematics Teacher Educator, 7*(2), 7-26.

Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing. In, J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning*, (pp. 171-200) Westport, CT: Ablex Publishing.

Cirillo, M., Bartell, T. G., & Wager, A. (2016). Teaching mathematics for social justice through mathematical modeling. In C. Hirsch & A. Roth McDuffie (Eds.) *Annual perspectives in mathematics education: Mathematical modeling and modeling with mathematics.* Reston, VA: National Council of Teachers of Mathematics.

Diefes-Dux, H. A., Hjalmarson, M. A., Miller, T. K., & Lesh, R. (2008). Model-eliciting activities for engineering education. In *Models and modeling in engineering education* (pp. 17-35). Brill.

Felton-Koestler, M. D. (2020). Teaching Sociopolitical Issues in Mathematics Teacher Preparation: What do Mathematics Teacher Educators Need to Know?. *The Mathematics Enthusiast, 17(*2), 435-468.

Gee, J. P. (2014). *An introduction to discourse analysis: theory and method (4th ed.).* New York: Routledge

Hamilton, E., Lesh, R., Lester, F., & Brilleslyper, M. (2008). Model-eliciting activities (MEAs) as a bridge between engineering education research and mathematics education research. *Advances in Engineering Education*, *1*(2), 1-25.

Jung, H., Brady, C., King, C., DeAraujo, Z, De Leon, J., Salama, C., & Bratsch-Hines, M. (in preparation). Empowering Students with Choice through Equitable and Interactive Mathematical Modeling. In preparation for submission to *Journal for Research in Mathematics Education.*

Jung, H., & Brand, S. (2021). Student actions for social justice-oriented mathematical tasks. *Mathematics Teacher: Learning and Teaching PK-12, 114*(5), 378-385.

Jung, H., & Magiera, M. T. (2021). Connecting mathematical modeling and social justice through problem posing. *Mathematical Thinking and Learning*, 1-20.

Lesh, R., & Doerr, H. M. (2003). Foundations of a models and modeling perspective on mathematics teaching, learning, and problem solving. In R. Lesh, & H. M. Doerr (Eds.), *Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching* (pp. 3-33). Mahwah, NJ: Lawrence Erlbaum.

Lesh, R. A., Hamilton, E., & Kaput, J. J. (Eds.). (2007). *Foundations for the future in mathematics education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Lesh, R., Hoover, M., Hole, B., Kelly, A., & Post, T. (2000). Principles for developing thought-revealing activities for students and teachers. In R. Lesh, & A. Kelly (Eds.), *Handbook of research design in mathematics and science education* (pp. 591-645). Hillsdale, NJ: Lawrence Erlbaum.

Radford, L. (2014). Towards an embodied, cultural, and material conception of mathematics cognition. *ZDM, 46*(3), 349-361.