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Interactive Demo of the Modeling and Evidence Mapping Environment (MEME) for Supporting both Elementary and Graduate Students

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Abstract: The Modeling and Evidence Mapping Environment (MEME) was designed to support elementary students in using evidence to create a model of an ecosystem. While drawing inspiration from prior modeling environments, MEME is unique in combining the following: 1) MEME incorporates explicit systems scaffolds based on the Phenomena, Mechanism, Component (PMC) framework; 2) MEME supports collaborative, qualitative model building; 3) MEME directly incorporates evidence within the model and modeling environment, and 4) students and teachers can provide and reply to comments directly on the model itself. We will give participants an opportunity to use MEME and share models produced both by 5th grade students learning about ecosystems, and graduate students exploring cultural historical activity theory (CHAT).

Keywords: modeling, science education, complex systems, collaborative learning, activity theory

Introduction

Modeling is a core scientific practice across scientific domains and disciplines, and is thus is also central to science education (Lehrer & Schauble, 2005; NRC, 2013; Schwarz et al., 2009). However, students struggle with developing and refining robust models (Pierson, Clark, & Sherard, 2017). In particular, students rarely use evidence to support the process of model evaluation and revision (Moreland et al., 2020). We therefore developed the Modeling and Evidence Mapping Environment (MEME) to support students in collaboratively developing and refining scientific models of a phenomena while explicitly referencing evidence in their model construction and refinement. Furthermore, while MEME can support modeling in any context, we explicitly developed MEME to support students in exploring complex systems, which have similarly proven challenging for students (Hmelo-Silver & Azevedo, 2006; Wilensky & Reisman, 2006; Yoon et al., 2016). Below we briefly outline our theoretical framework and design, and then summarize our proposed approach to the interactive demo.

Theoretical framework

Our work is grounded in activity theory, which locates learning within meaningful, goal-directed activity (Engeström, 1987; Greeno & Engeström, 2014). In this framework, activity is a collective phenomenon made up of a community of people pursuing a shared object or motive. Activity theory further highlights how individual actions are mediated, or transformed by aspects of the activity system including the physical and conceptual tools in the environment, the community of people who are also part of the activity, the rules that the participants observe, and thee division of labor which shapes participation within the environment (Wertsch, 2017). For example, students might be pursuing an object of developing an explanation of how algae in a pond is impacting fish survival. The idea that a model requires evidence to support it might mediate, or change how students pursue this object and lead them to look for and link evidence to their model if they accept that it is a valid idea. Similarly, having a tool that makes this link between evidence and a model salient as in MEME, may lead students to be reminded of the importance of evidence as they aim to construct a model. This set of relationships is often depicted as a triangle (Engeström, 1987) as in Figure 1.

Our goal in developing MEME was to plan for robust modeling activity, and then identify the features of both the software and the activity itself that would support this. For example, in order for the software to effectively support iterative refinement of a model, it not only needs to be easy to edit a model, but the classroom activities need to include time and motivation to do so. These relationships are discussed in our empirical papers (Moreland et al., 2020), and will also be part of our discussions during the interactive demonstration.

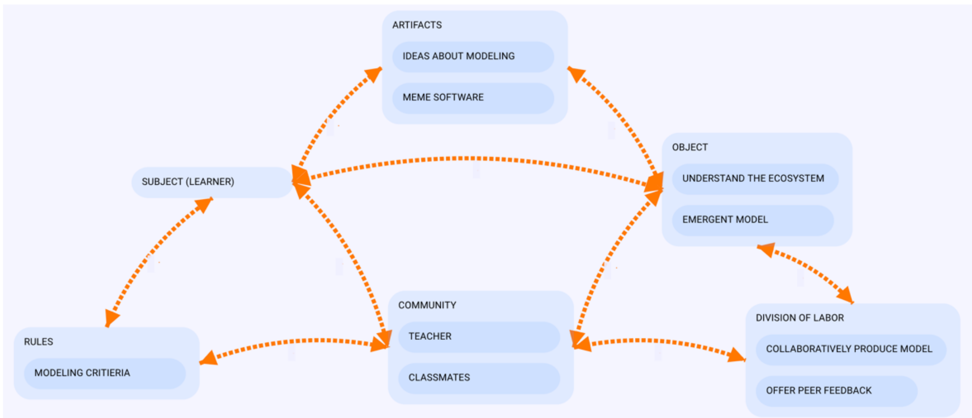

Figure 1: The MEME activity system modeled using MEME

The Design of MEME

As stated above, MEME was designed to mediate the process of creating and refining a model based on evidence. We decided to make MEME cloud-based and collaborative so that we could easily support students in working together on their individual models, or by engaging in giving and / or receiving feedback from peers. The design of MEME is reminiscent of a concept map because students have found concept maps powerful for representing ideas (Schwendimann, 2015) and because we have found students are more likely to revise this kind of simple visual model than one where they've dedicated more time such as a drawing (Moreland et al., 2020). Four key features of MEME that we will describe below are: 1) MEME incorporates explicit systems scaffolds based on the Phenomena, Mechanism, Component (PMC) framework; 2) MEME supports collaborative, qualitative model building; 3) MEME directly incorporates evidence within the model so that users can explicitly indicate the evidence supporting different features of their model, and 4) students and teachers can offer and reply to comments (see Figure 2).

Systems Scaffolds

One challenge that students have with understanding complex systems is that they operate at multiple levels (Hmelo-Silver & Azevedo, 2006). Students tend to focus on the superficial structures within a system rather than the ways that those structures are linked through mechanisms to produce a phenomena. Therefore, MEME explicitly represents ideas in terms of the **components** in a system, the **mechanisms** through which the components interact, and the **phenomena** that results, based on the component-mechanism-phenomenon or CMP (Danish, Saleh, Andrade, & Bryan, 2017). We renamed the components in the system "entities" and the mechanisms "processes" because students struggled with understanding what the original terms meant. Thus students can construct a model out of entities that are linked via processes (see Figure 2). The entire model represents the phenomena. However, we also found in early implementations that students had trouble distinguishing between entities that were in the system, and the observable or interesting outcomes relevant to understanding a phenomena. Therefore we added "outcomes" as an element in the modeling interface in the hopes that separating these two would help them think about how the one leads to the other.

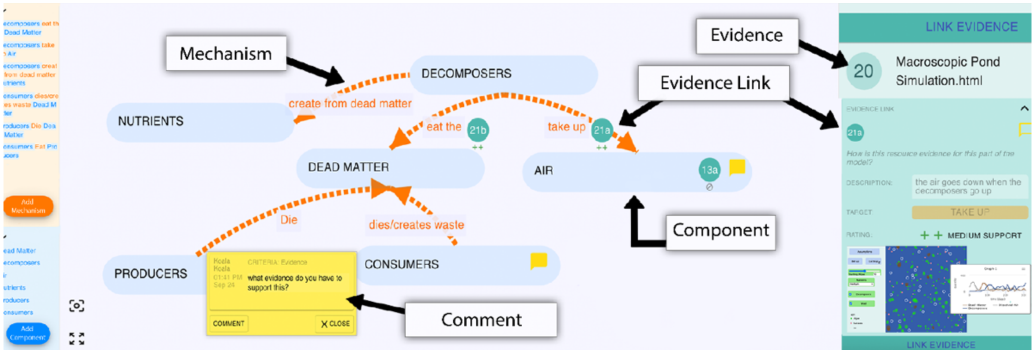

Figure 2: Screenshot of the MEME Software

Collaborative, Qualitative Models

Many systems modeling tools support students in creating quantifiable models that they can then "run" to see how the model produces a measurable outcome (See for example SageModeler, Bielik, Damelin, & Krajcik, 2018). While this has proven productive, our experience also indicates that, qualitative tools such as concept mapping environments may be more useful when students first begin exploring an idea, allowing them to play with and articulate relationships that they are not yet ready to quantify. Therefore, we opted to focus on supporting students in representing relationships without having to worry about how they might be quantified. We also made this collaborative so that students could simultaneously edit their models while engaging in productive debate and discussion.

Incorporating Evidence

Prior research has shown that having evidence within the same interface that students use to construct an explanation, and explicitly linking the two can be beneficial for helping students see the two as linked, particularly if classroom activities support this understanding (Reiser et al., 2001; Sandoval & Reiser, 2004). Therefore, we made the evidence resources a key part of the interface, and furthermore allow students to link evidence directly to elements of their model. In an effort to scaffold discussion about evidence quality (Duncan, Chinn, & Barzilai, 2018), we also provide students with tools to indicate how well each source of evidence supports specific model elements.

Integrated Feedback

Research has also shown that it is important for students to recognize the value of feedback and critique in supporting model refinement and revision (Ford & Taylor, 2006). However, students don't naturally offer productive critique, nor are they adept at incorporating it without practice, which may be crucial for appreciating the value of this practice in supporting modeling. We therefore incorporated a "sticky note" feature to support students in incorporating feedback directly within a model, on the specific component being referenced. Furthermore, each comment can explicitly reference the classroom criteria for what makes a good model, a practice that has been shown to increase appreciation for the relationship between critique and model revision (Duncan et al., 2018).

Proposed Interactive Demo

We have implemented MEME with several 5th grade classrooms as well as with a graduate seminar on activity theory. Our goal is to demonstrate how the features of MEME might support learners across these different contexts. We are therefore proposing to organize our demonstration into 3 "rooms" using Zoom breakout rooms. In the core room, we will describe MEME, demonstrate features, and offer participants a login token so that they can access one of two MEME classrooms that we will have running (or both). The first classroom will mirror our work with 5th grade students and include the evidence that students used to explore aquatic ecosystems. Participants will be able to create their own model, view simulated student models that mirror those created in our studies, or offer feedback to other models in the system. This will be supported by the first breakout room where a team member will be available to answer questions. The second classroom will emulate the recent graduate course on activity theory featuring MEME, and will likewise afford participants an opportunity to view evidence and create their own models, or view re-creations of student models from the class. This will also be facilitated by a team member who participated in the original class. Participants will be encouraged to move between the main room and breakout rooms to explore.

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