

# Teacher and Curriculum Factors that Influence Middle School Students' Sense-Making Discussions of Force/Motion

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**Abstract.** This study investigated small-group discussions in an inquiry-based middle school science classroom. The purpose of the study was to determine the teacher and curriculum factors that provide support (or not) for students' sense-making discussions. To do this, two student groups were videotaped as they participated in force/motion activities. Analysis revealed that sense-making discussion was influenced by an occasional lack of teacher adherence to the curriculum philosophy, particular types of discussion prompts, the drawing of free-body and energy diagrams, and other teacher and curriculum factors.

## RATIONALE AND PURPOSE

The National Research Council [1] recommends that science education should be grounded in collaborative inquiry. Inherently, sense-making discussions are an important aspect of this type of activity.

In my earlier analysis of sense-making discussions in middle school classrooms, it was found that there were a number of group- and student-specific factors that influenced the type and quality of scientific sense-making discussion. [2] The present study builds on this earlier analysis by introducing two additional factor types: teacher factors and curriculum factors. In investigating sense-making discussion (SMD), it is crucial to include these types of factors because of the reality that teacher behavior and curriculum structure are the two factors over which science educators have the greatest control.

Recognizing that particular aspects of teacher behavior and curriculum structure are likely more effective at promoting SMD than others, the goal of the present study is to answer the following question: Which teacher and curriculum factors support (or hinder) middle school students' small-group sense-making discussions?

## PARTICIPANTS AND DATA

I videotaped two four-person groups for five weeks as they worked through a portion of the Force and Motion unit of the Constructing Ideas in Physical Science (CIPS) middle school curriculum. [3] As supplemental data, I collected each participant's worksheets, homework, and exams. I also recorded whole-class video and fieldnotes for each class period.

CIPS is an inquiry-based physical science curriculum that engages eighth grade middle school students in constructing meaningful understanding of physical science concepts. CIPS achieves this goal by having the students interact with each other in small groups, participate in whole-class discussions, perform experiments, observe computer simulations, and use notebooks to keep track of the change in their understandings of physical science. CIPS content units are broken into cycles (sub-units). For instance, in the pilot version of CIPS that was investigated here, the Force and Motion unit was broken into Exploring Motion, Pushes and Pulls, Combining Pushes and Pulls, Resistive Interactions, and Gravity. In this study, data were collected on the last 3 cycles of the Force and Motion unit.

The data collected in this study are identical to the data that were collected for my earlier research on

group and individual factors affecting SMD; the data have been re-analyzed with a new focus on teacher and curriculum factors.

## THEORETICAL FRAMEWORK

My six-component framework for SMD is as follows.

1. Predicting a phenomenon or experimental outcome.
2. Clarifying the facts of a phenomenon or experimental result.
3. Describing and explaining a phenomenon or experimental result.
4. Defining, describing, clarifying, and connecting scientific concepts, procedures, processes, and representations.
5. Testing knowledge compatibility.
6. Making a request for any of the above.

Each of these six components of SMD is explained in detail in my earlier report on group and individual factors affecting SMD.

## ANALYSIS PROCEDURE

Once the student discussions were transcribed, instances of student sense-making were classified according to the six-component scheme listed above. An overall numerical distribution of these instances was formulated (omitting requests for SMD), which was then statistically compared to the expected distribution (as determined by the distribution of sense-making prompts in the actual curriculum materials). In addition, the percentage of time dedicated to SMD was calculated for each activity.

The final step focused on qualitatively identifying those teacher and curriculum factors that helped to explain the differences in SMD, both in terms of instances of sense-making and sense-making percentages. This identification and analysis [4] of factors was performed by making several analytical passes through the session transcripts and associated videotapes; during these data passes, I carefully

checked for supporting evidence, consistency, and alternative explanations.

## QUANTITATIVE RESULTS

**TABLE 1. Distribution of Sense-making Instances in Group Discussion Compared to the Distribution of Sense-Making Prompts in the Curriculum Materials.**

Component of SMD	Instances of Component in Group Discussion	Number of Prompts Addressing Component in Materials
CL	173 (33%)	25 (20%)
P	47 (9%)	18 (14%)
UE	122 (23%)	26 (21%)
DDC	113 (21%)	52 (41%)
TC	71 (13%)	5 (4%)

Abbreviations: CL = Clarifying, P = Predicting, UE = Underlying Explanation, DDC = Defining, Describing, Connecting; TC = Testing Compatibility

$\chi^2$  tests show that all discussion/materials differences in Table 1 are significant at the  $p = 0.05$  level, except for differences in underlying explanations.

**TABLE 2. Percentage of Time that Groups Engaged in SMD, by Activity.**

Activity	%	Activity	%
C3/A1	17	C4/A5	10
C3/A2	17	C4/A6	10
C3/A3	7	C5/A1	9
C3/A4	8	C5/A2	14
C4/A1	17	C5/A3	39
C4/A2	14	C5/A4	22
C4/A3	35	C5/A5	1
C4/A4	44		

Abbreviations: C3/A1 = Cycle 3, Activity 1, etc.

## QUALITATIVE RESULTS

There were two teacher factors and five curriculum factors that contributed to the most dramatic sense-making differences found in Tables 1 and 2.

### Teacher Factors

*Factor 1: Due to the unexpected length of certain activities and the teacher's desire to complete the entire CIPS curriculum, the concluding sense-making sections of some activities were skipped.*

In the pilot version of the curriculum, many activities took much longer to complete than the developers intended. As a result, the teacher - who made it known that he felt obligated to go through the entire five-unit curriculum, if possible - would sometimes start a day with a new activity, even though the class hadn't quite finished the end of the previous activity. Of importance here is that the final sections of the activities were key sense-making sections. These concluding ("Making Sense") sections focused on in-depth scientific explanations, and so the skipping of these sections was one of the factors that led to there being fewer DDCs than expected. This factor also contributed to the variation in SMD from activity to activity; had these sections not been skipped, the percentage of time engaged in SMD would likely have been higher in the truncated activities (e.g., C3/A3, C4/A5, C5/A5).

*Factor 2: The teacher would, on occasion, fail to adhere to the CIPS curriculum philosophy by revealing in advance the ideas that groups were supposed to construct on their own, and so SMD sometimes became unnecessary.*

One of the hallmarks of an effective teacher is the ability of that teacher to outline for the students, without being too specific, the types of science ideas that will be addressed by the day's activities. The notion of being "too specific" is important in CIPS, because of the curriculum's philosophy that idea generation should come from the students, not the teacher. Occasionally, the teacher in this study, in the interest of getting the students properly focused, would violate this philosophy by explicitly telling the students the scientific concept underlying the day's activities.

For example, the teacher introduced the activity about resistive forces (C4/A1) by stating that "friction has now entered the world" - with the unsurprising result that students quickly offered this explanation for the interactions discussed in the activity. Had the teacher not made his introductory statement, it is very likely that student SMD in this case would have been much more in-depth.

## **Curriculum Factors**

*Factor 1: Group discussion of concepts not explicitly addressed by the curriculum resulted in a greater number of clarifications of facts than expected.*

There were a number of topics that the CIPS developers intentionally omitted from the curriculum in order to ensure that the curriculum could be completed in a single school year. These omitted topics included instantaneous speed, the distinction between friction and drag, and the extent of gravity in the universe. Nevertheless, groups dedicated sense-making time to these topics as students attempted to clarify the facts about speed, drag, and the pull of gravity. Areas of student concern included the following: Can a speed be considered "constant" if an object possesses that speed for a second, or less? What is the exact difference between friction and drag? Is there gravity in the Earth's outer atmosphere?

*Factor 2: Groups enthusiastically engaged in SMD in activities that were interesting, personally relevant, and/or asked the students to be creative.*

Activity C4/A4 had the highest sense-making percentage of all the activities: 44%. In this activity, students were asked to consider which sports might be playable without friction, and were also asked to give reasons why they would or would not want to live in a frictionless world. These relevant and engaging questions led to creative discussions that were consistently deep and thoughtful. The discussions were carried on at great length, and were unique in the fact that they appeared to be truly enjoyable for the students.

*Factor 3: Curriculum prompts that required students to inquire about and record their fellow group members' ideas were effective at promoting SMD.*

Over 99% (523 out of 526) of the sense-making instances in this study were direct or indirect responses to questions or other sense-making prompts in the curriculum materials. This demonstrates the crucial role played by the written materials in supporting SMD in middle school classrooms.

A particularly effective type of curriculum prompt consisted of a series of "fill-in-the-blank" statements that prompted students to elicit and record the ideas of their fellow group members. For example, in C5/A3, students were asked to consider whether a hammer on Earth or a hammer on the Moon would hit the ground first if dropped simultaneously, using the following prompt format: "\_\_\_\_ thinks that [one of the hammers will drop first] because \_\_\_\_." One final summative prompt was then added to help ensure a rich discussion: "After our discussion, our groups think [one of the hammers will drop first] because \_\_\_\_."

Lengthy verbal responses to these prompts played a large role in helping the students achieve the 39% sense-making percentage in C5/A3.

*Factor 4: Certain activities dealt with experimental results or scientific explanations that were too obvious, and so SMD was sometimes unnecessary.*

In the pilot version of the curriculum, because of the heavily constructivist stance of the curriculum developers, students performed experiments that tested the validity of each and every benchmark idea - even in cases when the ideas of interest were relatively commonsense. From the students' perspective, this translated into a handful of experiments that were deemed unnecessary because the students felt that they already had an intuitive understanding of the ideas explored in the experiment. Such experiments could be found in C3/A1 (combined weight is the sum of individual weights), C3/A2 (a pulley system moves towards the side with more weight), and C5/A2 (all objects are affected by gravity).

The following is a typical student comment regarding these experiments: "Why are we doing this? I mean, we know what the answer is." In these cases, SMD was kept to a bare minimum because group members felt that their understanding of the experimental results (and accompanying scientific explanations) was already adequate.

(Note that the current version of CIPS improves greatly on the pilot version, and so the time and content issues discussed above are no longer problematic.)

*Factor 5: Activities that required students to draw free-body or energy diagrams generated a significant amount of SMD.*

Conceptualizing a physical system in terms of energy types and transfers is a powerful, yet incredibly abstract process. Due to the high level of abstraction involved, the CIPS students' energy-oriented descriptions and explanations tended to be imprecise, brief sentences in which students confused/ignored the different types of energy transfers, and also did not differentiate between the various parts of the system. However, exceptions to this tendency towards vagueness and a lack of SMD can be found in those activities (e.g., C4/A3) where students were asked to fill out an energy transfer diagram. These energy transfer diagrams, which contained "fill-in-the-blank"

spaces for system parts and energy transfers, provided the conceptual scaffolding that supported rich SMD by requiring students to explicitly consider different types of system objects and energies - something that they may or may not have considered doing previously.

Free-body diagrams served a similar function by requiring students to identify and draw individual forces in a quantitatively precise way, and so free-body diagrams also tended to lead to rich SMD in groups.

## CONCLUSION

Many teacher and curriculum factors influenced the SMD in this study: the teacher's skipping (for time reasons) of important sense-making activity sections; the teacher's occasional lack of adherence to the CIPS curriculum philosophy; the omission of certain specific science topics; relevant and creative science activities; particular types of discussion prompts; the drawing of free-body and energy diagrams; and the performance of commonsense experiments that students deemed unnecessary.

These factors have implications for classroom practice. Assuming that the teacher is using an inquiry-based curriculum, the teacher should make an effort to consistently support sense-making (both verbally and in the written curriculum) as well as adhere to the curriculum philosophy, while also remaining open to opportunities for improving activities by making them more relevant and grade-appropriate.

## REFERENCES

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