

Cognitive Facilitation: A Method for Promoting Reflective Collaboration

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Abstract

We introduce a method for promoting reflective conversations during collaborative work which enables participants to explore their cognitive goals and processes and thereby develop a metacognitive understanding of their practice. This method, termed "cognitive facilitation," seeks to provide a conceptual and linguistic basis for metacognitive reflection by "seeding" conversations with a cognitive vocabulary that is carefully chosen to promote the collaborative inspection of cognitive activity. We illustrate the usefulness of cognitive facilitation in two situations: middle-school students designing and carrying out scientific inquiry projects, and apprentice teachers seeking to understand inquiry-oriented science teaching through analyzing videotapes of classrooms.

Keywords—metacognition, collaborative learning, inquiry, science teaching

Introduction

In this paper, we introduce a method for promoting reflective conversations during collaborative work so that these conversations lead to a metacognitive understanding of the goals and processes implicit in problem solving. Our proposal is to provide a conceptual and linguistic basis for metacognitive reflection by "seeding" such conversations with a cognitive vocabulary that is carefully chosen to promote a collaborative inspection and analysis of cognitive activity. We will use two problem-solving contexts to illustrate this method: (1) middle school students learning how to engage in scientific inquiry as they collaboratively design and carry out research projects (White & Frederiksen, in press), and (2) apprentice teachers learning how to teach inquiry-oriented science classes by watching and evaluating video

recordings of science classes. In each case, the problems are ill structured and open to multiple approaches. And in each case, learning to solve problems includes developing not only technical knowledge of concepts and methods of practice, but also a knowledge of one's knowledge and how it can be employed in solving problems.

In our earlier work in which we analyzed videotapes of students undertaking collaborative inquiry projects or of teachers discussing video exemplars of teaching (e.g., Frederiksen, 1994), we have found that the metacognitive content of reflective conversations in these situations is fairly sparse. We conjecture that this may be due to the lack of an explicit language and conceptual base for supporting such discussions. Schön (1987) emphasizes this crucial role of language in his analyses of coaching. The coach needs to "initiate students into 'traditions of the calling' and help them by 'the right kind of telling' to see on their own behalf and in their own way what they need most to see (p. 17)." The right kind of telling incorporates a language for talking about the goals one has adopted during problem solving (the ends to be sought), the methods or processes one is using (the means to be employed), and evaluations of one's current problem-solving approach or model (a critical examination of the framing goals and processes in relation to current outcomes). Much of the discourse between coaches and students is seen by Schön as a search for convergence in meaning, which will allow them to communicate in this way about practice. Collaborative work between a coach and student or, we add, within groups of apprentice practitioners depends on establishing a convergence in meaning for this language of practice.

These considerations lead us to propose a method for promoting the development of metacognitive skills

through the "cognitive facilitation" of discourse in collaborative activity. Cognitive facilitation is based on the idea that developing metacognitive competence depends upon acquiring a linguistic basis for recognizing and reporting on cognitive activities. In cognitive facilitation this basis is provided by seeding conversations with categories chosen to represent particular functional aspects of cognition. The categories are functional in that they refer to the purposes of cognitive activity without establishing the particular methods employed, which will vary from situation to situation and from moment to moment in working on a problem. Since the functional categories must be interpreted to make sense in any particular cognitive activity, our conjecture is that use of such categories will open up cognitive activity to collaborative inspection and analysis. In cognitive facilitation, the categories are introduced explicitly through an interpretive and evaluative task which is designed to promote the needed convergence in meaning. Versions of this task we have experimented with include having students engage in self and peer assessments of their work on projects, and having teachers evaluate videotapes of their own or others' classroom teaching.

In choosing the functional categories for representing cognitive activities, we distinguish two conceptual areas: reflection on goals entailed in carrying out problem solving (goal reflection), and reflection on the intellectual processes involved in implementing those goals (process reflection). These are reified in the form of explicit concepts for describing and evaluating goals and processes. For example, in the context of students' carrying out scientific research, the goal concepts provide a high level structure for carrying out scientific inquiry by characterizing the goals that are operative at various stages of a research project. These include formulating hypotheses, designing investigations, analyzing observations, creating models to account for outcomes, and evaluating ones research as to its soundness and usefulness. Such a classification of goals allows one to contextualize the methods and cognitive processes involved at each stage of inquiry. Classification of cognitive processes in turn provides a basis for both recognizing, monitoring, and communicating about cognitive activities. These processes include generating multiple options, employing systematic strategies, developing and using representations, and reasoning carefully. Each of these functional classes can be further decomposed in terms of particular strategies and methods that are employed at each stage of the research process.

In the context of teachers' developing a model for viewing and interpreting inquiry-based science teaching, the teachers are introduced to a hierarchical, interpretive framework made up at the top level of high level functional goals of teaching, such as having an effective pedagogy, developing a social climate that supports learning, having students be engaged in worthwhile activities, and having scientific thinking and inquiry

happen in the class. For each high level teaching goal there are associated methods and processes used in accomplishing them. For instance, processes for developing classroom thinking include making the thinking of participants explicit, encouraging multiple perspectives, using scientific terms in ordinary classroom discourse, and exploring thinking processes. In each of these cases, of students learning to carry out scientific inquiry and of teachers developing a model of how to teach inquiry-based classes, our conjecture is that introducing explicit terminology for referring to goals and cognitive processes will enable apprentice practitioners to deepen the metacognitive basis of their collaborative discourse while supporting reflective collaboration.

We believe that the best way to learn such reflective concepts is through conversations about performance situations that exemplify them. Concepts then may be indexically defined in reference to situations where students are performing particular goals and activities of a scientific investigation and teachers are viewing and discussing videotapes of classroom teaching (Barwise & Perry, 1983; Brown, Collins, & Duguid, 1989). The properties of these situations and of cognitive processes that they entail emerge in sense-making conversations about the concepts we have introduced and how they are shown in performance. This process is familiar to teachers who have had the experience of learning to score students' performance assessments. It is our hypothesis that developing a set of categories for describing complex performances opens up the exploration of practice by providing a texture to our perceptions of cognitive performance as well as a basis for organizing our reflective discourse. Their use in turn facilitates communication among students or teachers about goals, plans, and processes, which promotes coordination of work in their collaborative research task. Introducing such concepts brings cognitive processes explicitly into the social and linguistic space of collaborative work and thereby facilitates development of self knowledge of cognition and the regulation and control of cognition – the components of metacognitive competence (Brown, 1987). This metacognitive expertise develops by first being practiced in the group and then becoming internalized through participation in collaborative, reflective activities (cf., Vygotsky, 1978). The main elements of this view of acquiring metacognitive competence are summarized in Figure 1.

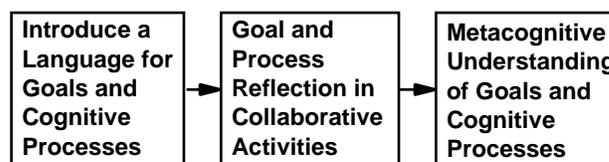


Figure 1. The elements of cognitive facilitation.

Reflective Collaboration in Students' Scientific Inquiry

The first domain in which we have been evaluating these conjectures is within our ThinkerTools Inquiry Curriculum (White and Frederiksen, in press). The ThinkerTools Inquiry Curriculum focuses on the development of scientific inquiry strategies and skills and on their use by students in developing an understanding of science. Currently, the science domain addressed is the physics of force and motion, although we have been extending the approach to topics in genetics, health, cognitive science, and mathematics. The curriculum seeks to develop students' metacognitive knowledge, namely, their knowledge about the nature of scientific laws and models, their knowledge about the processes of modeling and inquiry, and their ability to monitor and reflect on these processes. The curriculum centers on inquiry activities that make use of computer-based tools for modeling as well as hands-on materials for experimentation. Pedagogical strategies include carefully scaffolding students' inquiry process and having students make their conceptual models and inquiry processes explicit. Cognitive facilitation was provided by introducing an interpretive framework which students used in reflecting on their progress and in evaluating their project work.

A goal structure for inquiry. The curriculum centers around a generic inquiry cycle which provides a top-level model of the inquiry process. The inquiry cycle is made explicit to students and is presented as a sequence of goals to be pursued (Question Predict Experiment Model Apply Question etc.). The students begin the cycle by formulating a research question. They then generate alternative hypotheses related to their question. Next, they design and carry out investigations in which they try to determine which of their hypotheses, if any, is accurate. They carry out their investigations in the context of both computer simulations and real world observations. After the students have completed their experiments, they then analyze their data and formulate a law or a model to characterize their findings. Once the students have developed their model, they then consider how it applies to a number of alternative real-world situations in order to investigate its utility and its limitations. Identifying the limitations of their conceptual model raises new research questions, and the students begin the inquiry cycle again.

Process criteria. In addition to a goal structure for guiding their scientific inquiry, we introduce students to a set of criteria for reflecting on their cognitive and social processes in doing research. These include high-level summaries such as "understanding the processes of inquiry," process-oriented criteria, such as "being inventive," "being systematic," "understanding and using representational tools," and "reasoning carefully," and socially-oriented criteria such as "communicating well"

and "teamwork." The definitions for these criteria were designed to help students understand the nature of cognitive processes in research. For instance, "being systematic" is defined as: "Students are careful, organized, and logical in planning and carrying out their work. When problems come up, they are thoughtful in examining their progress and in deciding whether to alter their approach or strategy." The students use these criteria in a process we call reflective assessment in which they evaluate their own and each others' research using a 5-point scale (Miller, 1991; Towler & Broadfoot, 1992). When students evaluate the research they have just completed, they are asked to justify their score by describing how their work deserves that score. Our hypothesis is that reflective assessment based upon the performance concepts we have introduced will help students to better understand the purpose and steps of the inquiry cycle, and encourage them to continually monitor and reflect on their work. This metacognitive reflection should be especially important for low-achieving students, who do not have strong metacognitive skills such as those of monitoring and reflecting on their work (Campion, 1984; Nickerson, Perkins, & Smith, 1985).

Our curricular experiments were conducted in urban middle schools (grades 7 through 9). We experimentally varied the introduction of concepts for process reflection, along with the conversational and self-assessment activities that make use of those concepts. We did this by having matched classes for each teacher, with one class in each pair using the process concepts for reflection (the Reflective Assessment Classes) and the other having in their place general discussions about what they liked and didn't like about the curriculum (these are the Control Classes). We also analyzed students' understanding and meaningful use of the process reflection concepts by evaluating the written rationales that the students generated in their self assessments. This enabled us to see if students who had developed a clear understanding of the process concepts were more successful in learning how to carry out scientific investigations than those who had not. Our results should show whether introducing such reflective assessment practices into middle school classrooms is beneficial both in students' learning how to carry out inquiry and in their developing an understanding of the science content. Here we will review some of our results bearing on the success of cognitive facilitation. For a full presentation of our findings, see White and Frederiksen (in press).

Cognitive Facilitation and Students' Learning

One of our assessments of students' scientific inquiry knowledge was a scientific inquiry test that was given both before and after the Thinker Tools Inquiry Curriculum. In this written test, the students were asked to investigate a specific research question: "What is the relationship between the weight of an object and the effect that sliding friction has on its motion?" The

students were asked to come up with alternative, competing hypotheses with regard to this question and to design an experiment that would determine what actually happens. Then they were asked to carry out a *gedenken* experiment and make up data that they thought they would get if they actually carried out their experiment. Finally, they had to analyze their made-up data to reach a conclusion and to relate this conclusion back to their original hypotheses. In scoring this test, the focus was entirely on the students' inquiry process, not on the correctness of the physics content. We found that students in the Reflective Assessment Classes showed significantly greater improvement on this inquiry test than did students in the Control Classes. The gain scores for each component of this test as shown in Figure 2 for each group of classes. The advantages of introducing reflective assessment are

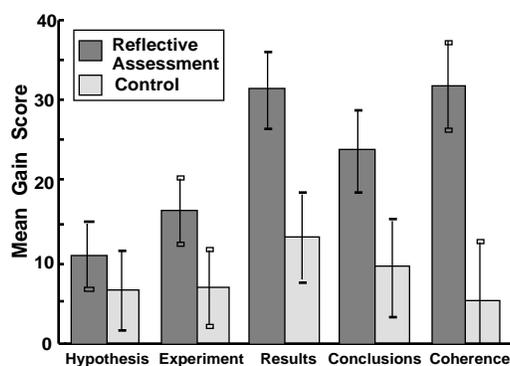


Figure 2. Average gains on the Inquiry Test Subscores for students in the reflective assessment and control classes.

greatest for the more difficult aspects of the test: generating plausible results and analyzing them to provide backings for their conclusions. In fact, the greatest gain scores on this test were those for a measure we call "coherence," which captures the extent to which their experiment, hypotheses, results, and conclusions are consistent with one another. This kind of overall coherence in research is, we think, a very important indication of sophistication in scientific inquiry.

Next we turn to the results from the students' actual research projects. Students carried out two research projects in this course, one about half way through the curriculum and one at the end. The projects were scored by teachers using a 5-point scoring rubric. For the sake of brevity, we have added the scores for these two projects together in Figure 3. These results show again that students in the Reflective Assessment Classes do better on their research projects than students in the Control Classes. The results also show that cognitive facilitation is particularly beneficial for the low-achieving students: low-achieving students in the Reflective Assessment Classes perform almost as well as the high-achieving students. We also went on to evaluate whether

students could generalize their inquiry skills across projects in which the scientific phenomena being investigated differed. We found that approximately 75% of students were able to generalize their research skills in investigating new science topics.

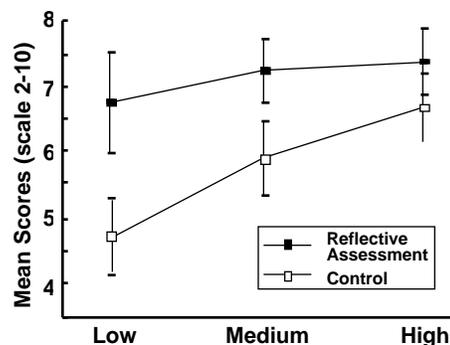


Figure 3. Mean scores on two Inquiry Projects for students in the Reflective Assessment and Control classes for three achievement levels.

The reflective assessment concepts were chosen to address principally the process of inquiry and only indirectly the conceptual model of force and motion that students are attempting to construct in their research. Moreover, within the curriculum students practice reflective assessment primarily in the context of judging their own and others' work on projects, not their progress in solving physics problems. Nonetheless, we might ask if reflective assessment has had an influence on students' success in developing conceptual models for the physics phenomena they have studied? Our hypothesis is that it should, through its effect in improving the learning of inquiry skills that are instrumental in their developing an understanding of physics principles. To evaluate the effects of reflective assessment on students' conceptual model for force and motion, we developed a Conceptual Model Test. Our findings, presented in Figure 4, show that the effects of reflective assessment extend to students' learning the science content as well as to their learning the processes of scientific inquiry, and that the benefits of cognitive facilitation are greatest for the academically lower-achieving students.

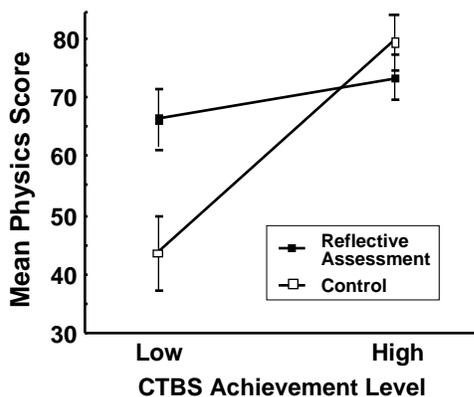


Figure 4. Mean scores on the Conceptual Model Test for students in the reflective assessment and control classes with high and low achievement levels.

Students' Understanding of Cognitive Concepts

If we are to attribute these effects of introducing cognitive facilitation to students' developing metacognitive competence, we need to show that the students have developed an understanding of the assessment concepts and can use them to describe multiple aspects of their work. One way to evaluate their understanding of the assessment criteria is to compare their use of the criteria in rating their own work with the teachers' evaluation of their work using the same criteria. If students have learned how to use the criteria, their self assessment ratings should correlate with the teachers' ratings for each of the criteria. We found that students in the Reflective Assessment Classes, who worked with the criteria throughout the curriculum, showed significant agreement with the teachers in judging their work, while this was not the case for students in the Control Classes, who were given the criteria only at the end of the curriculum for judging their final projects. For example, in judging Reasoning, students who worked with the assessment concepts throughout the curriculum had a correlation of .58 between their overall ratings of their final projects and their teachers'. The average correlation for these students over eight criteria was .48, which is twice that for students in the Control Classes.

If the reflective assessment concepts are acting as metacognitive tools to help students as they ponder the functions and outcomes of their inquiry processes, then the students' performance in developing their inquiry projects should depend upon how well they have understood the assessment concepts. To evaluate their understanding, we rated whether the evidence they cited in justifying their self assessments was or was not relevant

to the particular criterion they were considering. We then looked at the quality of the students' final projects, comparing students who had developed an understanding of the set of assessment concepts by the end of the curriculum with those who did not. Our results, shown in Figure 5, show that students who had learned to use the interpretive concepts appropriately in judging their work produced higher quality projects than students who had not. And again we found that the benefit of learning to use the assessment concepts was greatest for the low-achieving students.

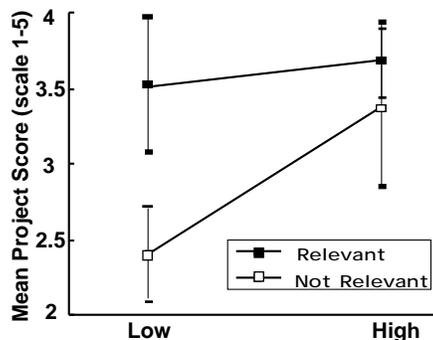


Figure 5. Mean scores on final projects for students who differed in their ability to provide evidence relevant to the assessment concepts.

Taken together, these research findings clearly implicate the use of the assessment concepts as a reflective tool for learning to carry out scientific inquiry. Introducing process reflection improves the quality of students' scientific inquiry and also their understanding of the science content knowledge. Students who showed a clear understanding of the reflective concepts produced higher quality investigations than those who showed less understanding. Thus, there were strong beneficial effects of introducing a set of concepts to direct students' reflective explorations of their work in classroom conversations and in self assessment.

Student Conversations

To get a better idea of students' qualitative understanding and use of the assessment concepts, we transcribed videotapes of two classroom periods in which assessment discussions were taking place in the context of students presenting their projects. Students gave oral presentations of their projects accompanied by a poster and sometimes a computer demonstration, and they answered questions about it posed by the teacher or other students. Following each presentation, the teacher would pick a few of the assessment categories and ask students in the audience how they would rate the students' presentation. In these conversations, students were respectful of one another and generally gave their peers high ratings (ratings of 3-5 on a 5-point scale). However, within the range of high scores they used, they

did make distinctions among the criteria and offered insights into their evaluation of the project that had been presented. The following presents some illustrative classroom discussions based on the assessment concepts.

Inventiveness. When asked how the students' presentation showed Inventiveness, one student said, "I gave them a 5 because they had a completely different experiment than almost everyone else's I've seen. So, being inventive, they definitely were very inventive in their experimentation." Another added, "I would have to give them a 5 too because I like how they did something with friction and compared it to mass. I don't think anyone else did that." These two students clearly have a normative idea of inventiveness – producing a project that clearly shows originality.

Reasoning. When asked how the students' presentation showed Careful Reasoning, one student said, "I gave myself a 5 because I had to compute the dot prints between the experiments." Students, like this one, often pick a particularly difficult part of their analysis as an example of Reasoning Carefully. This illustrates one of the intended features of Reflective Assessment – to develop a perspective on a particular characteristic of one's work so as to distinguish where and how it takes place.

Communication. In judging Communication, a student who presented a project gave this self assessment: "I gave myself a 4 because I always told my partner what I thought was good or what I thought was bad, and if we should keep this part of our experiment or not. We would debate on it and finally come up with an answer." This is one of the intended meanings for Communication, namely, that between students as they carry out their research. We also wished for students to consider their effectiveness in presenting their projects through their written and oral reports as an aspect of Communication.

In summary, the students can be said to have produced interpretations of projects that are in the ballpark with respect to the intended meanings and uses of the assessment concepts. In some cases their meanings tend to be more concrete than perhaps we would have liked, but this enabled students for the most part to provide relevant evidence to support their assessment. If we are to err, it is probably best to err in the direction of concreteness so that students will focus clearly on the evidence in a project and its presentation, not on ephemeral judgments of quality that cannot be supported or defended. We should emphasize again that in assessing others (particularly in classroom conversations), students are very considerate of each other and most of their assessments are high. Nonetheless, they do succeed in distinguishing aspects of projects that are more or less meritorious.

Reflective Collaboration among Apprentice Science Teachers

The second situation in which we have explored the use

of cognitive facilitation in reflective practice is that of a video analysis seminar in which apprentice science and mathematics teachers were engaged in learning how to teach science (and mathematics) through developing and supporting students' inquiry processes. Our approach in the seminar was to introduce the teachers to a set of concepts for viewing and interpreting teaching that could provide a basis for a collaborative exploration of their teaching goals and methods and how they are implemented with students in a classroom. Our hypothesis was that engaging in this reflective activity should help the apprentice teachers to develop a shared language for viewing and talking about teaching which, in turn, should help them to explore, reflect on, and improve their own teaching practices.

The members of the seminar were 10 graduate students enrolled in UC Berkeley's MACSME Program (standing for Master's and Credential in Science and Mathematics Education), including 6 first-year students and 4 second-year students. The students were concurrently taking courses covering educational theory as well as practicum courses, and the second year students were also involved in supervised classroom teaching. The purpose of the video analysis seminar was to provide a place where students' knowledge of educational theory could become connected with actual classroom teaching practice through viewing and analyzing videotapes of classroom teaching.

The approach taken in the seminar was to introduce a framework for viewing teaching and to have students apply it in evaluating videos of classroom teaching. Initially, the exemplar tapes were a mixture of tapes of classes of middle school science teachers who were using the ThinkerTools Inquiry Curriculum and classes of high school mathematics teachers. The focus at this stage was on learning the framework and using it to evaluate teaching. Approximately half way through the semester, the seminar began to function as a "video club." In preparation for each video club, one of the apprentice teachers would make a videotape of his or her practice teaching and distribute it to the members of the seminar the week prior to the club meeting. At the video club, the discussion of the tape was run by the practicing teacher and the emphasis was on having the group provide feedback on any aspects of the tape that the teacher wished to raise for discussion. Also present in the seminar were two or three faculty members whose role was to introduce the interpretive framework and video analysis activity, to encourage students to explore distinctions being made by the different framework concepts, and occasionally to draw attention to "meta" (general) issues that came up implicitly in the discussions.

Our hypothesis was that through conversations about actual teaching situations, the seminar participants would construct appropriate meanings for the teaching concepts introduced through the interpretive framework, and that these would in turn provide support for their

collaborative exploration of the teaching process. Our research goals were therefore (a) to identify the students' constructed meanings for the teaching concepts we introduced, (b) to attempt to identify the implicit causal relations among the concepts as students used them to describe teaching, and (c) to evaluate whether their use of the concepts was worthwhile in facilitating productive discussions of teaching. This research was carried out collaboratively with the four second year students, Nathania Chaney Aiello, Brian Colety, Jake Disston, and Staci Richard, and the results of these analyses became the basis for their master's projects.

Interpretive concepts for teaching. The interpretive framework we used was derived from our earlier research on using video portfolios for assessing teaching (Frederiksen, 1994; Frederiksen, Sipusic, Sherin, & Wolfe, 1997). The framework, a portion of which is shown in Figure 6, is hierarchical, made up of a set of six high level functional goals at the top level and with methods and processes for teaching and learning grouped under each of the teaching goals. The 6 high-level goals include: (1) having an effective pedagogy, (2) having efficient management, (3) developing a social climate that supports learning, (4) having students engaged in worthwhile activities, and (5) ensuring that scientific thinking and (6) scientific inquiry are taking place in the class. For each high level teaching goal, there are a set of associated methods and processes used in accomplishing them. For instance, processes for developing classroom thinking include making the thinking of participants explicit, encouraging multiple perspectives, using scientific terms in ordinary classroom discourse, and exploring thinking processes.

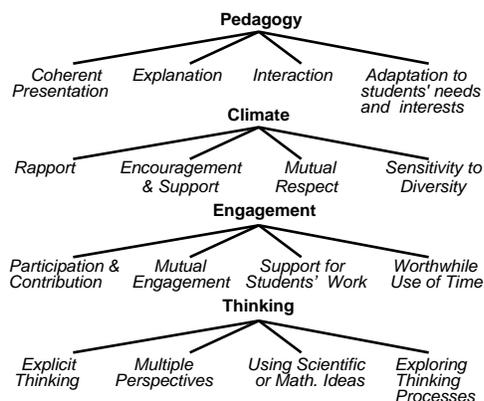


Figure 6. A portion of the interpretive framework used for cognitive facilitation in the video analysis seminar with student teachers.

Video analysis. Video analysis begins with members of the seminar individually viewing videotapes of science and mathematics teaching and evaluating them using the top-level goals of the framework. While viewing a tape, the analysts create a list of "call outs" of

activities or interactions shown on the tape that they think are pertinent in evaluating the teacher's accomplishment of each of the goals. After finishing the tape, they assign a score for each of the criteria and, drawing on their call outs, they write a rationale for why they assigned that score. In the seminar discussions of a tape, the participants, led by one of the graduate students, would first survey their overall evaluations for each criterion and then explore and try to resolve differences in their analyses and interpretations. These discussions involved them in an "unpacking" of the methods and processes used by the teacher and an analysis of how they support the high level goals of teaching. In the second half of the seminar, when graduate students viewed tapes of each other's practice teaching, the discussion did not involve any formal scoring. However, the members of the seminar did write down call outs and evaluations for each of the criteria which they would refer to in their discussion. The purpose of these discussions was to help the student teachers improve their teaching practices.

Meanings Constructed by Participants

While a set of teaching goals along with their associated methods and processes were explicitly introduced as a basis for video analysis, we did not have the illusion that the meanings for these concepts constructed by the teachers would precisely correspond with our intended meanings. Indeed, it is our contention that it is through the collaborative evaluation of video exemplars that meanings for the concepts we had introduced would be developed by the seminar participants. Our first research goal was therefore to identify the "emergent" meanings for the six teaching goals that the participants had constructed through their collaborative analyses of teaching. To pursue this goal, we carried out a semantic analysis of the participants' use of language in describing teaching. We also investigated how the teachers' emergent concepts are interrelated by looking at how they were co-applied in describing teaching. The ideal source of data for such an investigation would be the teachers' descriptions, in their own words, of the features of the classroom video that led them to their score for each teaching goal. Such a source of data is available to us in the form of the rationales that they wrote after viewing each video.

The semantic analysis followed methods we developed in our earlier analysis of the scoring of video portfolios (Frederiksen, et. al., 1997). We began by reading each of the rationales written by the graduate students for each of the six categories and parsing it into the distinct ideas it contains. The total number of ideas generated by the seminar participants in scoring 45 classroom videos was 4,098 (an average of 2.9 ideas per rationale). Many of the ideas expressed by the scorers were quite similar to one another, so we went on to reduce the large list of generated ideas to a smaller list of conceptually distinct ideas. We did this by examining the ideas for each of the six teaching goals and

combining ideas that could be regarded as paraphrases of one another. The result was an emergent set of 229 semantic categories that covered the set of ideas generated, with an average of 38 distinct ideas for each teaching goal. Finally, we categorized each of the ideas generated by a student teacher in scoring under the appropriate emergent category. The result was a data base containing the emergent categories applied by each scorer to each videotape for each of the six teaching goals.

Our second step was to analyze the patterns in which the scorers co-applied the emergent categories within each of the teaching goals (Pedagogy, Management, Climate, Engagement, Scientific Thinking, and Inquiry) as they described the video tapes of teaching. Our goal in this analysis was to see how the emergent categories form clusters, representing more basic processes of teaching and learning that the teachers implicitly had in mind. We used the technique of multidimensional scaling (MDS) to visualize these patterns of co-application.¹ In this representation, the emergent categories are treated as points in space and the distance between them is used to represent their similarity in use, with close distances corresponding to similar patterns of use. One example of the resulting spatial representation is that for Pedagogy, shown in Figure 7. Four clusters of emergent categories that are conceptually related are identified in Figure 7. These include a central cluster representing methods for creating an Interactive, Student-Centered Class in which teachers facilitate students' learning. Additional clusters of categories include: Assisting Students in Exploring their Thinking, Emphasizing Coherency in Presenting Activities, and Adapting Materials to Students' Current Understanding.

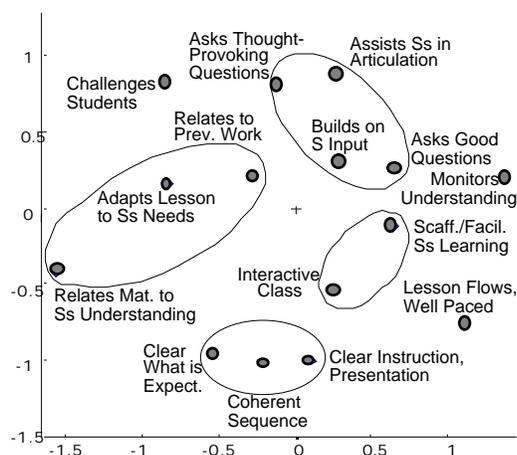


Figure 7. MDS Configuration Plot showing emergent categories for Pedagogy.

¹ The MDS analyses were based on the emergent concepts that represent positive aspects of performance.

The principal emergent clusters for four of the teaching goals, Pedagogy, Climate, Engagement, and Thinking are illustrated in Figure 8. We found that the seminar participants had internalized many of the processes of teaching represented in the framework (compare, for example, Figure 8 with Figure 5), but they also developed some perspectives of their own. For instance, in evaluating Pedagogy they brought out the important idea that teachers should assist students in developing and articulating their ideas. For Climate, they brought out the importance of creating a comfortable collaborative atmosphere. And for Thinking, they brought out the students' engagement in designing investigations and experimenting. This shows that they were striving to integrate Scientific Inquiry within the purview of Scientific Thinking (Inquiry was represented as a separate teaching goal in the framework we had given them). This was also a result of the emphasis placed on inquiry in the classroom videos that they were evaluating. A final point to be made is that the conceptual clusters are based upon an analysis of the 10 graduate students' written rationales taken together, so the consistencies in usage of language we have identified reflect the group's success in constructing a shared set of concepts for viewing teaching.

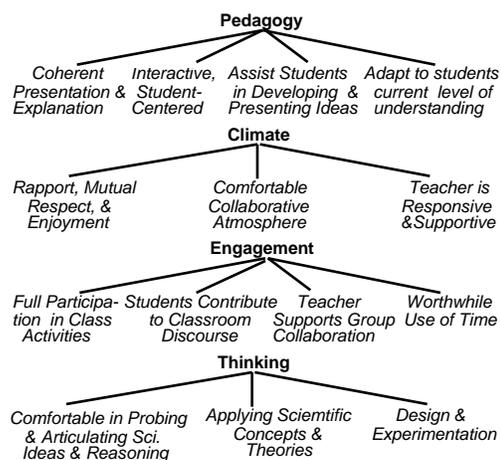


Figure 8. Concepts of Pedagogy, Climate, Engagement, and Thinking that emerged in the teachers evaluations of video tapes of teaching.

Implicit Causal Relations among the Teaching Concepts

Our second research goal was to identify the implicit causal relations among the teaching concepts as students used them to describe teaching. From our viewpoint, the concepts of Pedagogy and Management refer to methods and processes that teachers can carry out in order to influence the social climate of the class, to encourage students' engagement, and to support students' thinking

and inquiry. The concepts of Climate and Engagement represent characteristics of the class as a whole, which in turn also have important influences on the thought and collaborative activities that students engage in. Finally, the concepts of Scientific Thinking and Inquiry capture the students' on-going intellectual accomplishments in their collaborative activity, which we view as the ultimate goal of the teacher.

While informal observations of the seminar discussions suggest that this is a plausible account of the causal relations among the six teaching concepts as viewed by the student teachers, we carried out a more formal analysis of the reasonableness of this model as representing the views of seminar participants as they evaluated videotapes of teaching. The statistical approach we chose was a path analysis of the correlations among the six scores assigned by individual graduate students to each of the 45 videotapes. This analysis is based on writing a recursive system of regression equations reflecting the possible causal pathways of influence among independent (Pedagogy, Management), intervening (Climate, Engagement), and dependent variables (Scientific Thinking and Inquiry), and then testing the significance of the path coefficients. Separate path analyses were carried out for each independent variable (Pedagogy and Management). Figure 9 shows the influences among variables in the analyses for which we found statistically significant path coefficients. For instance, there was evidence of a direct influence of Pedagogy on Thinking, but no evidence of a direct effect of Management on Thinking. And the effect of Climate on Thinking is only indirect, through its influence on Engagement. The path analysis model corresponds well with the implicit causal model we had posited linking the teaching concepts within the conceptual framework. It is of considerable interest that the apprentice teachers appear to have developed this model without its directly being presented to them in the seminar materials. And again, the data analysis is based upon individual scores generated by each student teacher and thus the correlations demonstrate that the causal model was shared by the participants in the seminar.

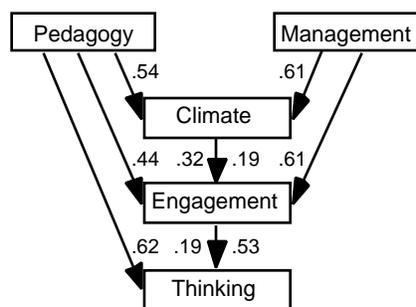


Figure 9. Path diagrams using Pedagogy and Management as independent variables.

Usefulness of the Concepts in Facilitating Discussions of Teaching

Our analyses have shown that the participants in the seminar developed a shared perspective on teaching that was facilitated by introducing an initial reflective framework and then using it as a basis for evaluating videotapes of teaching. This shared perspective was a reinterpretation by the participants of the set of teaching concepts that we introduced. Our remaining research question is whether the use of this conceptual frame was worthwhile in facilitating productive discussions of teaching.

Since we had videotaped all of the seminar meetings, we could address this through an analysis of the conversations about teaching that took place in the seminar. We selected six tapes of video club conversations about student teaching and four tapes of conversations held in evaluating non video club tapes. The recorded seminar conversations were then parsed into conversational units by the four graduate students in the research group, based upon where there were changes in the discussion topic. This yielded a total of 108 conversational units. Each of these units was then classified and rated using a scoring system developed by the research group.

Of interest here are two particular features: *Framework Association*, which deals with whether or not the language used in the conversations made explicit reference to the framework we had introduced, and *Productiveness*, which is a rating of whether or not the conversation was thought-provoking and reflective, with many members of the group actively participating. Interscorer reliabilities for these judgments were 90% and 94%. In our analyses we found that there was a significant influence of Framework Association on the Productiveness of a conversation. Of the conversations that made reference to the conceptual framework, 82% were rated as productive, compared with 56% for conversations that were not framework related. This effect of framework use was independent of whether the conversation was in the context of a video club or was an evaluative discussion of a tape that was being scored. It was also independent of whether or not a faculty member played a role in precipitating the conversation. It thus appears that the conversations that most successfully explored the processes of teaching involved an explicit use of the interpretive framework of teaching goals and process. Thus cognitive facilitation has helped to open up the complexities of interpreting classroom videotapes to a systematic exploration and analysis by this group of preservice teachers.

Summary & Conclusion

We have found that introducing a conceptual and linguistic basis for metacognitive reflection was effective in promoting the collaborative inspection of cognitive activity. We have demonstrated this in two contexts,

that of middle school students carrying out scientific inquiry projects, and apprentice teachers seeking to understand inquiry-oriented science teaching through analyzing videotapes of classroom teaching. For the students, we found that understanding and using the conceptual goals and processes through peer and self assessment improved their performance in carrying out scientific inquiry and in learning the domain science. Our analyses of the students' conversations suggests that the meanings of the concepts approximated those we had intended. For the teachers, we found that there was active engagement in constructing meanings for the teaching concepts, and that their constructions extended and enriched the taxonomy and characterizations of teaching processes we hoped they would develop. In our analysis of conversations using a very strict criterion for category involvement (i.e., explicit use of the terminology), we found that category use was associated with conversations that were highly productive in their explorations of the teaching process. It is important that the categories we introduced in our cognitive facilitation of collaborative reflection were chosen to represent functions of doing science and teaching. This quality invited the participants to develop instantiations of them in multiple situations, thereby promoting their generation of metacognitive knowledge for recognizing their cognitive strategies and processes, and for controlling and improving their cognition.

Acknowledgments

This work is supported by the James S. McDonnell Foundation (CSEP grant 95-6) and by the Educational Testing Service.

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