cussion of the forces acting on the paper bridges that made them collapse as weight was added or one about the nature of the paper itself that can resist breaking under weight in some conditions and not in others. Although the teacher seemed initially interested in engaging students in the topic of the scientific properties of paper bridges, when two of them mentioned their interest in those differences, he redirected their attention to the rest of the written problem that focused on the graph of those data and not on the nature of the material objects that were used to generate the data.

A second example appears in the text of the data from the fictional class in Maryland: only average breaking weights are displayed, not standard deviations (*i.e.*, a measure of central tendency, but no measure of variation). Later in the transcript (line 9), the teacher says, "Now, their data was a little bit scattered, a little more scattered than ours was." It was not clear to me whether he was referring to the distribution of data points around each average for a given number of pennies (*i.e.*, variation) or whether their average data points fell further from the line on the graph than those of the current class. Within the science world, variation due to measurement error would be an important topic, since all inquiry activities are subject to measurement error that can mislead or distort findings. So, scientists and science students must try to differentiate signal from noise in their data and in their data representations. There may be different models to explain the signal and the noise. In addition, some scientific models (*e.g.*, Darwin's theory of evolution) propose that variation is actually an important causal agent. Thus, a focus on variation is important in science education, but is de-emphasized in this transcript.

A third example appears in the transcript from line 14 through to the end and illustrates these different approaches to modeling. In the mathematics world, models need to be internally consistent. Thus, definitions play an important role in outlining the nature, purpose and limits of a model. Both linear and curvilinear functions enable predictions to be made about observable relationships between variables in a data set that should be valid for data already collected, data that could be collected in the future and for data that would be impossible to collect (*e.g.*, data with negative values for mass). Abram's answer (line 27), which refers to a mathematical object (a linear relationship), is consistent with modeling in the mathematics world. In contrast, Christy's answer (line 31), which refers to the information from the data being modeled, seems more aligned with models in the science world, where models are evaluated in terms of what they can tell us about the objects of scientific inquiry.

Note

[1] These imaginary worlds are often evoked in mathematics and science classrooms to motivate students or help them understand that disciplinary practices influence classroom practices. Nevertheless, it is probably more accurate to refer to them as a mathematics education world versus a science education world, since the world of classroom instruction in these two fields is more similar than either instructional world is to its disciplinary base (see Ford & Forman, 2006).

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Purposeful grammar

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I am interested in that last question from the teacher, "...what's the purpose here? Why do we even bother doing this?" and the problem the students have answering that question. My framework for analysis comes from systemic functional linguistics (*e.g.*, Halliday & Matthiessen, 2004), a theory of language that recognizes meaning in language choices and enables systematic analysis of the choices that speakers and writers make. In this transcript, an analysis of some linguistic patterns in the data shows that the answer to the question about *purpose*, while presented in the text that the class read, was not foregrounded, repeated or brought to students' attention in the discussion. The students remain focused on the particular cases of the Maryland class and their own experiment, and do not make the move to generalization about the utility of the construction of the graph and line of best fit that the teacher wants them to make and understand. In addition, the analysis demonstrates that the teacher was non-authoritative in responding to students, leaving it unclear in what ways the students' contributions were missing the larger point. The transcript reveals the difficulty of helping students develop technical language, as progress in learning requires that the technical language be understood and used to go beyond individual cases in order to generalize about the knowledge being developed.

In doing this analysis, I focus on two types of grammatical processes presented in the text read aloud from the textbook: processes of *doing* and processes of *being*. The *doing* processes construe the actions of students; the *being* processes construe the definitions of concepts. The focus changes from the particular case to a generalization about the possibilities that the use of a graph model offers.

Here is the relevant part of the text read aloud by Josh, with clauses containing *doing* processes <u>underlined</u> and clauses with *being* processes marked in **bold**:

> <u>The class then made a graph of the data</u>. They thought **the pattern looked somewhat linear**, so <u>they drew a line to show this trend</u>. **This line is a good *model* for the relationship** because, for the thicknesses the class tested, **the points on the line are close to points from the experiment**. [...]
>
> **The line that the Maryland class drew is a graph model for their data. A graph model is a straight line or a curve that shows a trend in a set of data**. Once <u>you fit a graph model to a set of data</u>, <u>you can use it to make predictions about values in between and beyond the values in your data</u>.

The "doers" in this text are the Maryland class who "made a graph" and "drew a line", as well as the generalized "you" (the reader, in this case) who can "fit a graph model to a set of data" and "can use it to make predictions". It is the sentence with the generalized doer that the teacher is most interested in, as it makes the point that the purpose of a graph model is to enable predictions to be made. Introduced with "once" construing the conditions under which predictions can be made, it is this sentence that makes the more general point about the purpose of utilizing a graph model. But without having the general nature of this point highlighted and put into focus, the students do not grasp the point.

As we see in the ensuing discussion, the word "prediction" never comes up again. The teacher repeats the definition of graph model that points out that the graph model can be a "straight line or a curve", but without specific attention to the possibility of a curve, this never becomes salient to the students. When we look at the *being* processes in the text, we see that the linear nature of the pattern is what gets repeated again and again, with a focus on the line: "the pattern looked somewhat linear"; "This line is a good model for the relationship; the points on the line are close to points from the experiment"; "The line [...] is a graph model for their data". The students' understanding of what the graph model is useful for remains focused on the linear relationships apparent in the particular examples of their own and the Maryland class's work.

When Abram offers, in line 27, that the purpose is "to show the linear relationship", the teacher adopts an unassertive and non-authoritative stance in responding. He accepts Abram's contribution ("yeah"), but suggests that the linear nature of the relationship could be seen even without the graph model, from just examining the plotted points. He does not mark this as a view that is contrasted with Abram's, however (we can imagine a "but" after the "yeah" although this is not expressed). But the teacher is clearly not satisfied with Abram's answer and goes back to his question, which Abram has now obviously not answered correctly, "Why did I draw the line in?", again wanting the students to focus on the purpose. When Christy's contribution also does not focus on the predictive nature of the graph model, the teacher unenthusiastically accepts her contribution ("well, maybe that's part of it") and then refocuses students on the definition again. His redirection of the students' attention back to the definition shows that the students have not answered in the way he wants them to.

While the teacher may not have been able, in that moment, to recognize why the students were unable to answer his question about the purpose of the activity, we can see from the transcript that, in fact, there was little time spent during the discussion on the general utility of the graph model, nor did the discussion bring to the fore the point that not all relationships will be linear. I believe that this highlights a key pedagogical challenge; raising the knowledge that students develop in discussing contextualized examples like that in the textbook to the level of generalizability that enables them to apply the knowledge in new contexts. Key to this is being able to understand and use the technical language, in this case, the notion of a graph model. The teacher focuses the students on the meaning of the term, but does not recognize the crucial elements of the definition and statement of purpose that can help students develop the more general principle. The students needed more opportunity to focus on the notions of prediction and the possibility of a non-linear relationship, in order to understand and respond to the teacher's question.

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Hedged maxims

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The teacher, Josh, puts his finger on the really important question when he asks the class "Lance, what's the purpose here? Why do we even bother doing this?" (lines 34-35). We never find out what answer Josh has in mind, but it probably has something to do with prediction (which is, literally, the textbook answer). It would be interesting to know whether the TMM definition of a "graph model" is either meaningful or helpful to the students. The problem with modeling "real" data with mathematics is that interesting mathematics rarely "fits" the data very convincingly. A glance at the table of results in the textbook suggests that no straight line will fit this particularly well, because the weight/pennies increments for unit thickness increments vary from 4 to 14.

Given the general messiness of the situation, perhaps it is unsurprising that there is vague language in abundance (Channell, 1994; Rowland, 2000; Cutting, 2007). Vague language occurrences include, at the outset:

Cory: Theirs is like heavier or something.

Josh: Maybe. Maybe it was thicker.

Cory's utterance is a tentative response to a question from Josh about the differences between their data and that of the Maryland students. He qualifies his proposal that theirs was "heavier" with the hedge "or something", which leaves open the possibility that what he is claiming might not be quite correct. "Or something" is an example of an adaptor, a hedge located inside the proposition itself, marking some fuzziness in connection with class membership (Prince *et al.*, 1982). The word "like" is very versatile (Andersen, 2000): here, it seems to be acting as a discourse marker (as with "you know"), and could be expected to precede a moment's hesitation before "heavier". This in turn suggests some uncertainty on Cory's part about the claim he was about to make.

Josh's "maybe" is a classic plausibility shield (Prince *et al.*, 1982), a type of hedge located outside the proposition (that it was thicker). Channell (1994) identifies a number of goals, which speakers and writers achieve by the use of vague expressions. These include: giving the right amount of information; expressing uncertainty; protecting oneself against making mistakes; expressing politeness. The first of these readily connects with Grice's (1975) maxims of conversation, specifically those of quality and quantity. Cory is vague because to be otherwise might mislead his audience.