LEVERAGING MATHEMATICAL MODELING FOR EDUCATION AND ACTION (25W5498)

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Introduction

Mathematical modeling has long been recognized as a powerful tool for interpreting theoretical ideas and explaining real-world processes, with its effectiveness demonstrated across both mathematics and industry [6, 7, 13]. In fields such as engineering, environmental science, and economics, models are routinely used to predict outcomes, optimize systems, and guide decision-making. Similarly, within mathematics education, modeling provides learners with opportunities to bridge abstract concepts with real-world problems, enhancing both their analytical and problem-solving skills. When learners engage in modeling activities around community-based issues, they not only practice critical numeracy but also develop social agency [2, 5, 15, 16, 17, 26].

Existing teaching curricula tend to detach mathematics from social concerns, relying on decontextualized tasks that marginalize minoritized voices [1]. Scholars in critical mathematics education and culturally responsive pedagogy argue that this detachment reproduces inequitable power structures and fails to engage learners meaningfully. In contrast, a growing body of research advocates for socially responsible mathematical modeling tasks—grounded in community concerns—that encourage students' engagement with the social issues in their communities. (e.g., [24, 4]). The workshop *Leveraging Mathematical Modeling for Education and Action (25w5498)* traded on these ideas and contributed to this purpose by exploring how mathematical modeling can be designed both for cognitive development and as a vehicle for social transformation. Through this lens, the learning process becomes rooted in shared values and a collective desire to cultivate critical thinking, problem-solving skills, and a commitment to addressing current and future societal challenges.

The Banff International Research Station (BIRS) and Casa Matemática Oaxaca co-hosted this bilingual workshop with 53 participants—34 attending in person and 18 virtually—from K 12 schools, universities, and Indigenous community organizations in Mexico, Canada, and the USA. Sessions were conducted in both English and Spanish. Participants shared a common goal: to explore how mathematical modeling can both enhance skills and support communities in inclusive and meaningful ways. This report synthesizes the key discussions and outcomes of the five working groups formed during the workshop.

Workshop Methodology

The workshop featured prominent scholars from various worldwide contexts as keynote speakers: **Dr. Hyunyi Jung (Texas A&M University, USA):** A leading researcher whose frameworks for integrating social justice in mathematical modeling have been instrumental in Mathematics Education worldwide. **Dr. Diana Solares (Queretaro University, Mexico):** Her work with indigenous communities in Mexico, emphasizing the mathematical knowledge of marginalized communities, such as working children and their families. **Dr. Magda Pando (Southern Methodist University, USA):** Specializes in addressing the biases in AI tools and exploring how bilingual teachers and students may engage with these tools critically and effectively. **Dr. Milton Rosa (University of Ouro Preto, Brazil):** A pioneer in developing the Ethnomodelling framework, advocating for integrating indigenous knowledge and contextual practices to develop critical mathematics learning experiences. **Dr. Anthony Ware (University of Calgary, Canada):** A leading mathematician with industry experience whose research focus is on connections between mathematical modeling and industry needs from an equity, diversity, and inclusion (EDI) perspective.

The keynote sessions provided a foundation for structuring the working group discussion rounds, offering both thematic direction and critical insights. Building on these presentations, we incorporated additional topics and guiding questions designed to approach mathematical modeling from multiple perspectives and to generate contributions that advance the field.

Three rotating discussion rounds structured the program. Each round began with guiding questions, proceeding through the working groups dialogue. After each round, presentations were made by each group where participants from other groups provided feedback and had an opportunity to ask questions. Presentations were in English and Spanish with the aid of bilingual members of each presenting group. The last day of the workshop consisted of plenary reflection. The table below is a summary of the rounds of discussion:

Round	**Guiding Focus**	**Prompt**
1	Framing social-justice connection	How can collaborations among diverse populations leverage modeling to address complex real-world local issues?
2	Student engagement	How can mathematical modeling tasks resonate with students across educational levels; what supports accessibility and engagement?
3	Teacher support and assessment	What types of professional development resources are required to support teachers, and what assessment tools are required to advance community-based modeling?

Table 1: Summary of each round of discussion and guiding questions.

The workshop participants formed five working groups, each focusing on a topic aligned with their interests and research priorities. The topics included: (1) Indigenous Education and Mathematical Modeling; (2) A Call to Action: Reflecting on the Mathematical Knowledge of Minority Groups through Mathematical Modeling; (3) Connections between Everyday Practices and Mathematical Modeling; (4) Community Participation through Mathematical Modeling Tasks (online); and (5) Environmental Justice and Mathematical Modeling: Designing Tasks that Link Mathematical Modeling to Environmental Justice and the Climate Crisis. Each group defined its own objectives and approaches to address the challenges within its focus area. The following sections present a synthesis of the main objectives, discussions, and key findings emerging from each group.

Working Groups Synthesis

Indigenous Education and Mathematical Modeling Group

Group Objectives and Key Questions

This was a diverse group involving researchers in mathematics education, teacher educators, activists, teachers and teachers with administrative positions. As a diverse group, members brought different perspectives and purposes related to the broader theme of Indigenous education and mathematical modeling. The purposes varied among the following themes:

- Improve mathematics learning in Indigenous communities
- Promote Indigenous language and culture through mathematics
- Prepare teachers working in Indigenous communities
- Promote an agenda of social justice and decolonization

This group spent time sharing diverse issues related to education in Indigenous communities, such as:

- In some communities, women are expected to marry and dedicate themselves to their families after finishing secondary school, which means they do not continue formal education. As a result, Indigenous migrant women workers acquire arithmetic skills that are very different from conventional arithmetic, which often places them in a vulnerable position in their workplaces.
- On the other hand, the expectation for men is often to migrate to the US. For this reason, it might be the case that at some schools English is preferred instead of Spanish.
- While schools in some communities value the extracurricular work that implies relating the curriculum with the community activities (e.g., cropping and harvesting), teachers in other communities have little chance of taking the students out of school.

The conversations throughout the workshop were sparked by the following questions:

- Which populations are you coming from? This was relevant to positioning ourselves within the group.
- What is activism? How can we move from perpetuating the status quo to systemic change? This question followed the positioning of one member as an activist.
- What is mathematics and mathematical modeling? The group asked for clarification on these terms, and we explored assumptions regarding the nature of mathematics.
- Why are you in this group? This question arose by the end of the workshop and related to what we expected as outcomes from the work in the group.
- How to engage in teacher professional learning? This was the final question.

Discussion Summary

The discussion centred initially on the members' backgrounds and positioning. This helped to understand the diversity within the group. Among the group members, there were three Indigenous teachers from Oaxaca. They explained many of the political issues in the region that could prevent teachers from implementing community activities related to mathematical modeling. Also, access to some communities might be difficult due to a lack of trust of the population with different levels of government, including violent events such as the murder of local activists. This discussion also included the role of educators in Indigenous communities, including a conversation on terms such as *empowering, self-determination,* and *decolonization.*

There was also a conversation regarding the purpose of education and its relationship with the community. This conversation included the role of mathematics within and beyond school. For instance, some cases relating to Indigenous, migrant, working women were presented in which adult women have arithmetic skills that are very different from conventional arithmetic and the use of calculator, which put them in a vulnerable situation. One option suggested was stressing connections between their languages and Western mathematics. Another purpose of education in this case was the preservation of culture and language. Teachers from the group commented that often they do not speak their students' languages, a situation that hinders communication and the promotion of the original languages. The role of the communitarian work was stressed as one of the traditions in Indigenous communities. One suggestion was to start from the local situations or problems in the community and then try to design projects involving mathematical modeling related to such situations. This discussion also included a conversation on the nature of mathematics. The group proposed to take into account embodied and spiritual aspects in mathematics.

By the end of the workshop, the group focused on plans for teacher professional development. It was stressed in the conversations that educators should not limit themselves to simply tell teachers what to do. Rather, educators could start learning from what teachers are already doing at their schools and try to build from that. This suggestion addresses two situations. On the one hand, schools are restricted to local situations, such as infrastructure, equipment, local political environment and social and cultural aspects. On the other hand, some teachers are already doing a great job, and educators and researchers can learn from them. Based on this conversation, it was suggested that this could be a good starting point for collaboration with Indigenous teachers or teachers working in Indigenous communities. While we did not discuss a formal plan, we agreed that educators and researchers in the group could work with local teachers, as some of the Indigenous teachers in the group could serve as a liaison for implementing professional learning events with teachers in Oaxaca.

A Call to Action: Reflecting on the Mathematical Knowledge of Minority Groups through Mathematical Modeling

Group Objectives and Key Questions

- To discuss the cycles of mathematical modeling.
- To analyze the clear gaps in the literature on mathematical modeling in relation to minority groups.
- To propose an extensive review of the literature on mathematical modeling in relation to social justice.

- To consider ways to address the needs of specific groups, such as bilingual students, students with Autism Spectrum Disorder, and the Deaf community, when designing and teaching through mathematical modeling.
- To rethink mathematical modeling cycles to include different forms of communication and representation.
- To rethink culturally inclusive approach to mathematical modeling.
- To explore the relationship between the reflection on inclusive mathematical modeling and the practices of schools, within the context of school mathematics education.

Although the group discussions were based on the guiding questions for each round of the workshop, it is worth noting that within the group, we raised a key question: *What are the complex problems faced by minority groups that could be addressed through a mathematical modeling perspective?* This will remain a recurring question, as understanding what we mean by "minority groups" requires ongoing reflection. On the other hand, while reflecting on the documented experiences we have with three minority groups, important nuances emerged regarding the concepts of communication and representation. In this context, communication is not simply about the language used to interact with others, but rather a cultural expression of the group to which the speaker belongs. Similarly, representation is not merely about using icons or symbols to display information, but refers to the resources used in argumentation that emerge during mathematical modeling activities. The specific questions that emerged were:

- How does mathematical modeling make it possible to include minority groups through their specific characteristics?
- In what ways can the formulation of real-life situations support inclusion and a sense of belonging within the student community (including minority groups)?
- How does mathematical modeling foster communication and interaction between students and teachers to develop informal representations and their evolution into formal representations?

Finally, in general terms, the concept of social justice was addressed, understood as the inclusion of these minority groups. However, the focus was not on inclusion from a human rights perspective (such as access to schools or educational institutions) but rather on being recognized as individuals who have their own ways of thinking mathematically, which the school system still does not yet fully know or acknowledge. Consequently, these individuals are frequently excluded by a curriculum designed for the "general" student population.

Discussion Summary

Within the group, we identified two major themes to consider, namely: Mathematical Modeling and Minority Groups. The main concepts of mathematical modeling were:

- **Mathematical modeling:** Mathematical modeling is a process that involves representing real-world phenomena, situations, or problems using mathematical expressions (such as equations, functions, graphs, systems, etc.) in order to analyze, interpret, solve, or make predictions.

- **Mathematical modeling cycles:** refer to iterative processes through which learners translate real-world situations into mathematical models, analyze and refine these models, interpret the results within the context of the original problem, and revise their models to enhance both accuracy and contextual relevance. Over time, various researchers have proposed versions of these cycles to support modeling in educational settings [21, 3, 9, 19, 8, 18, 10, 12, 22].

- **Social Justice:** Social justice is the ethical and political principle that seeks equity in the distribution of resources, opportunities, and rights within a society, ensuring that all individuals—regardless of their background, gender, class, ethnicity, or orientation—can live with dignity and under equal conditions.

- **Inclusion:** The process and practice of ensuring that all individuals, especially those who have been historically marginalized or excluded, are fully involved in all aspects of social, educational, occupational, and cultural life.

After discussing the above concepts, the group reflected on the importance of conducting a literature review on these two broad topics and their nuances, given the relevance of inclusion and social justice. Based on the plenary discussions, we identified books and scientific articles—some authored by members of the Workshop—that we consider as a foundation for reflecting on Mathematical Modeling as an agent of inclusion within Minority Groups.

Future Work

The participants identified concrete next steps to continue and expand the collaborative efforts initiated during the workshop. The group agreed to focus on two key tasks: (1) developing a comprehensive research protocol to refine the modeling approaches and address the specific needs of diverse learners, and (2) establishing a detailed work schedule to coordinate implementation, analysis, and dissemination. A central focus of this future work is the study of three minority groups: (a) a deaf community of students who use sign language in a private school exclusively for deaf children, taught by bilingual(English and Spanish speakers) teachers, following the curriculum and assessment standards set by the Mexican Secretariat of Public Education (SEP); (b) emerging bilingual students from diverse countries and cultural backgrounds who are required to unify their language learning with English in order to access formal education; and (c) a 13-year-old student diagnosed with Autism Spectrum Disorder (ASD), verbal, and currently enrolled in the second grade of a public secondary school. By integrating the experiences of these groups, the research aims to develop inclusive mathematical modeling practices that reflect diverse ways of knowing and learning. These steps will not only sustain the collaborative work but also ensure that the outcomes are relevant and accessible to marginalized communities.

Community Participation through Mathematical Modeling Tasks (Online Group)

Group Objectives

We consider civic participation to be activities by any individual in a society which contribute to the well-being of their communities and overall society. Colleagues noted that civic participation can suggest allegiance to the nation state and/or prerequisites for a legal definition of citizenship; the group revised the theme to socially informed participation in society. In this regard Chronaki and Yolcu (2021) [11] mention that "Mathematics for citizenship" should be discussed "in the context of a globalised neoliberal economy grounded in the history of colonial practices and power concerning the governing of a political community that travels across spaces and time." (p. 243).

Due to these ideas our group redirected task design towards community agency rather than state centric duties and broadened inclusion. Models are influenced by the values of the modeler: choice of variables, data sources, and simplifications encode the modeler's assumptions. Participants reflected on Orey and Rosa's [20] ethnomodeling and Steffensen and Kasari's [24] social action loop onto the Guidelines for Assessment and Instruction in Mathematical Modeling Education (GAIMME) cycle to create checkpoints for interrogation, community validation and to reflect on shared values. Additionally, the discussion brought some ideas from Su (2020) [25], in which part of the individual mathematical flourishing is related to their values and ideas that consider power, justice, freedom and community.

Discussion Summary

Connecting mathematical modeling tasks for community identified problems are a powerful way to integrate mathematical modeling for social benefit; such as optimizing the deployment of volunteers in Nova Scotia in coastal litter clean up, predicting smoke day frequency for Alberta schools, allocating pallet shelters and organizing their layout amid housing crises. Projects in data exploration can also be used to teach students to critique sources, check biases, and determine limitations before formal model construction. Furthermore, it was agreed that the direction in which modeling cycles should operate are to start from social issues within the community, then develop mathematical models around them to assist with fulfilling those societal needs. Community members can be consultants and partners in assisting connect mathematical modeling to community issues.

Engaging Learners Across Levels. Strategies that surfaced included co designing sessions with the involvement of community members. Therefore, building partnerships is an important requirement to achieve this task. This step would entail identifying and understanding a problem at a local level and developing the mathematical modeling techniques around them.

Active investigations were another strategy discussed to engage learners. This is a technique where students are introduced to a new concept through motivational examples and case studies. Students are able to develop mathematical intuition about a concept before seeing algebraic expressions. An entry point to mathematical modeling is through "toy" models for learners to experiment with. This may include the use of computer software for learners to examine outcomes of models after entering different parameter values into a model or entering a different set of data. Further engagement may be achieved by connecting mathematical modeling with topics of interest to the current generation of learners including climate change, parks design, AI and social media impact, and housing affordability. In addition, interviews and quick questions in classroom sessions may bring new ideas for the design of modeling problems linked to students' interests.

Teacher Professional Development. Participants agreed that it is necessary to assist teachers with effectively delivering content to learners. Teachers can play an important role as facilitators between students and the community. However, there are also challenges which many teachers face, such as exposure to rigid traditional teaching models which may make it difficult to implement ethical mathematical cycles, and access to resources. Providing adequate teacher training and professional development is essential but may also be challenging to implement. Still, because teachers are often members of the communities they serve, they are well positioned to create meaningful connections between classroom learning and local issues. For example, inviting community experts to share their perspectives can offer multiple lenses on a single problem and strengthen the relationship between mathematical practice and community engagement. We discussed teachers as "community builders," this means individuals who actively shape the relationships, values, and

shared understandings within and beyond the classroom. As community builders, teachers have the potential to bridge school and society. This role extends the impact of teaching beyond academic outcomes and positions mathematics education as a meaningful contributor to community well-being and transformation. Adding to this, "community members" are positioned as consultants who help transmit community values to future generations. We conceive this relationship as a key interaction in the construction of a community of practice that aims to create a shared sense of purpose, foster mutual learning, and ground mathematical modeling in lived, local experiences.

The Socially Enhanced Modeling Cycle. By studying the work of Orey and Rosa (2021) [20] and Jung and Magiera (2021) [17], we consider the development of a Socially-Enhanced Modeling Cycle (SEMC) which integrates societal values into mathematical formalization. This SEMC also includes community validation, quantifiable measurement of actions and reflection and refinement by the modeler. Our SEMC proposes a holistic approach which combines values of the modeler and societal partners, attempts to remove or minimize biases or misconceptions by the modeler and also proposal community accountability due to the involvement of community partners with the modeler on projects important for the community. These are aspects which are absent from existing traditional mathematical modelling cycles. While "values" have been discussed by Rosa and Orey in an extensive way, we position the "values of the modeler" as Step 0 in our SEMC. These values influence both the selection of variables and the framing of the problem, ultimately shaping the model's outcomes and interpretations. Since all models carry implicit biases, acknowledging the modeler's values is essential. We see values as a crucial element for meaningful community engagement, serving as the bridge between mathematical modeling and community participation.

Sustaining Community Partnerships. On one side, universities may be able to incentivize engagements through service learning credit, community engaged research grants, and promotion criteria recognizing public scholarship. On the other, schools may be able to assist by providing time and space for collaborative projects and recognizing the value of community partnerships as part of professional development. Additionally, building long-term relationships with local organizations, respecting community timelines, and ensuring mutual benefit are essential to sustaining these partnerships over time.

Actionable Recommendations

- Educators can begin with listening and forming community partnerships: Meet with stakeholders and conduct interviews inquiring about their needs before designing tasks.
- Adopt the SEMC: Develop community-based modeling with checkpoints embedded in the GAIMME assessment criteria.
- Layer scaffolds: Sequence from data explorations to simplified, then full, models.
- Support teachers: Establish professional development programs, teacher training summer schools, and shared resource hubs.
- Utilize software with critical integration of AI: Position students in a way there is a baseline understanding of programming and software so they can audit AI generated results to enhance models.
- Assess, reflect and refine: Balance reasoning and community relevance, alongside mathematical rigor, measure outcomes, reflect on process and refine.

Environmental Justice and Mathematical Modeling: Designing Tasks that Link Mathematical Modeling to Environmental Justice and the Climate Crisis

Group Objectives

Throughout the sessions, the group discussed the implications of designing sequences of tasks to address socio-environmental issues with mathematical modeling at school. The work was organized around three issues: the participation of various actors in the design of activities; the dilemma of weather to emphasize the design on the mathematical contents, on the understanding of the socio-environmental problem, or on a situated articulation between the two; and the features we consider important in a design. Finally, the group shared plans for future collaborative work, focusing on the development of specific sequences and analyzing both the tensions and the learning opportunities they generate.

Discussion Summary

Working with Diverse Participants to Design Activities

We questioned ourselves about who should be involved in making such designs. We have found different ways to encourage collaboration among diverse participants to address complex real-world problems through mathematical modeling in mathematics classes. We discussed the roles of various participants in the design, including students, teachers, families, community organizations, communities, professionals from different disciplines, and researchers in education, particularly in the field of educational mathematics. The question of how to involve diverse actors in designing school activities that address environmental justice issues and analyze the climate crisis led us to reflect on our research projects. Some examples are: Understanding the knowledge of professionals, The voice of the community in educational mathematics, The "Museum of the Atoyac River", and Children's perspectives on the territories affected by industrial pollution.

What to prioritize in the design?

Regarding the design of activities oriented towards environmental justice and involving mathematical knowledge, we discussed the differences between focusing on understanding the socio-environmental problem and the approach to mathematical content.

One of the proposals that arose from this question was that, if one seeks to address a socio-environmental problem through mathematics education, the school curriculum requires adaptations because the mathematical notions involved in socio-environmental problems do not always align with the temporal and sequential logic of the current curriculum. This idea presents a challenge and involves extensive work, as exemplified by the current educational reform in Mexico's basic education system, "The New Mexican School", which seeks to incorporate problems linked to the students' communities in the classroom [23]. This change has drawn the attention of many teachers, who have raised concerns about how to approach the content they are accustomed to teaching, as well as mathematics education researchers who have identified a potential trivialization of the learning processes associated with mathematical notions [27].

We did not arrive at a definitive answer regarding where the emphasis would be on these designs. However, we are confident that the curricular adaptations and situated design work will enable us to continue the discussion and encourage further research.

What characteristics do we think are important to fulfill in a design?

The purposes for addressing socio-environmental problems with the support of mathematics are considerably variable, and this has implications both in the design process and in implementation. Some of these purposes are: to deepen the understanding of the socio-environmental problem, to build empathy with those most affected, to explore possible solutions, or to facilitate a collective elaboration of loss. A starting point is that we are interested in exploring the possibilities of school and educational research in the sense of looking for activities that do not only turn the responsibility to the individual, but facilitate reflection on systemic problems, while also not compromising the capacity for effective political action among children, adolescents, and their families.

One challenge is the differing frames of reference among team participants regarding the teaching and learning of mathematics, socio-environmental problems, and modeling. In particular, the concept of modeling is quite broad in the discipline of mathematics education.

Future Work

We have several designs to do: (a) a sequence of activities to study in secondary school the water crisis in Xochimilco starting from the community's perspectives on the problem, (b) a school situation for the training of engineers starting from professional tasks, (c) a didactic sequence to study in primary school the industrial pollution in the Atoyac watershed starting from children's descriptions of their environment, d) a school project to study water scarcity in a community of the state of Querétaro, Mexico; with a middle school group of students, based on the identification of the problem by the students themselves, e) a project involving researchers from several Latin American countries that will follow up the experience of the Atoyac river project earlier referred. What we intend to do from here on are exchanges on these sequences, dialoguing on: the implications of having taken each of the different actors as a starting point, seeing the advantages and limitations of each one; the challenges we face together, namely, the tensions and links between mathematical and environmental knowledge, the students' learning processes, the tensions and relations with the school curriculum.

Connections between Everyday Practices and Mathematical Modeling

Overview of the group and subgroups

This was a large group that was geographically and linguistically diverse, involving researchers working in Mexico, Canada, Brazil, and the US. In their work, they foregrounded a variety of theoretical and methodological approaches to modeling, though a strong common theme was a commitment to partnership with teachers, youth, and communities, to use modeling to explore themes of socio-cultural importance. In our initial meeting, group members shared themes in their work and interests they wanted to pursue in the work-sessions. This enabled us to divide into sub-groups, and it suggested an emergent structure to unify the work of subgroups into a coherent collaborative effort. We determined from our initial introductions, that it would be extremely valuable to see our animating ideas and themes in action, in the context of a (hypothetical) "pedagogical action" – that is, a planned engagement with a community around modeling work. We conjectured that "the Water Crisis" would be a generative topic, as researchers attested both that there was a strong awareness about this idea in their own contexts, and also that the Water Crisis manifested differently for different communities. Thus, we expected that hypothetical plans for a pedagogical action on this theme would express a diversity of perspectives in both researchers and in communities.

Shared Objectives and Interests

Throughout subgroup activities and sharing sessions back to the group, several themes emerged in the objectives and interests of the members. These key/generative themes included:

- **Social justice.** Pressing each other and ourselves about what social justice means in the context of our work and discussions. Recurrent theme. Partial definition in terms of consciousness raising (conscientização) / awareness / critical analysis of systems of production and of oppression. In the discussion, we found useful examples of the importance of a coherent social justice frame – in particular, moments where phenomena are not treated as uniform or simple, but as provoking differential impacts and impacts across many aspects of life at many scales. The group felt that in general, there can be social justice entry points when interpretation is foregrounded and the connections between solutions and values are identified, contested, and negotiated.

- **Authentic mathematical activity.** Again, the group found it important to press one another and ourselves for working definitions of this term, as a guide for our design and implementation work. Also, we asked, where is authenticity located? There were some ideas about locating authenticity in the mathematical content (is the problem engaging in a deep way with the mathematics) [authenticity in the design]; as well as ideas about locating authenticity in the relation/stance that the student forms with the activity [authenticity in the implementation] (cf. Lesh, Chevallard). Our goal was not to resolve this or other such issues uniformly, but to use reflective questioning about them as a way to orient our research, design, and partnership efforts. We asked similar questions about the vitality and utility for our efforts of descriptive terms like: culturally sustaining; culturally responsive; socio-cultural; socio-ecological; and socio-critical.

- **Design Elements** of Modeling Activities that encourage implementations that foster agency in students, openness in problem-solving, and multidimensionality / complexity in mathematical models. Elements that foreground mathematical modeling as an interpretive and value-laden activity. An important tension here was between (on one hand) the complexity and high-dimensionality of the real-world contexts that we want to engage with, as well as the richness of the ethnomathematics-in-context that we might want to draw upon; and (on the other hand) the concreteness of a quantified response (measure, model, strategy) that students will express in mathematical language. Here, we discussed how in these contexts to navigate the inherent tensions between the real world and models (as simplifications), and the inherent tensions between "emic" and "etic" perspectives (on cultural practices and resources). In school settings, there is also a tendency (sustained by the majority of activity-types found in schools), which we need to resist, in order to keep activities and inquiries 'open' – avoiding single right answers, single models, single interpretations, single perspectives, etc. In this connection, we discussed an interesting example (from work by Rodriguez, Moreno, and Zaldívar), where a modeling activity was motivated by an assumption in the public discourse about water conservation – that scarcity was (exclusively, or mainly) due to individuals' usage practices. It was NOT a desired outcome to replace that assumption with another limited assumption (e.g., that scarcity was exclusively or mainly due to corporations' usage practices), but rather to open the inquiry and provoke reflective discussion of the ways both of these factors play in, how they relate, and how different behavioral changes at different levels can promote improvement / change. Maintaining openness in facilitating the classroom group's work (encouraging diversity of focus and attention in modeling) can

potentially provide opportunities for the diversity of work in the class to express a range of models and understandings so that the class's productions are not reduced to a single outcome, answer, model, explanation, or perspective. Synthesis across these may not be possible or even desirable.

- **Mathematics for Peace.** Focuses on the political and psychological effects of engaging in mathematical activities that raise questions about social justice.. On one hand, members shared experiences of how engaging meaningfully with issues, with a blend of values and intellectual engagement, provided participants with a sense of direction and capacity for understanding and action. A rich example came from Orey and Rosa's work around a change of fares for public transportation – modeling and analyzing the situation offered opportunities for the community to understand and articulate a response grounded in data. This theme also included concerns, for example, about how to engage deeply with climate change issues without provoking 'climate despair' or other senses of LACK of power. Certainly "Peace" in the phrase "Mathematics for Peace" does NOT mean satisfaction with the way things are, nor a lack of impulse to action. On the contrary, it points to a state of increased groundedness, awareness, and purposiveness – a state in which we are more prepared for coherent and effective action.

- **Strategies for facilitating Pedagogical Actions** that integrate different kinds of modeling activities and engaging in various moments with different participant populations. Some of the issues raised here involved Pedagogical Actions addressing social inequalities in the classroom where only some students identified racially or culturally with historically marginalized groups. The discussion emphasized the importance of avoiding placing the burden on these students to 'be the voice of' their race or culture.. Other questions had to do with how to introduce background reading to a topic, so that students can be inducted into the discourse around an issue while still feeling they have agency and voice to express (and mathematize) their perspectives on the issue. (This issue arose in a university-level context, but there are versions of the issue whenever the context is approached or needs to take into account, a broader academic, social, or political discourse, not in the students' experience.) Still other issues related to questions of method – what research practices can help to ensure that researchers are representing cultural knowledge, practices, or other resources accurately, appropriately, and with fidelity. This discussion dealt with ethnographic and qualitative methods to support researchers in getting close to research partner/participants; it highlighted participant observation, ethnographic interviews, and how to be rigorous in 'member checking' about data and observation; working with participant/partners to co-construct the account of community ideas and practices. In reflecting on and responding to these questions, the group articulated aspects of a theory of ethnomodeling practices that helped to ground the group's emerging conversations.

Summary of Sub-Group Work on the Water Crisis Theme

As part of developing pedagogical actions and modeling ideas around the theme of The Water Crisis, four sub-groups generated preliminary products that reflect the key features and focal points of their discussions. These products, ranging from technical tools to philosophical reflections, emphasize the diverse perspectives brought forward during the workshop.

- **Sub-Group 1 – Case Study on Water Issues in Northern Mexico.** This group focused on water challenges in Saltillo, Coahuila. They created a university-level Harvard-style case study, using systems modeling tools like VenSim to explore the complexities of water

management. Their approach emphasized local relevance while maintaining applicability to broader contexts.

- **Sub-Group 2 – Fog Catchers as a Pedagogical Provocation.** This group investigated innovative cultural practices, particularly the use of fog catchers to collect water from humid air. The topic serves as a pedagogical provocation, inspiring mathematical exploration of the effectiveness and design of such systems. This approach represents a ''middle phase" of modeling instruction, where students work within a chosen theme but select their own problems to pursue.

- **Sub-Group 3 – Activity Design for Water Equity and Infrastructure.** This group developed two concrete activities designed for classroom implementation: (a) planning water distribution infrastructure and (b) exploring equitable water allocation among communities. Their design process aimed to provoke theoretical reflection while ensuring adaptability to diverse instructional contexts.

- **Sub-Group 4 – Agent-Based Modeling and Student Inquiry.** This group explored how students could engage in student-led modeling inquiries using agent-based modeling tools like NetLogo. Their work aimed to make complex systems modeling accessible without requiring advanced coding skills, enabling students to conceptualize problems through collaborative role-playing and dynamic simulations.

Scientific Progress Made During the Workshop

The scientific progress achieved during the workshop emerged from the collaborative efforts of the five discussion groups, each exploring a different theme at the intersection of mathematical modeling, education, and real-world problems. The groups worked toward developing pedagogical strategies, task designs, and research agendas that integrate community perspectives, promote social justice, and foster inclusive mathematical practices. Together, these efforts reflect a collective commitment to advancing mathematical modeling as an educational process capable of addressing real-world challenges.

The **Indigenous Education and Mathematical Modeling Group** centered its efforts on improving mathematics learning in Indigenous communities while promoting Indigenous languages, cultural values, and a broader agenda of social justice and decolonization. A key outcome of their discussions was the recognition that teacher professional development should be rooted in collaboration rather than top-down directives. The group emphasized the importance of learning from teachers' existing practices, which are often permeated by local realities such as infrastructure, resources, political contexts, and cultural traditions. By building on the strengths of teachers who are already implementing innovative approaches, educators and researchers can co-create professional development initiatives that are both culturally relevant and responsive to community needs.

The **A Call to Action: Reflecting on the Mathematical Knowledge of Minority Groups through Mathematical Modeling Group** focused on analyzing gaps in the existing literature and rethinking mathematical modeling cycles to be more culturally inclusive and accessible. Their work emphasized the need to incorporate diverse forms of communication and representation, particularly to better serve minority groups such as bilingual students, students with autism spectrum disorder (ASD), and the Deaf community. As a key outcome, the group proposed two immediate steps: (1) developing a comprehensive research protocol to refine inclusive modeling approaches, and (2) creating a work schedule to coordinate the implementation and dissemination

of findings. Central to this future work is an in-depth study of three minority groups: (a) Deaf students taught by Spanish/English speaking teachers in a private school aligned with the Mexican SEP standards, (b) emerging bilingual learners from diverse cultural and linguistic backgrounds, and (c) a 13-year-old verbal student diagnosed with ASD and enrolled in public secondary school. The integration of the unique expertise of the individuals in this group allow them to step towards the design mathematical modeling practices that reflect multiple ways of knowing and promote social justice in school mathematics education.

The **Community Participation through Mathematical Modeling Tasks Group** focused on designing modeling activities that prioritize community agency and inclusion, shifting away from state-centric approaches. The group emphasized that models inherently reflect the values and assumptions of the modeler—through the selection of variables, data sources, and simplifications—and therefore require critical reflection. Drawing on the concepts of ethnomodeling and the social action loop, the group integrated these perspectives into the GAIMME cycle, adding checkpoints for community validation and value reflection. Inspired by Su's [25] notion that mathematical flourishing involves considerations of power, justice, freedom, and community, the group outlined five actionable steps for future work: (1) building strong partnerships with stakeholders by listening and conducting needs-based interviews, (2) developing community-based modeling using the SEMC framework and GAIMME criteria, (3) layering scaffolds from data explorations to complex models, (4) supporting teachers through professional development, summer schools, and shared resources, and (5) refining tasks through iterative assessment, reflection, and a balance between mathematical rigor and community relevance.

The **Environmental Justice and Mathematical Modeling Group** explored how mathematical modeling can be used to design meaningful task that address socio-environmental issues, with a focus on the climate crisis. Their discussions were structured around key guiding questions, such as the role of different actors in the design process and whether to prioritize mathematical content, the socio-environmental problem, or a balanced integration of both. The group also reflected on essential design features that foster student engagement and deepen understanding of complex environmental challenges. As a result, they outlined five future projects: (1) a secondary school activity sequence on the water crisis in Xochimilco, informed by local community perspectives; (2) a professional task-based scenario for engineering students; (3) a primary school didactic sequence addressing industrial pollution in the Atoyac watershed, starting from children's observations of their surroundings; (4) a middle school project on water scarcity in Querétaro, co-designed with students to reflect their own problem identification; and (5) a collaborative research initiative involving several Latin American countries to build upon the Atoyac river project. These initiatives aim to connect mathematical modeling with urgent socio-environmental issues while fostering both critical thinking and community relevance.

The **Connections between Everyday Practices and Mathematical Modeling Group** explored how mathematical modeling can emerge authentically from everyday practices, with a strong focus on social justice, student agency, and pedagogical strategies that promote meaningful engagement. Key themes included the design of modeling activities that encourage critical thinking, mathematics for peace, and strategies for facilitating pedagogical actions that bridge students' lived experiences with formal mathematical concepts. As part of their contributions to the group's broader theme of The Water Crisis, the group developed and analyzed four preliminary products that reflect both technical and philosophical dimensions of modeling: (1) a Harvard-style case study on water issues in Saltillo, Coahuila, using systems modeling tools like VenSim; (2) a study of fog catchers as a cultural and mathematical provocation, encouraging exploration of sustainable water collection methods; (3) classroom-ready activities addressing water distribution infrastructure and equitable allocation of water resources; and (4) a student-led agent-based modeling inquiry, designed

to make complex systems modeling accessible without advanced coding expertise. Together, these initiatives highlight how everyday practices and community-based problems can drive innovative modeling approaches that are both contextually relevant and socially meaningful.

Conclusion

The work of the five groups illustrates the richness and diversity of perspectives on mathematical modeling that emerged during the workshop. This work highlights also key challenges when engaging in mathematical modeling grounded in real-world problems, including the need for curricular adaptations, rethinking teacher practices and professional development within this framework, and carefully considering the culture and language spoken by students. From advancing inclusive modeling practices and supporting teacher professional development to connecting environmental and community challenges with mathematical inquiry, the discussions and proposed projects represent significant steps toward both scientific and educational innovation. The future work outlined by each group—including the design of culturally responsive tasks, collaborative research protocols, and community-based projects—promises to extend the workshop's impact and contribute to a broader understanding of how mathematical modeling can address pressing social, cultural, and environmental issues.

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