

CHAPTER 5: RESULTS -- SENSE-MAKING DISCUSSION

This dissertation documents the extent to which middle school students engage in small-group sense-making discussion, and also identifies those factors which provide support (or not) for small-group sense-making discussion (SMD). This chapter addresses the first concern: the extent of students' sense-making discussion.

In Chapter 4, I described how I generated my framework for SMD by starting with Hatano's (nonverbal) theory of comprehension activity and then modifying his theory to reflect the specifics of SMD that were seen in the small-group discussions in this study. After careful analysis of these discussions, my resulting framework for SMD posits that sense-making discussion is broken into six components:

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

It is this framework that was used to identify SMD in the course of investigating the second research question:

To what extent do students engage in sense-making discussion?

The first section of this chapter documents students' SMD by presenting a) distributions of sense-making instances, and b) average values for the percentage of time that groups were engaged in sense-making discussion.¹ The final section of this chapter summarizes prominent differences in these quantitative measures of SMD. It is the purpose of the next chapter, Chapter 6, to explain the existence of these quantitative differences through a discussion of the person-, group-, task-, and context-based factors that influence small-group SMD.

The first five steps of the six-step method of analysis (as outlined in chapter 3) allowed me to arrive at the sense-making results presented here.

These steps are:

1. Identify those sub-sections of each activity where, based on the structure of the CIPS pedagogy, students are expected to engage in significant SMD. (Henceforth, I will refer to these sub-sections as "relevant sub-sections".)
2. Document instances of sense-making in relevant sub-sections according to the six-component scheme
3. Determine the distribution of sense-making instances for each group, student, activity, activity sub-section, and curriculum cycle

¹ Instances of sense-making are individual clarifications, predictions, etc. As one would expect, sense-making discussions are composed of numerous sense-making instances that (ideally) build on and connect to one another.

4. Calculate the average percentage of time dedicated to sense-making discussion for each group, activity, activity sub-section, sub-section type,² and curriculum cycle
5. Identify significant differences in sense-making across groups, students, activities, activity sub-sections, sub-section types, and curriculum cycles

The activity sub-sections identified in Step 1 can be found in Appendix 3.

Results: Instances of Verbal Sense-Making

The total number of instances of SMD sorted by group, curriculum cycle, sub-section type, and student are presented in the tables below.

Summarizing the data in this manner helps to answer the following types of questions:

- Did the curriculum cycles equally support the generation of all six components of SMD, or did one cycle support a particular component more than the other cycles?
- What was the overall distribution of sense-making instances over cycles 3-5?
- Did one group tend to emphasize certain components of verbal sense-making more than the other group -- or were the sense-

² By sub-section "type", I mean one the following reoccurring sub-sections: "Prepare your wipe board!", "What does your team think?", "What really happens?", "Making sense", and "Now what does your team think?"

making foci of the two groups (clarifying, predicting, explaining, etc.)
roughly identical?

- Did any students engage in particular components of SMD more frequently than the other students? Or did students engage in the six components of SMD equally?

In the tables below, the components of SMD are abbreviated as follows:

CL (**C**larifying the facts of a phenomenon or result), **P** (**P**redicting), **UE** (Describing or providing an **u**nderlying **e**xplanation for a phenomenon or result), **DDC** (**d**efining, **d**escribing, clarifying, and **c**onnecting scientific concepts, procedures, processes, and representations), and **TC** (**t**esting knowledge **c**ompatibility).

Numbers above the dotted lines (-----) represent requests for that particular component of SMD (i.e., they represent instances of the sixth component of SMD). Numbers below the dotted line represent actual instances³ of that component. Instances of **P** are presented in Level 1/Level 2 format. All times refer to the total time spent in the activity sub-sections where SMD was expected (i.e., time spent on those sections identified in Step 1 of the analysis) -- not the actual time that students spent engaged in sense-making discussion.

³ An "actual instance" is an actual act of clarifying, predicting, etc., rather than a request for a clarification, prediction, etc.

The distribution of sense-making instances for each activity and activity sub-section can be found in Appendix 4. Samples of coded transcripts can be found in Appendix 5.

Instances of sense-making: curriculum cycles, sub-section types, overall.

This section summarizes sense-making instances in cycles 3-5 (the cycles of interest) of the Force and Motion unit. Also presented is the overall ("total") distribution of the six components of SMD for all three cycles.

Total times in the relevant sections are provided to give an indication of how much time was available for SMD.

Table 5-1. Instances of verbal sense-making, by cycle (both groups).

	CL	P	UE	DDC	TC	Total		Time in relevant sections
Cycle 3	2	0	1	13	2	18		143 min
	-----	-----	-----	-----	-----	-----		
	11	9/5	14	42	9	90		
Cycle 4	9	1	26	8	8	52		145 min
	-----	-----	-----	-----	-----	-----		
	89	5/12	72	36	41	255		
Cycle 5	22	5	23	12	9	71		132.5 min
	-----	-----	-----	-----	-----	-----		
	73	11/5	36	35	21	181		
Total	33	6	50	33	19	141		420.5 min
	-----	-----	-----	-----	-----	-----		
	173	25/22	122	113	71	526		

If we split the total number of sense-making instances into two tables -- one table for the first five components of sense-making (actual instances) and

one table for the sixth component (requests for sense-making) -- and convert the "total number" values to percentages, we get the following:

Table 5-2. Distribution of requests for sense-making (percentages), by type of request.

CL	P	UE	DDC	TC
23	4	35	23	13

Note. N = 141 total requests. Requests from both groups are included.

Table 5-3. Distribution of actual instances of sense-making (percentages).

CL	P	UE	DDC	TC
33	9	23	21	13

Note. N = 526 actual instances. Instances from both groups are included.

For the values in Table 5-3 to be meaningful, we must now compare the overall distribution of instances to the expected distribution of instances. As I outlined in Chapter 3, the expected distribution was based on the distribution of sense-making components in the written curriculum. (The curriculum consisted of the questions, directives, and graphing/diagramming activities in cycles 3-5 of the Force and Motion unit.) Table 5-4 compares these expected and actual distributions:

Table 5-4. Distribution of sense-making components in the curriculum materials compared to the distribution in group conversations.

	CL	P	UE	DDC	TC
Curriculum materials	25 (20%)	18 (14%)	26 (21%)	52 (41%)	5 (4%)
Group conversations	173 (33%)	47 (9%)	122 (23%)	113 (21%)	71 (13%)

Note. Top values in each cell are actual numbers. Bottom values (in parentheses) are percentages.

Instances of sense-making: groups and individual students. The distributions in the previous section focus on sense-making in each cycle and over all three cycles. This was done to provide some insight into how each cycle supported (or did not support) the different components of sense-making. The next set of distributions summarize the sense-making instances of each group and student in order to highlight the differences between groups 1 and 2 and between the eight individual students. These group- and student-specific distributions help illustrate the effects of group and student characteristics on group sense-making in CIPS.

Distributions of sense-making instances for group 1 (Darla, Grace, Lacey, and sometimes Porter) and group 2 (Roxanne, Sabrina, Arthur, and sometimes Jasper) are as follows:

Table 5-5. Total number of instances of verbal sense-making, by group.

	CL	P	UE	DDC	TC	Total
Group 1 (225.5 min)	13	3	29	19	5	69
	-----	-----	-----	-----	-----	-----
	67	14/13	47	53	33	227
Group 2 (195 min)	20	3	21	14	14	72
	-----	-----	-----	-----	-----	-----
	106	11/9	75	60	38	299

The total distribution of requests for sense-making (requests for clarifications, underlying explanations, etc.) does not differ across groups, $\chi^2(4) = 7.9$, $p > .05$; also, the total distribution of actual instances of sense-

making (actual clarifications, underlying explanations, etc.) does not differ across groups, $\chi^2(4) = 7.4$, $p > .05$.

Breaking the Table 5-5 overall results into a cycle-by-cycle summary, we get:

Table 5-6. Instances of verbal sense-making in cycle 3, by group.

	CL	P	UE	DDC	TC	Total
Group 1 (75 min)	2	0	0	9	1	12
	-----	-----	-----	-----	-----	-----
	5	7/3	5	27	5	52
Group 2 (68 min)	0	0	1	4	1	6
	-----	-----	-----	-----	-----	-----
	6	2/2	9	15	4	38

Table 5-7. Instances of verbal sense-making in cycle 4, by group

	CL	P	UE	DDC	TC	Total
Group 1 (84 min)	3	0	19	3	1	26
	-----	-----	-----	-----	-----	-----
	32	3/7	26	12	17	97
Group 2 (61 min)	6	1	7	5	7	26
	-----	-----	-----	-----	-----	-----
	57	2/5	46	24	24	158

Table 5-8. Instances of verbal sense-making in cycle 5, by group

	CL	P	UE	DDC	TC	Total
Group 1 (66.5 min)	8	3	10	7	3	31
	-----	-----	-----	-----	-----	-----
	30	4/3	16	14	11	78
Group 2 (66 min)	14	2	13	5	6	40
	-----	-----	-----	-----	-----	-----
	43	7/2	20	21	10	103

Below is the overall distribution of sense-making instances for each student. Distributions for each student for each individual cycle can be found in Appendix 6.

Table 5-9. Total number of instances of verbal sense-making, by student.

	Student	CL	P	UE	DDC	TC		Total	
Group 1	Darla	2 ----- 21	3 ----- 4/2	11 ----- 16	9 ----- 25	2 ----- 14		27 ----- 82	
	Grace	2 ----- 22	0 ----- 5/3	7 ----- 12	5 ----- 10	1 ----- 4		15 ----- 56	
	Lacey	8 ----- 23	0 ----- 4/8	11 ----- 12	5 ----- 15	2 ----- 14		26 ----- 76	
	Porter (cycles 3-4)	1 ----- 1	0 ----- 1/0	0 ----- 7	0 ----- 3	0 ----- 1		1 ----- 13	
	Group 2	Arthur	3 ----- 48	1 ----- 6/2	6 ----- 29	4 ----- 27	2 ----- 13		16 ----- 125
		Roxanne	3 ----- 26	1 ----- 3/2	4 ----- 28	1 ----- 17	5 ----- 17		14 ----- 93
		Jasper (cycle 3)	0 ----- 0	0 ----- 0	0 ----- 0	0 ----- 0	0 ----- 0		0 ----- 0
Sabrina		14 ----- 32	1 ----- 2/5	11 ----- 18	9 ----- 16	7 ----- 8		42 ----- 81	

Results: Percentage of Time Dedicated to Sense-Making Discussion

The percentage of time dedicated to sense-making discussion in each activity, activity sub-section, group, and cycle is presented in the tables below. These overall averages involved careful averaging over activities, activity sub-sections, groups, and/or cycles, as outlined in chapter 3.

As with a distribution of sense-making instances, the percentage of time spent on SMD gives some indication of the extent of sense-making discussion in the groups in this study. The main difference between the two types of measures is that instance distributions depict the relative frequency of each component of sense-making, while sense-making percentages allow relative comparisons between the time spent on verbal sense-making versus the time spent on everything else: writing, reading, goofing off, setting up the experiment, and anything else that groups do or discuss in a science classroom. Therefore, both measures together provide a richer picture of group SMD than either measure separately.

A sub-section by sub-section summary of the percentage of time that groups engaged in SMD is presented in Table 5-10, Table 5-11, and Table 5-12.

Table 5-10. Percentage of time engaged in sense-making discussion in cycle 3, by sub-section and group.

Activity	Sub-section	Group 1	Group 2	Avg.
A1	What does your team think?	50	25	37.5
	What really happens?: Hanging weights	11	2	6.5
	Prepare your wipe board	8	8	8
A2	What does your team think?	38	x	
	What really happens?: Lego pulley	2	6	4
	Making sense	42	0	21
A3	What really happens? Force simulations	19	4	11.5
	Making sense	4	x	
A4	Now what does your team think?	x	x	
	Prepare your wipe board	0	16	8

Note. An x indicates that the sub-section was skipped.

Table 5-11. Percentage of time engaged in sense-making discussion in cycle 4, by sub-section and group.

Activity	Sub-section	Group 1	Group 2	Avg.
A1	What does your team think?	25	25	25
	Prepare your wipe board	9	8	8.5
A2	What really happens?: Rubbing hands	15	x	
	What really happens?: Energy ideas	17	x	
	What really happens?: Hanging weights Exploring bumpiness	16	x	
	Making sense	3	13	8
A3	What really happens?: Sliding blocks	30	39	34.5
	Making sense	x	x	
A4	Making sense	55	33	44
A5	What really happens?: Exploring drag	4	16	10
	Making sense	x	x	
A6	Now what does your team think?	x	x	
	Prepare your wipe board	11	8	9.5

Note. An x indicates that the sub-section was skipped.

Table 5-12. Percentage of time engaged in sense-making discussion in cycle 5, by sub-section and group.

Activity	Sub-section	Group 1	Group 2	Avg.
A1	What does your team think?	25	12	18.5
	Prepare your wipe board	2	2	2
A2	What really happens?: Gravity caused by magnetism?	4	2	3
	What really happens?: Gravity caused by rotation?	8	38	23
	What really happens?: Gravity caused by air pressure?	35	24	29.5
	Making sense	0	x	
A3	What really happens?: What causes gravity?	x	57	
	What really happens?: Earth vs. moon gravity	31	0	15.5
	Making sense	62	20	41
A4	What really happens?: Dropped paper	26	18	22
A5	Now what does your team think?	0	x	
	Prepare your wipe board	1	x	

Note. An x indicates that the sub-section was skipped.

To ensure a fair comparison between groups in cycles 3-5, we replace skipped sections in Tables 5-10, 5-11, and 5-12 with projected values (as described in chapter 3), omit the last activity per cycle (also described in chapter 3), and average together the various sub-sections to form activity averages. We then get the following:

Table 5-13. Percentage of time engaged in sense-making discussion, by activity and group.

Cycle	Activity	Group 1	Group 2
3	A1	23	12
	A2	27	3
	A3	40	4
4	A1	17	17
	A2	13	13
	A3	30	39
	A4	55	33
	A5	4	16
5	A1	14	7
	A2	12	21
	A3	47	26
	A4	26	18

We then average over activities to form cycle averages, and averaging over all three cycles determines the overall percentage for each group:

Table 5-14. Percentage of time engaged in sense-making discussion in cycles 3-5, by group.

Cycle	Group 1	Group 2
3	30	6
4	24	24
5	25	18
Overall	26	16

Leaving behind the comparison of groups, let us now move on to a comparison of curriculum cycles and sub-section types.

Table 5-15. Percentage of time engaged in sense-making discussion, by cycle (both groups).

	A1	A2	A3	A4	A5	A6	Overall
Cycle 3	17	17	7	8	x	x	12
Cycle 4	17	14	35	44	10	10	22
Cycle 5	9	14	39	22	1	x	17

Note. An x indicates that, in that cycle, the activity did not exist.

Activities in the CIPS curriculum consisted of one or more distinct sub-sections. In these sub-sections, groups made predictions ("What does your team think?"), performed experiments ("What really happens?"), developed and reconsidered their scientific ideas ("Making sense", "Now what does your team think?"), and constructed explanations on presentation boards ("Prepare your wipe board!").

The following table presents the percentage of time engaged in sense-making discussion in each sub-section type.

Table 5-16. Percentage of time engaged in sense-making discussion, by sub-section type (both groups).

	What does your team think?	What really happens?	Making sense	Now what does your team think?	Prepare your wipe board!
Cycle 3	32	7	12	x	8
Cycle 4	25	16	26	x	9
Cycle 5	19	26	21	0	2
Overall	25	16	20	x	6

Note. An x indicates that both groups skipped the sub-section.

Results to be Explained in Chapter 6

The data tables point clearly to eight results that deserve additional attention and discussion.

1. There were more instances of clarifying facts than expected, and fewer instances of describing/defining/connecting scientific concepts, procedures, processes, and representations than expected. [Table 5-4]
2. More than half of the predictions were not supported by evidence. [Table 5-1]
3. The percentage of time that groups dedicated to sense-making discussion was highest in "What does your team think?" and "Making sense" sub-section types and lowest in the "Prepare your wipe board!" sub-section type. [Table 5-16]
4. The percentage of time dedicated to sense-making discussion in individual sub-sections varied quite a bit. Some sub-sections where sense-making discussion had been expected contained very little to no sense-making discussion. [Table 5-10, Table 5-11, Table 5-12]
5. The percentage of time that groups dedicated to sense-making discussion was quite a bit higher in some activities than in others. [Table 5-15]
6. The percentage of time that groups dedicated to sense-making discussion was lowest in cycle 3. [Table 5-15]

7. The percentage of time dedicated to sense-making discussion was higher in group 1 than in group 2. [Table 5-14]
8. In both groups, the amount and type of sense-making statements per group member varied quite a bit. [Table 5-9]

The results are described in more detail below, although answers to the "why" questions associated with these results (e.g., why was the sense-making different in the two groups?) are presented in Chapter 6, the chapter on factors affecting SMD.

Result 1: There were more instances of clarifying facts than expected, and fewer instances of describing/defining/connecting scientific concepts, procedures, processes, and representations than expected.

The percentages for clarifying facts (33%) and describing/defining/connecting (21%) are surprising because of the fact that 20% and 41% of the worksheet questions were directed at clarifying facts and describing/defining/connecting, respectively.

Result 2: More than half of the predictions were not supported by evidence.

There were twenty-five level 1 predictions (predictions without evidence) and twenty-two level 2 predictions (predictions with evidence).

Result 3: The percentage of time that groups dedicated to sense-making discussion was highest in "What does your team think?" and "Making sense" sub-section types and lowest in the "Prepare your wipe board!" sub-section type.

The percentage of time dedicated to SMD in "What does your team think?" and "Making sense" sub-section types was 25% and 20%, respectively. The percentage in the "Prepare your wipe board!" sub-section type was only 6%.

Result 4: The percentage of time dedicated to sense-making discussion in individual sub-sections varied quite a bit. Some sub-sections where sense-making discussion had been expected contained very little to no verbal sense-making.

Both groups spent time in 22 of the 35 sub-sections (i.e., 13 sub-sections were skipped by at least one group). Of these sub-sections, the top four sub-sections in terms of the percentage of time dedicated to SMD (averaged over both groups) were the following:

- "Making sense", from activity 4 in cycle 4 (44%)
- "Making sense", from activity 3 in cycle 5 (41%)
- "What does your team think?", from activity 1 in cycle 1 (37.5%)
- "Sliding blocks", from activity 3 in cycle 4 (34.5%)

The bottom four sub-sections in terms of the percentage of time dedicated to SMD (from the same set of 22, and also averaged over both groups) were the following:

- "Prepare your wipe board!", from activity 1 in cycle 5 (2%)
- "Is gravity caused by the earth's magnetism?", from activity 2 in cycle 5 (3%)
- "What really happens?", from activity 2 in cycle 3 (4%)
- "What really happens?", from activity 1 in cycle 3 (6.5%)

Percentages for individual groups ranged from 62% ("Making sense" from activity 3 in cycle 4, group 1) to 0% (five separate sub-sections).

Result 5: The percentage of time that groups dedicated to sense-making discussion was quite a bit higher in some activities than in others.

The percentage of time dedicated to SMD was highest (35% or higher) in the following activities:

- activity 3 (Slowing Down) and activity 4 (No Friction?) from cycle 4
- activity 3 (More Exploration of What Causes Gravity) from cycle 5

This percentage was lowest (10% or lower) in the following activities:

- activity 3 (Lots of Pushes and Pulls!) and activity 4 (Putting it All Together) from cycle 3
- activity 5 (What's a Little Drag?) and activity 6 (Putting it All Together) from cycle 4

- activity 1 (What Causes Gravity?) and activity 5 (Putting it All Together) from cycle 5

Result 6: The percentage of time that groups dedicated to sense-making discussion was lowest in cycle 3.

For cycle 3, the average percentage of time that groups engaged in SMD was 12%. For cycles 4 and 5, the average percentages were 22% and 17%, respectively.

Result 7: The percentage of time dedicated to sense-making discussion was higher in group 1 than in group 2.

Group 1's percentage of time dedicated to SMD (26%) was 63% higher than group 2's percentage (16%).

Result 8: In both groups, the amount and type of verbal sense-making per group member varied quite a bit.

Group 1. As Table 5-9 shows, above, Darla and Lacey made more requests for sense-making than either Grace and Porter. There were 27 requests for Darla, 26 requests for Lacey, 15 requests for Grace, and only 1 request for Porter. Likewise, Darla and Lacey engaged in more instances of defining/describing/connecting and tests of knowledge compatibility than either Grace or Porter. Darla and Lacey engaged in 25 and 15 instances of defining/describing/connecting, respectively, and Grace and Porter engaged in 10 and 3 instances of defining/describing/connecting, respectively. Both Darla and Lacey engaged in 14 instances of testing for knowledge compatibility;

Grace and Porter engaged in only 4 and 1 instance(s) (respectively) of this component of SMD. Overall, Porter engaged in only 14 instances of verbal sense-making (1 requests + 13 actual instances) over the course of two cycles.

Group 2. Sabrina made many more requests for sense-making (42 requests) than either Arthur (16 requests) or Roxanne (14 requests). Arthur engaged more frequently than Sabrina and Roxanne in clarifications of facts/phenomena/results (48 vs. 32 and 26, respectively) and definitions/descriptions/connections (27 vs. 8 and 17, respectively). In the 3 days that he was in the group, Jasper did not engage in any sense-making discussion.