Session #: ___________

(note: Session # will be added by the editor following final paper submittal)

STUDENTS' MODELING THROUGH VISUAL AND VERBAL REPRESENTATIONS

John Mendoza-Garcia[1,2], **Les Grundman**[1], **Junqiu Wang**[1], **Senay Purzer**[1]

[1] *Purdue University, West Lafayette, Indiana; Email:* mendozag; lgrundma; jqwang; spurzer @purdue.edu

[2] *Pontificia Universidad Javeriana, Bogotá, Colombia; Email: john.mendoza@javeriana.edu.co*

ABSTRACT

Engineers use models to validate the solutions they build. Professors also ask engineering students for functional prototypes, mathematical models, and diagram models that show the functionality of the students' designs. Typically, students' grades are based upon their model outcomes; professors have no knowledge of the start-to-finish details of the process used by the students in modeling and solution. This process includes all of the students' work from the initial problem specification to the moment they hand in their final product. How is it possible to help students during this solution process if that process is not understood? Understanding how students approach problems and how they achieve resolutions is crucial to answering that question. One way to enhance the knowledge about the way engineering students approach problems is related with understanding their use of models. Two questions have been answered in this work to contribute to that understanding:

- What modeling methods do engineering students use?
- Why do students model?

To answer the research questions, data was collected as follows: two students were asked to solve a problem, one problem in the context of the United States and another problem in the context of a foreign country. The students had one hour to solve the problem. The students' dialogues, sketches, and computer screens were recorded. This recorded data was analyzed by the authors with the goal of identifying the modeling methods used and the underlying reasons for using the models. The data was examined for visual, symbolic, concrete and/or verbal models, and the frequency of use for each modeling method, along with the underlying reason, was established. The authors found that the students primarily used visual and verbal representations as modeling approaches. The results also showed that the students modeled for a variety of reasons, but the reason with the highest frequency count was to evaluate alternative designs.

1. RESEARCH QUESTIONS

The team's two research questions were:

- What modeling methods do engineering students use?
- Why do students model?
-

2. BACKGROUND

Wicklein and Rojewski (1999) defined *modeling* as "the process of producing or reducing an act or condition to a generalized construct which may be presented graphically in the form of a sketch, diagram, or equation; presented physically in the form of a scale model or prototype; or described in the form of a written generalization." The process Wicklein and Rojewski described covered a multitude of types of models. Gilbert and Boulter (2000) brought a complementary perspective. They proposed a definition of *models* as "simplified representations of specific aspects or phenomena produced in order to facilitate [the] production of visualisations." (p. 197) These visualisations occurred after one explanation, and, according to Gilbert and Boulter, "all explanations make extensive use of models." (p. 197) Gilbert and Boulter offered the following typology of models (p. 197):

- *Concrete models* are physical objects in which a behavior or response can be observed, for example, a scale model of an airplane.
- *Verbal models* consist of metaphors and analogies that are produced in text or speech.
- *Mathematical models* contain mathematical expressions that represent relationships.
- *Visual models* use graphical pictorial forms, such as pictures and sketches.
- *Gesture models* use body language, and are usually mixed with verbal models.

Gilbert and Boulter, while describing an explanation of an eclipse given in a science classroom, gave an example of how modeling methods could be mixed: "Gestural acting out of the positions of the earth, the sun and the moon may be used with verbal explanations." (p. 52)

The idea proposed by Gilbert and Boulter (2000), that models are behind explanations, was crucial for this data analysis. In the data that was collected, the students explained to each other their individual understanding of the requirements and of possible solutions before they finally decided on a solution. Using Gilbert and Boulter's idea of use of models while explaining, it was feasible to identify many different types and incidents of modeling.
Paragraphs should be justified, using single spacing, with no paragraph indentation. Use Times Roman font, 12 point. Leave one clear line between paragraphs within a section; also one clear lines before a main or secondary heading.

3. DATA COLLECTION AND RESEARCH METHODS

3.1 Research Data

The researched dyad team consisted two freshman engineering students, one male and one female. This team worked on two problems: first, a global water-supply problem and, several days later, a local natural disaster water-supply problem. The duration of each project was less than an hour. The supplied research data for each project consisted of the original problem statements, a transcript of the students' conversations, a screen capture of their web searches, sketches of their proposed solutions, and a post-design interview questionnaire.

3.2 Research Methods.

The first research method used was analysis of the students' sketches for the types of modeling methods they used. The graphics were inspected visually and commented on by all team members, and key sections were captured digitally for later reuse. These key sections were later correlated to the students' transcripts and simultaneous web searches.

The next stage of the research required synchronizing the transcript with the web searches. Images of the screen play were captured at critical points in the timeline and, along with the transcript text and sketch cutout images, placed in an Excel spreadsheet. The modeling typology of Gilbert and Boulter (2000) was used to create classification "buckets" for later coding.

Finally, the merged and synchronized data set of transcript, sketches, and screen image captures was used to determine the frequency of methods and reasons why students model. The local and global problems were each analyzed to determine the number of instances of "how students modeled" and the reasons "why students modeled", and the counts were tabulated for later analysis.

This research approach has several limitations. Some of these limitations are:

- Low sample size; only one team was examined
- No video footage was available for detailed analysis of interaction and gestures
- Sequencing effects that resulted from the team first having worked together on the global problem
- No knowledge of prior relationship of the dyad

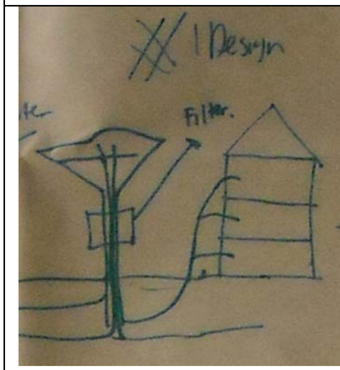
4. DATA ANALYSIS AND RESULTS

The data analysis of the combined data set revealed that the students used a mixture of combined visual and verbal, pure verbal, combined symbolic and verbal, and inherited models. Some examples are presented in the following figures. In figure 1, there are evidences of visual models used by students. In the table 1, there are evidences of the use of verbal models mixed with visual models, and in the table 2, there are evidences that show the use of symbolic and verbal models:

Figure 1 - Evidences of graphic modeling

Table 1: Evidence of verbal models mixed with visual models

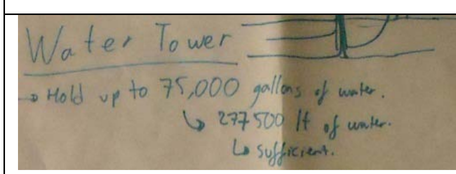
Graphic model	Verbal modeling



Video time	Stud.	Conversation
0:17:40	MG	I think the water tower, the best part is it relies on the gravity because you put the water higher.
0:17:50	FG	No. You take the water from underground right? And you put it…
0:18:00	MG	Yeah I think so uh in time we store water here and then when just in case like theres a disaster or something there will be saved water. These are like the containers
0:18:10	MG	Needs no electricity to distribute the water…
0:18:20	MG	It's like uhh potential energy
0:18:30	FG	Like gravitational
0:18:40	MG	There are like two types of energy
0:18:50	FG	Oh yea potential energy. But what keeps the water not going down?
0:19:00	MG	Well we can put like a valve

Table 2: Evidences of the use of symbolic and verbal models

Symbolic model	Verbal model



Minute	**Student**	**Conversation**
0:15:40	FG	One hundred thousand gallons
0:15:50	FG	Gallons equals to how many kilograms
0:16:00	MG	How many liters. It's pretty much
0:16:10	FG	So one hundred thousand…
0:16:20	MG	Well the regular one can hold up to seventy five thousand. This one is the new one. I think we have to go according to the seventy five thousand just in case. Holds up to… 75 thousand gallons.
0:16:40	FG	A gallon equals to 3.8
0:16:50	MG	[not audible] 3.7. It's times 75 thousand.
0:17:00	MG	Well uh equals to. I think it's enough

The number of instances of occurrence for each modeling classification is shown in Figure 2 Instances per modeling. It should be noted that Gilbert and Boulter's (2000) classifications were combined into new combination classification groups based on the students' modeling process.

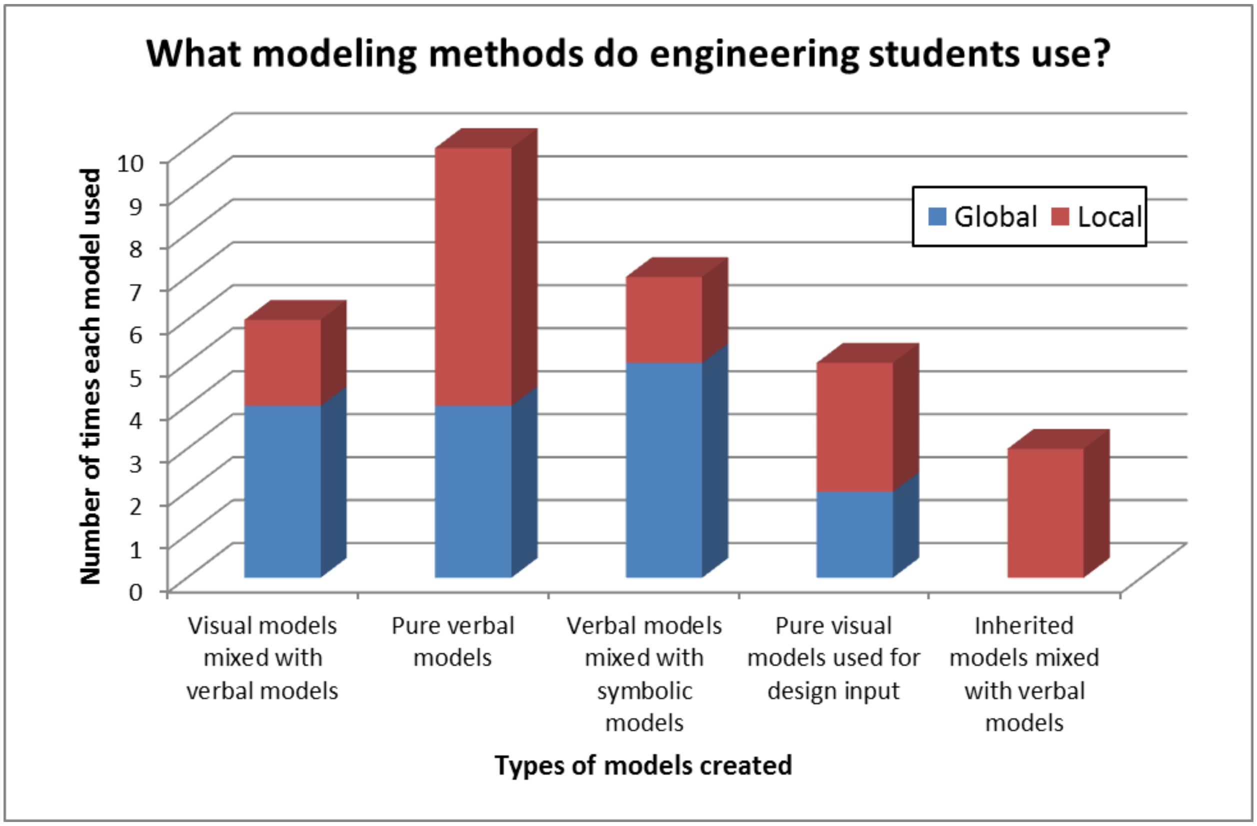


Figure 2 - Types of models vs. Number of times is used

Analysis of Figure 2 - Types of models vs. Number of times is used, revealed that the students predominantly used the verbal modeling method, which was followed in frequency by the visual modeling method. In addition, from looking at 1, 2, and 4, it could be concluded that students used visual models as input for understanding how things work in order to replicate the behavior in their own models.

One more finding that was revealed in the research was related to the use of models that the students had seen or reflected about previously. These models are called here *inherited models*. The inherited models found were due to the sequence of the problem solution and the team formation; the same student dyad first worked on the global problem and then carried over and applied that background experience to the local problem. The students also defined the problem more quickly in the local problem (minute 17:40) than in the global one (minute 19:20). The definition of the solution took longer in the global problem (minute 47:00) than in the local one (minute 34:00).

Analysis of the combined dataset to determine "Why do engineering students model?" led to the results in Figure 5, which shows the frequency count of instances the dyad used each reason for the local and global problems.

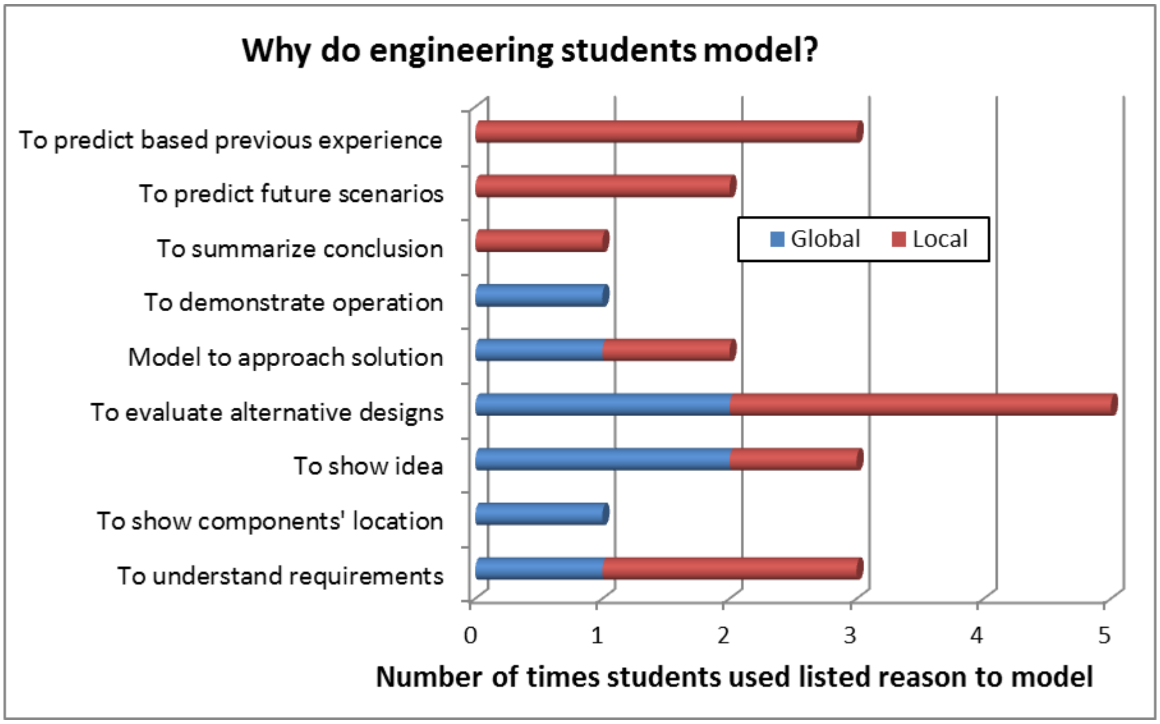


Figure 3 - Why do engineering students model?

5. CONCLUSIONS AND RECOMMENDATIONS

The results showed that students primarily used the visual and verbal modeling approaches. The results also showed that the students modeled for a variety of reasons. In the combined global and local problem solving exercises, the reason to model that had the highest frequency count was "to evaluate alternative designs." The reasons to model with the three next highest counts for the combined global and local problem solving were:

- To predict based on previous experience
- To show ideas
- To understand requirements

These results showed that students created models in an effort to assist in problem definition and solution assessment.

Analysis of the steps the dyad used in problem solving showed that they typically used the following sequence:

1. Define/identify clients' needs
2. Research available models
3. Create models

Because there is a tendency, as identified in this research, for students to use visual models as input for creating their own solutions, professors should consider including more visual models, such as charts, graphics and schemes in their explanations in addition to verbal models.

7. FUTURE WORK

Future work could address a number of issues. The noted limitation of sample size could be addressed by researching additional student teams. The limitation of team background could possibly be addressed by randomizing formation of teams trying to ensure that they don't know each other in advance, and/or surveying the teams to uncover their work and interaction history. A correlation between their history and the models they use to solve problems could be uncovered. Additional future work could attempt to answer if whether modeling approaches change with increased problem complexity, additional available time, supplementary problems to be solved by the same team or increased group size. Finally, a further exploration of the proposed inherited modeling method could be developed, either to provide rigorous evidence of the method's existence or to discard it.

REFERENCES

Gilbert, J. K., & Boulter, C. J. (Eds.). (2000). *Developing models in science education*. Kluwer Academic Publishers.

Wicklein, R. C. and Rojewski, J. W. (1999). Toward a "unified curriculum framework" for technology education. *Journal of Industrial Teacher Education, 36* (4).