DOCUMENT RESUME

ED 356 764	IR 015 985
AUTHOR	Hickey, Daniel T.; Petrosino, Anthony
TITLE	Effects of Generative Video on Students' Scientific Problem Posing. Draft.
PUB DATE	11 Nov 92
NOTE	36p.; Paper presented at the Annual Meeting of the Mid-South Educational Research Association (Knoxville, TN, November 11-13, 1992).
FUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Creative Thinking; Critical Thinking; *Discovery Learning; Educational Television; Elementary School Science; Elementary School Students; Grade 6; Instructional Effectiveness; Intermediate Grades; Learner Controlled Instruction; Learning Strategies; *Problem Solving; Progressive Education; Questioning Techniques; *Space Exploration; *Videotape Recordings
IDENTIFIERS	*Learning Environments

ABSTRACT

A central premise of the discovery-learning and progressive education movements was that the child's own questions are the most appropriate starting point for instruction. Recent advances present new opportunities for discovery-oriented learning. This project has been attempting to create a classroom environment which affords students the opportunity to pose meaningful problems within the domain of a specific scientific challenge. One component of this environment is a brief videotape which invites students to generate problems which would have to be solved in order to carry out a mission to the planet Mars. Two studies explored several aspects of sixth graders' performance in this environment. In the first study, which involved 48 average/high ability suburban school students, the content of the problems which students posed was categorized, and changes in problems across three stages of the process were evaluated. In the second study, which involved low/average students from an inner city school, the effectiveness of the video was compared with a typical educational video about travelling to Mars. While these studies confirmed that these students are able to pose "educationally worthwhile" problems in this environment, it was concluded that more explicit guidance is needed. Proposals for providing this guidance and additional research questions are described. The appendix includes a figure describing the conceptual framework. (Contains 30 references.) (ALF)

Effects of Generative Video on Students' Scientific Problem Posing

Daniel T. Hickey and Anthony Petrosino
with
The Cognition and Technology Group at Vanderbilt[1]
Vanderbilt University Learning Technology Center

Mid-South Educational Research Association Annual Conference
Knoxville, TN

November 11, 1992

DRAFT

Running Head: GENERATIVE VIDEO

---

[1] Members of the Cognition and Technology Group who have contributed to this work include Jim Pellegrino, John Bransford, Susan Goldman, and Bob Sherwood. The work described in this paper was supported by the Tennessee Space Grant Consortium, NASA Space Grant College and Fellowship Program. Thanks to Dr. Alvin M. Strauss, Director, TSCG, for his input and support. Thanks to Holly Martin at Eakin Elementary School and Jeff Swink at Carter Lawrence and Janet Hamlett at Christ the King and their students for contributing their time and talent. Direct correspondence to Dan Hickey, Vanderbilt Learning Technology Center, Box 45, Peabody Station, Nashville TN, 37203; hickeydt@vuctrvax.edu.

Abstract

A central premise of the discovery-learning and progressive education movements was that the child's own questions are the most appropriate starting point for instruction. Recent advances present new opportunities for discovery-oriented learning. We have been attempting to create a classroom environment which afford students the opportunity to pose meaningful problems within the domain of a specific scientific challenge. One component of this environment is a brief video tape which invites students to generate problems which would have to be solved in order to carry out a mission to the planet Mars. Two studies explored several aspects of sixth graders' performance in this environment. In the first study, we categorized the content of the problems which students posed and attempted to evaluate changes in problems across three stages of the process. In the second study we compared the effectiveness of our video with a typical educational video about travelling to Mars. While these studies confirmed that these students are able to pose "educationally worthwhile" problems in in this environment, we concluded that more explicit guidance is needed. Proposals for providing this guidance and additional research questions are described.

Effects of Generative Video on Students' Scientific Problem Posing

The National Space Grant College and Education Fellowship Act of 1987 gave NASA the mandate to greatly expand its educational mission. In order to "help maintain America's preeminence in aerospace science and technology," the act mandated that NASA devote a portion of its appropriation to ensuring a trained pool of scientist and engineers in the years to come. While a substantial portion of the Space Grant resources are devoted to University-level training, K-12 education is also an important focus. One of the primary objectives specified for individual Space Grant programs is:

> To arouse the interest of a generation of K-12 students in mathematics and science, to improve their levels of competency in such subjects, and to stimulate their collective interests in, preparation for, and dedication to careers in diverse technology based occupations (NASA, 1990, p. 10).

This statement embodies the two strongly interrelated challenges facing NASA and the nation as a whole. The first of these challenges is fostering an interest in science careers in general and the aerospace sciences in particular. Interest among freshmen in science and engineering over the last decade has dropped by one quarter to one third, depending on the field, (NASA, 1990). In many countries, including the U.S., researchers find a substantial decline in interest in math and science during the high school years (Jones, 1988; Lehrke, Hoffman, & Gardner, 1985).

The second challenge facing NASA is developing in today's youngsters the academic abilities need to prepare for college-level science and engineering careers should they choose them. This academic challenge can be further considered in terms of two interrelated components. The first is in basic skills, i.e., the verbal and math skills traditionally measured by the SAT and other standardized tests. The second component of the academic challenge is in the area of critical thinking skills. The poor problem solving abilities of U.S. students is well documented.

Particularly in complex academic domains such as math and science, students demonstrate marginal (and declining) ability to generate and evaluate arguments, engage in informal reasoning, and generate and solve moderately complex problems. (Jones, 1988; Kouba, Brown, Lundquist, & Silver, 1988). While the basic skills of students who plan to purse college majors in math and sciences has remained relatively constant, their ability to to solve more complex problems continues to decline; Among the students who do not plan to study science and math in college, the decline in basic math and science skills as well as critical thinking skills has been substantial (Jones, 1988). While a great deal of research has been devoted to improving academic abilities, little formal research has been directed at increasing interest. While NASA and other federal agencies have invested extensively in K-12 outreach programs designed to increase interest, we lack an adequate research base for evaluating the impact of these programs on students academic achievement.

With the support of the Tennessee Space Grant Consortium, we have engaged in a research and development program designed to increase student interest in math, science and technology in a manner that directly impacts student academic achievement. We are attempting to create a classroom learning environment which anchors K-12 math, science, and cross-curricular content within the context of interplanetary travel--more specifically, planning a human mission to Mars. We are following a generative, problem-solving approach based on current psychological and educational research and are attempting to incorporate emerging multimedia technologies. A central feature of our approach is that it contextualizes learning around solving problems *that the students themselves generated.*

Our efforts are rooted in the writings of Dewey, and the British "open learning" and the American "discovery learning" movements. Central to these approaches is the belief that a student's own questions and wonderments represent a discrepancy in knowledge and a desire to learn, and are thus the most appropriate starting point for instruction. Scardamalia & Bereiter (1990) describe the historical antecedents of this perspective on student inquiry:

> Starting with the work of Susan and Nathan Isaccs (1930), the "child's own question" has been seen as a prized object that should be at the center of the curriculum. What makes a question the "child's own" is that it springs from a deep-seated interest of the child or arises from an effort to make sense of the world.... The source of questions is a gap or discrepancy in the child's knowledge or a desire to extend knowledge in some direction (p. 3)

The 1960's saw a massive investment by the National Science Foundation in developing and disseminating inquiry-oriented science curricula designed to present learners with the opportunity to discover important scientific principles by interacting with everyday objects. These programs were explicitly based on Piaget's theory of developmental sequences which presumed that experimentation strategies emerge during particular periods of the child's development. Thus the early discovery learning environments were designed to facilitate the emergence of scientific skills rather than teach them directly. One popular curriculum, the Science Curriculum Improvement Study (SCIS) followed a three-stage cycle consisting of exploration, concept introduction, and concept application (Atkin & Karplus, 1962). Rakow (1986) described the exploration phase as

> In the exploration stage (sometimes referred to as "messing around") students are given unfamiliar materials (for example, a set of geoblocks or a set of batteries, bulbs, and wires) and are instructed to find out everything that they can about the materials. This unstructured exploration leads students to ask further questions about the materials, which they may wish to investigate (p. 21)

In the concept introduction phase, the class uses the "concept invention" strategy to discover a scientific concept based on observations made during the exploration phase. In the concept application phase, the class applies the newly established scientific concept to a new situation. Many variants emerged and later programs typically incorporated more guidance, but all reflected the presumption that scientific strategies were something that "emerged."

Discovery learning advocates were able to amass substantial evidence that discovery learning programs led to greater performance on measures of both traditional basic science concept knowledge and "scientific process" skills (see Bredderman's 1983 meta-analysis). However, substantial controversy surrounded the large-scale implementation of discovery learning methods. Teachers' observations confirmed their commonsense notion that students following such approach will rarely "discover" a significant number of meaningful scientific concepts in such a setting. Teachers also observed that the confusion and frustration that can result from unguided inquiry often eliminates the increased motivation thought to follow when students are able to pursue their own questions (Linn, 1986). Despite the empirical support for the approach and the massive investment in dissemination and teacher training, the 1970's saw a return to the more traditional direct instructional approaches which are rooted in a "transmission/reception" model of teaching and learning. While these highly structured approaches offer clear benefits in terms of classroom management and assessment, there is broad agreement among researchers that such approaches are at odds with contemporary psychological theory (e.g., Resnick, 1989) and stated educational goals (e.g., AAAS, 1989). This renewed reliance on direct-instruction approaches has led science educators and educational researchers to reconsider the inquiry-oriented approaches of the previous generation.

Recent advances in cognitive and instructional psychology and the increased availability of classroom computing, multimedia, and telecommunications technology present new opportunities for discovery-oriented learning (Blumenfeld et. al., 1991). Earlier approaches to discovery-learning were based on theories of cognition, motivation, and learning which focussed on domain-general processes. Following the general paradigm-shift in cognitive psychology, researchers have begun reconsidering discovery learning with the assumption that cognitive processes and motivation are strongly bound to specific domains, or even specific content within a domain. In practice this has led to a focus on teaching generalizable cognitive processes in the context of meaningful, real-world content. Recent research carried out in the area of "Cognitive Apprenticeship" (Collins, Brown, & Newman, 1989), "Anchored Instruction" (Cognition and Technology Group at Vanderbilt, 1990, 1991, 1992, in press), and constructivism (e.g., Cobb, Wood, & Yackel, 1992, Duffy & Jonassen, 1992) provide a useful framework for reexamining and improving inquiry-oriented approaches. In general, these new approaches situate inquiry within a pre-specified problem"space," and attempt to induce transfer by leading students to apply newly-learned generalizable skills within a new domain.

The Mars Challenge

Our prototype learning environment is designed to lead students to pose educationally worthwhile problems and then support student inquiry into solving these problems. Figure 1 illustrates the three basic levels of the conceptual model which we have applied to the Mars Challenge project, and lists the instructional activities, learning affordances, and materials associated with each. The first level, Problem Generation, focuses on students' posing, defining, and categorizing of problems within the problem space. The second level, Knowledge Distribution & Teamwork, is concerned with establishing a cooperative environment based on individual efforts directed towards the larger group's common goal. The third level, Using Knowledge Tools, is concerned with facilitating the use of educational and reference resources to solve selected problems. While these levels are roughly sequential, the levels are highly iterative and interdependent. In particular, the activities that make up the problem generation level are viewed as ongoing throughout the entire process.

The focus of our efforts to date and the primary topic of this paper is problem generation. [Additional details regarding the larger learning environment are described in Hickey, Petrosino, Pellegrino, Goldman, Bransford, & Sherwood (1992).] We consider problem generation most essential because it affords the interest in the general topic and specific problems needed to motivate students during subsequent self-directed inquiry and learning.

In order to introduce students to the topic and the problem generation task, we developed a short video using existing NASA footage. The Mars Mission Challenge video suggests the range of factors that would have to be considered and challenges students to generate questions that would have to be asked and problems that would have to be solved to carry out such a mission. Over a series of classroom trials, problem generation has evolved into a three-stage process (see Figure 1) In the *problem posing* phase, students view the video and pose as many problems as they can. In the *problem definition* phase, students further define and prioritize their problems; in the *problem categorization* phase, students sort and categorize their problems.

In order to more formally evaluate the problem generation process, we must first establish criteria for evaluating problem generation outcomes. As the "artifact" of the process (Blumenfeld et. al., 1991) the problems themselves are the most obvious outcome. Our primary goal is to lead students to generate "educationally worthwhile" problems. We define these as problems which 1) fall within the general problem space of planning a mission, 2) are sufficiently open-ended to support inquiry in a manner that would require students to defend their solution, and 3) can plausibly anchor student inquiry in a manner that supports learning academic content. In the two studies reported here we have attempted to further define the first two of these criteria.

Our initial problem generation environment was minimally guided. While we did establish a detailed activity framework, this was necessary to guide youngsters through a task that would be challenging even for adults. Our objective was to provide a minimal amount of *intellectual* guidance within each step of the activity, and allow our classroom experience and ongoing theoretical development to shape the inclusion of additional guidance. We reasoned that excessive focus on teaching students about generating "good" problems would detract attention and interest from the content. To the degree possible, we allowed the students' knowledge of the content to guide the generation process.

Study One

Our pilot studies showed us that the difficulty which students (and teachers) have with domain-specific problem posing stems more from unfamiliarity with the task rather than inherent inability. Following some initial confusion over what exactly was expected of them, nearly all students were able to pose questions which could form the core of important and meaningful problems. The objective of this first study was to evaluate the content and quality of the problems which students pose and evaluate changes in the set of problems across the three phases of the generation process.

Method

Subjects. Forty-eight students from two sixth-grade classrooms participated. The first class consisted of average/high ability students from a suburban school. A few of these students had participated in space-related activities, including "Space Camp." The second class consisted of low/average ability students a from racially mixed inner-city school. Changes in procedure for the two classes precluded any analysis of the differences between the problems posed by the two groups.

Procedure. Students in the first class were were divided into four groups of six or seven students. After viewing the video as a class, the groups were instructed to "think up as many good problems as you can." Each group then took turns reviewing the videodisc scene-by-scene while attempting to pose additional problems. Then students participated in a pilot problem categorization activity for which we did not collect formal data.

Students in the second class viewed the video and were then instructed to individually pose as many problems as they could. They were then placed in seven groups of three or four and instructed to generate a master set from each individual's list, recording each problem on a single slip of paper. The groups together viewed the video a second time. The groups were then instructed to sort problems into categories and to come up with a name for each category. Each group then placed all similarly categorize problems in an envelope and wrote the name of the category on the envelope. With the first author's guidance, the entire class then categorized each groups' set of problems. This resulted in five sets of problems, each consisting of the envelopes of problems from the individual groups. Students then reassembled into five groups, with each student joining the category of choice. These new groups were instructed to assemble a master list of "the most important" problems from all of the individual problems which they had received.

Results and Conclusions

Problem posing. The four groups of students in the first class and the seven initial groups of students in the second class produced 346 problems. The groups in the first class posed 50, 56, 28, and 48 problems, while the groups in the second class produced from 11 to 37 problems, with an average of 23.4. Twenty-seven problems were eliminated because they were unreadable or incomprehensible. Many of the problems students posed were poorly defined reflections of a general question (e.g., "What about food?") while some were the well defined problems we had been seeking (e.g., "How many pounds of food will we have to bring?"). Several attempts to define reliable (and valid) measures for evaluating problem quality failed. The difficulty in defining criterion stemmed from 1) the generally poor definition of the problems, 2) the limited theoretical framework regarding the generation process, and 3) the absence of a clear framework for incorporating the problems into subsequent learning activity.

To summarize the content and nature of the problems, the first author evaluated the problems in light of their anticipated role as anchors for instruction in subsequent learning activities. Based on the materials available and the need to delimit the curriculum, we had initially decided that it would be reasonable to support inquiry in several broad content areas (Hardware, Mission Configuration, Health, Life Support, and Surface Activity; we later added politics). We considered a problem "inside" the problem space if it explicitly or implicitly reference content determined to fall under one of these six content areas. A great deal of inference was involved in assigning individual problems to particular content areas. Thus the analysis of problem content is exploratory and not intended intended to test any formal hypothesis. Table 1 summarizes the content of the 319 problems presented by each of these groups. We found that 188, or 59% of the problems were categorized as being inside the problem space. Most of the remaining problems are conceivably relevant, but which we have chosen to exclude. The category "conditions on Mars" was not considered as inside the space because these items were merely questions about Mars but were not considered in the context of how they impact on a mission. For example, questions about the surface of the Mars would have been considered inside if they had been posed within the context of planning a landing site. While problems relating to colonization or life on Mars are certainly relevant to planning a mission, we deemed them outside the domain of manageable inquiry. Clearly, addressing problems on the boundaries of the anticipated problem space represents a major challenge. While we have chosen not to support further investigations into these topics, we will not necessarily force students to abandon them either. The category *Problems* appears to be the result of some students interpreting "problems" as "things that might go wrong" rather than as a challenge needing to be solved, suggesting a need for more explicit instructions. Only 18 problems were deemed frivolous.

An important concern is the coverage of topics within groups of students. While we want students to eventually focus on more specific topics, we were concerned that students might focus their efforts on a single topic from the start, rather than allowing a focus to emerge within the larger problem context. In the first class, three groups posed problems from all five major topic categories (Politics was excluded), while one group posed problems from just three categories. In the second class, where the format appeared to lead the groups to pose fewer problems, only one group posed problems from all five content categories; two groups posed problems from four of the categories, two groups from three categories, and two groups posed problems from just two of the categories. The marginal coverage in the second class suggests appears to favor having students engage in the initial problem posing activity in small groups (as in the first class), rather than as individuals.

Problem categorization. As a pilot test of the categorization process, we were quite pleased with the process and outcome in the second class. The students engaged in spirited discussions about the quality and categorization of each others problems. We were particularly encouraged because students appeared to be emotionally invested in the problems which they and their groups produced. We also observed students spontaneously consulting existing classroom reference material (the encyclopedia) to support their arguments, and the students reported enjoying the process.

Table 2 lists the five categories and the "most important" problems which emerged from the categorization process in the second class. While the categories are fairly coherent, the problems are not very well defined and the relationship between problems within categories is not always apparent. While there is considerable overlap in the categories, this is not necessarily undesirable, since we would expect different groups to consider a similar topic from different perspectives.

The materials used in the second classes' generation activity were color-coded, providing a record of interim products at the individual posing, group definition, and group categorization stages. Evaluation of the problems collapsed across students at each of the three phases showed the proportion of problems scored as inside was roughly constant (around 60%). The questionable reliability and validity of our measures precluded formal evaluation of changes in the problems across the phases, and our cursory examination revealed no evidence to suggest that the problems were improved any way.

In summary, we conclude that students at this level need more explicit guidance during problem generation activity of this sort, but that we still lack the theoretical guidance and empirical findings to direct our inclusion of this guidance. It is likely that limitations in domain knowledge and general reasoning ability, as well as insufficient comprehension of the task are all factors in student performance. Thus it is not clear whether the most appropriate course of action is to provide students with more domain knowledge, more general activity guidance, or both. We expect continued theoretical development and classroom experience to help answer these questions.

Study Two

The first study demonstrated that while the problem generation task which we had defined was effective at leading students to generate educationally worthwhile problems within a specified domain, there is much room for improvement. A shortcoming of the first study was the lack of reliable and valid problem quality measures. In Study Two we attempted to evaluate a very specific aspect of the problem generation environment, the Mars Challenge Video, while attempting to use a new measure of problem quality.

The Mars Mission Challenge video represents a departure from the format of typical educational videos. Following from the traditional transmission/reception model of the teaching and learning process, most educational videos are designed to present a specified body of information. For example, other NASA Mars mission videos which we reviewed present facts about the planet, describe one or more potential mission scenarios, and describe how NASA plans to solve the many challenges that the mission presents. Following from a generative model of learning, the Mars Mission Challenge was designed to prompt students to construct questions to be asked and problems to be solved in addressing the challenge, based on each students' prior knowledge and interests.

In a study motivated by questions similar to ours, Scardamalia and Bereiter (1990; see also Scardamalia & Bereiter, 1991) compared the questions generated by students in CSILE (Computer-Supported Intentional Learning Environment) classes following a unit of instruction on a particular topic (endangered species) with the questions generated by CSILE students who had received no instruction on the topic and were challenged to "write questions reflecting what they wondered about or needed to know to advance their understanding of endangered species" In the former condition (referred to as "text-based" questioning) students tended to ask specific factual questions which could be answered by information presented explicitly in the lesson text; in the latter condition (referred to as "knowledge-based" questioning) students asked questions based on their prior knowledge. Analysis of the questions revealed that the knowledge-based questions 1) represented a higher-level of inquiry, 2) required a more complex answer, 3) were rated as "more interesting" by teachers, and 4) required more complex search for answers.

This study compares the problems posed by students who viewed the Mars Mission Challenge video with problems generated by students who viewed a comparison Mars mission video. We expected that the comparison video would lead students to pose more specific problems about facts presented in the video, and that their problems would be similar to the questions generated in the "text-based" condition above. In contrast, we expected the Mars Challenge video to lead students to pose problems based more on prior knowledge, and that their problems would be more similar to the questions generated in the "knowledge-based" condition above. Specifically , we expected the comparison students to pose more low-level questions that would call for yes/no or factual answers, whereas we expected the Mars Challenge video to lead students to pose more high-level questions that we expect will be more useful anchors for subsequent inquiry.

This study was also used to pilot test a new approach to the problem generation task. We felt that the goals and motivation we provided for the students to pose, define, and categorize problems in the first study were rather abstract and not connected to any real-world activity. Thus we attempted to situate the generation activity around the eventuality of asking different kinds of science experts for help in figuring out how to solve selected problems. We modified the instructions and the materials to situate the the need to posed and define good problems in the need to make the best use of the experts' time. The need to categorize problems was situated in the goal of asking the most appropriate question to the different kinds of experts.

Method

Students. Twenty-nine sixth graders from a suburban parochial school participated. The teacher assigned students to either the generative video or informative video condition using stratified random assignment. She was specifically asked to distribute the highest ability, lowest ability, and high domain-interest students evenly among the two groups.

Materials. The Mars Mission Challenge is a seven minute video which presents a myriad of images relative to planning a mission. It is set to upbeat music and features a narration that focuses on the many problems that would have to be solved in planning a mission. While the images present many clues to the students, we were very general in order to avoid pre-empting students. The video narration explicitly challenges students to pose problem related to the Mars mission and states that "each image has meaning and some scenes have many meanings." The video was designed so that after the first viewing, it can be reviewed scene-by-scene to further cue additional problems and further define problems already posed.

The comparison treatment featured a six-minute long video that presented a hypothetical mission to Mars. The narration describes the various aspects of the proposed mission in a fashion that would lead a young viewer to believe that NASA is already committed to such a mission configuration and is planning to actually carry it out. Some of the images on the video are the same as the images used in the Mars Challenge Video. In terms of content, the comparison video gave details about extended activity and short-term colonization of the planet, whereas the Mars Challenge video presented surface activity in the context of a short-term visit. Additionally, the Mars Challenge video raised the issue of past or present life on Mars, whereas the comparison video made no such reference. The source copy of the video was close captioned, so we re-recorded the tape with a black bar across the portion of the bottom of the screen where the closed-caption had been.

We created new materials to accommodate the changes in our approach. This included illustrated vignettes of nine different NASA scientists which featured a 3-5 sentence paragraph describing the experts and their domain of expertise. We also created a form for individual students to assign each of their problems to one or more of the experts. At the bottom of this form was a list of the nine experts and instructions to pick a first, second, and third choice of expert which the student would prefer to work with.

We also assembled nine small packets of NASA educational materials and a National Geographic article (One for each expertise area) for students to search through for information which was relevant to their problem in the final phase of the activity.

Procedure. The entire class was given a brief introduction and told that we would be working with them for several more days in their classroom. All students were read the same instructions (Appendix A) and given a piece of paper which stated at the top:

> *Can you think of any important questions that would have to be answered and problems that would have to be solved to send women and men to Mars and bring them back home safely? Please write down all of the questions and problems which you can think of.*

The two groups went to opposite ends of the room and watched the program on video monitors. Students then returned to their seats and were instructed to begin listing their problems. After 15 minutes, each group was allowed to watch the video again, stopping the video at any point that they wished (both groups only requested to review a few scenes).

In the following class session, students were given the expert vignettes to read. They were then instructed to copy each of their problems onto the categorization form under one or more experts and to select which of the experts they would most like to work with. In the third class session, students were regrouped around the nine expertise area. The categorization forms were cut up and the individual students' problems were distributed to each of the nine expertise groups. The groups were instructed to review the vignette of their expert and use the individual students problems to create a master set of the most important problems to work on with such a person. On the final day, we made a cursory attempt at letting the students in each expertise group try to find information about their problems in several pieces of NASA educational materials which we provided.

Results and Conclusions

Number of problems. The 15 students in the generative video condition recorded a total of 112 problems (Table 3). The number of problems per student ranged from 4 to 12, with a mean of 7.5 problems per student. The 14 students in the comparison condition recorded a total of 113 problems, ranging from 2 to 12 problems, with a mean of 8.1 problems per student. Thus there was no obvious impact of the type of video on the number of problems students generated.

Content of problems. In order to determine how effectively the videos delimited the problem space, we attempted to determine the proportion of problems which were not meaningful questions related to planning a Mars Mission. After extensive discussion and several attempts to score a test sample, we identified several factors for specifying that a problem was "outside" the problem space. This included potential catastrophes (e.g., "What if we run out of fuel?" and "What if the rocket blows up?" rather than the inquiry-oriented problems which we were seeking such as "How much fuel do we need?" and "What kind of rocket would we use?"). Some questions represented reasonable inquiry (e.g., "What does Mars look like?") but were judged too far removed from the challenge of planning a mission. Additionally questions where deemed as too frivolous (e.g., would we have cable television?"). Blind to the video condition, the authors independently scored the 225 problems as being inside or outside the problem space The raters were in agreement on 76% of the items and disagreements were settled by discussion. A proportion of problems rated inside the problem space was calculated for each student. The mean of this index for the two groups was M = .46, SD = .32, for the generative video and M = .65, SD = .22 for the comparison video. While substantial, these differences were not statistically significant. Efforts to systematically identify the locus of this difference in actual problems in the two sets was not successful.

In an attempt to validate the findings of the previous analysis and compare the content of the problems from the two groups, the first author categorized the content of each problem according to the topic dimensions used to analyze the content of the problems in the first study[2].

---

[2] The degree of inference involved in assigning a problem to a particular topic area precluded establishing any sort of reliability for this categorization. Because of the low reliability of this measure, we choose not to compute proportions of problems inside the problem space for each subject.

Table 4 lists the frequencies of content stated or implied in each each problem posed by the two groups. Collapsing across subjects, 66, or 58%, of the comparison video group's problems were "inside" the problem space, compared to 76, or 68% of the generative video group's problems. This finding contradicts the previous analysis and points to the continued difficulty . We conclude that the more reliable of the two analysis suggests that the problems generated in the comparison condition represented a higher level of inquiry, but that the non-significance of the difference coupled with the low reliability of the rating and our inability to specifying the locus of the difference precludes any conclusive statements regarding the impact of the two videos on the delimition of the problems space

Another question concerned how directly the two videos served to prime students problem posing. Examination of the content of the problems posed by the two groups in Table 3 reveals that the students in the comparison group posed many more problems which fell under the "colonization" and "surface activity" topics, while the generative video students posed more problems which fell into the domain of "life on Mars." Examination of these problems suggest that these differences reflect different emphases in the two videos. This was an expected finding, and suggest that the videos serve to prime problem generation beyond that which would be expected from prior knowledge alone. Additional studies comparing video with no video conditions would be necessary to confirm the impact of any video on the process.

Because the comparison video presented a specific mission scenario, we expected that the comparison students would generate more questions which make inquiries about specific aspects of the information in the video. These are questions or problems related to specific information in the video ("What if the plants in the greenhouses die?) rather than other questions which we presume to arise more from the learner's knowledge ("Can we grow plants in greenhouses on Mars?"). The first author reviewed the questions for both groups, searching for questions that appeared to ask specific questions of the information contained in the video. This showed far more text-based questions in the comparison-video group (20 out of 113) than in the generative video group (3 out of 112). However, since it was impossible to evaluate this content blind to condition, and most of these questions were generated by just four students in the comparison condition, we can't attribute the affect to the video (rather than a misrepresentation of the task).

Level of inquiry. In order to test whether the generative video condition yielded more high-level problems, we ranked problems according to the level of inquiry assigned to the question implicit in the problem. Each problem was categorized as *yes/no* (e.g., "Is everyone in good health before they go?"), *factual* (e.g., "What is the temperature on Mars?), or *open-ended* (e.g., "What kind of rocket would we take?" or "How much fuel would we need?")[3]. The two authors independently categorized each problem blind to the video condition. After the initial rating the raters agreed on 71% of the items, and disagreements were settled by discussion.

The three levels of inquiry (yes/no, factual, and open ended) were assigned the value of 1, 2 or 3 respectively. A mean score for each subject's problem set was computed. This score (minimum of 1 and maximum of 3) was treated as an estimate of the level of inquiry represented by the problems each student generated. The mean of this index for the two groups was very similar ($M = 2.10$, $SD = .536$ for the generative video condition and $M = 2.17$, $SD = .324$ for the comparison condition. Thus the expected difference between the two groups favoring the generative video was not observed. Once again, the relatively arbitrary scoring criteria, reflected in the unsatisfactorily low reliabilities, leads us to qualify the reliability of these results.

Problem categorization. The new problem categorization activity yielded mixed results. The students reported greatly enjoying assigning their individual problems to different experts, but it appeared that many of their problems were too general for them to confidently assign them. Additionally, some of the students appeared to have difficulty comprehending the difference between several of the experts, and during the second phase of the categorization activity, some

---

[3] We initially attempted to use a four-level scale with "open-ended" divided into "open-ended with obvious parameters" and "open-ended with unclear parameters" but we were unable to reliably differentiate between the two.

students complained that the other students had not provided them with enough "good" problems to work with. Examination of the final set of "most important" problem in the six categories for which we obtained data (Table 5) reveal substantial overlap and miscategorized problems.

It is not readily apparent whether the use of expert-domain categories is preferable over the format used in the first study. We changed many aspects of the environment between the first and second studies. Furthermore, discussions with teachers revealed that both classes in the first study had much more experience with open-ended and unstructured learning activities than the students in the study two classroom. Once again, it is not clear whether the difficulty stems primarily from limited domain knowledge, poor general reasoning skills, or a misunderstanding of task demands. While we viewed the task as an excellent "scientific literacy" activity, the materials and the process will need to be refined for this population of students.

Student inquiry. Our cursory attempt at supporting student inquiry was not successful. Inadequate support materials and limited classroom time led us to abandon this activity. Most of the written support materials were too difficult for these students, while the materials which were appropriate to their age level did not contain any of the information they were looking for. While some of the students were able to find or deduce information that answered their questions, many of the students became visibly frustrated or bored.

One observation provide a promising view of the apparent level of student investment in the problems. Because of the limited support materials and the poorly defined problems, we modified several of the expertise groups' problem sets before the final session. We were surprized, but ultimately quite pleased by the vehemence of their outrage over our modifying "their" problems without their knowledge. While the students agreed that the problems were not useable and understood why we made the changes, it appeared that the generation process left them very invested in their problems.

Our experience dramatized the need for more task-appropriate support materials. While NASA produces many excellent public-domain print and video materials, most which are made for younger audiences are documentaries and narratives which contain very little technical information. This is not surprizing, since these materials are designed to be interesting to a population, which, outside of an environment such as our, is not generally interested in the technical content. Development and testing of support materials is a major long-term goal for our project.

General Discussion

As could have been expected, these studies failed to conclusively answer our initial questions and raised many new questions. In the first study, we were unable to find evidence that the the quality of the set of problems improved across the stages of the categorization process. In the second study, one analysis showed that the proportion of problems outside the problem space was lower for the students who viewed the comparison video. The second study also showed that the level of inquiry of the problems for the students who watched the comparison video was almost identical to the students who watched the Mars Challenge video. We still lack an adequate framework for evaluating student problems and we cannot definitively state which is the most effective format for the problem generation activity. We expect this framework to emerge as we move beyond the problem generation phase into more formal attempts at supporting students inquiry into the problems which they generate.

We feel that it is appropriate to conclude that these studies demonstrate that our environment effectively leads students to generate educationally useful problems. We are reassured that despite the problems in these initial trials, students reported enjoying the process, appeared to be emotionally invested in the problems which they generated, were able to pose and categorize problems in an "educationally meaningful" fashion. Our efforts are guided by the belief that a poorly defined problem which the student is emotionally invested in is far more valuable than a well-defined problem which the individual has little intrinsic interest in solving. This is particularly important given the oft-cited findings by Miyake and Norman (1979) regarding the difficulty of asking good questions in the absence of domain knowledge. Studying the impact of the problem generation activities on student interest in both the general domain and in their specific problems is the primary near-term research goal for our activity. Our ideas in this area are influenced by an emerging body of primarily European research on content-specific intrinsic motivation (e.g., Renninger, Hidi, & Krapp, 1992, Scheifele, 1991).

Additional research goals include evaluating the contributions of domain knowledge, general reasoning ability, task-specific skills, and their interactions, to performance in this environment. Possible studies include examining how development (grade level) and domain knowledge (e.g., high versus average or low, as indicated by student self-report or selected populations such as space camp students) impacts problem generation. Contrasting baseline for performance from older, high knowledge students with younger and/or low knowledge students will inform our attempts to optimize each stage of the process. We also hope to devote more effort to studying the knowledge which students construct during the generation activity.

References

American Association for the Advancement of Science (1989). *Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology.* Washington, DC.

Atkin, J. M., & Karplus, R. (1962). Discovery or Invention. *Science Teacher, 29* (Entire Volume).

Blumenfeld, P.C., Soloway, E., Marx, R.W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-base learning: sustaining the doing, supporting the learning

Bredderman, T. (1983). Effects of activity-based elementary science on student outcomes: A qualitative synthesis. *Review of Educational Research, 53* 499-518.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 17,* 32-41.

Cobb, P. C., Yackel, E., Wood, T. (1992). A constructivist alternative to the representational view of mind in mathematics education. *Journal for Research in Mathematics Education, 23* (1), 2-33.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing and learning: Issues for a cognitive science of instruction.* Hillsdale, NJ: Erlbaum.

Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19(3),* 2-10.

Cognition and Technology Group at Vanderbilt. (1991). Technology and the design of generative learning environments, *Educational Technology, 31(5),* 34-40.

Cognition and Technology Group at Vanderbilt (1992). The Jasper experiment: An exploration of issues in learning and instructional design. In M. Hannafin & S. Hooper (Eds.), *Educational Technology Research and Development.*

Cognition and Technology Group at Vanderbilt (in press). The Jasper series as an example of anchored instruction: Theory, program description, and assessment data. *Educational Psychologist.*

Dewey, J. (1913). *Interest and effort in education.* Boston: Houton Mifflin.

Duffy, T. M., & Jonassen, T. M. (Eds.) (1992). *Constructivism and the technology of instruction.* Hillsdale, NJ: Erlbaum.

Issacs, S. (1930). *Intellectual growth in young children.* London, Routledge.

Jones, L. V. (1988). School achievement trends in mathematics and science, and what can be done to improve them. In E. Z. Rothkopf (Ed.), *Review of Research in Education* (Vol. 15, pp. 307-341).

Hickey, D. T., Pellegrino, J. W., & Petrosino, A. (1991, October). *Reconceptualizing space science education: A generative, problem-solving approach.*

Hickey, D. T., Petrosino, Pellegrino, J. W. Bransford, J. B., Goldman, S. R., & Sherwood, R. (1992, April). *The Mars mission challenge environment: A generative problem-solving school science environment.* NATO Advanced Studies Institute Workshop on the Psychological and Educational Foundations of Technology-Based Learning Environment. Kolymbari, Crete.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research 60(4),* 549-571.

Hidi, S., & Baird, W. (1986). Interestingness--a neglected variable in discourse processing. *Cognitive Science, 10,* 179-194.

Kouba, V. L., Brown, C. A., Carpenter, T. P., Lindquist, M. M., Silver, E. A., & Swafford, J. O. (1988). Results of the fourth NAEP assessment of mathematics: Numbers, operations, and word problems. *Arithmetic Teacher, 35(8),* 14-19.

Lehrke, M., Hoffmann, L. & Gardner, P. L. (Eds.) (1985). Interests in science and technology education. Keil: Institut für doe Pädagogik der Naturwissnschaften.

Linn, M. C. (1986). Science. In R. F. Dillon and R. J. Sternberg (Eds.) *Cognition and Instruction.* (pp. 155-204). Orlando, FL: Academic Press.

Miyake, N. & Norman, D. A. (1979). To ask a question, one must know enough to know what is not known. *Journal of Verbal Learning and Verbal Behavior, 18,* 357-364

NASA (1990, January). *First national space grant conference report* (NASA EP-275).

Rakow, S. J. (1986). *Teaching science as inquiry.* (Fastback Series No. 246). Bloomington ID: Phi Delta Kappa Educational Foundation.

Renninger, K. A., Hidi, S. & Krapp, A. (Eds.) (1992). *The role of interest in learning and development.* Hillsdale: Earlbaum

Resnick, L. G. (Ed.) (1989). *Knowing, learning, and instruction: Essays in honor of Robert Glaser.* Hillsdale, NJ: Earlbaum.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *Journal of the Learning Sciences, 1(1),* 37-68.

Scardamalia, M. & Bereiter, C. (1990). *Text-based and knowledge-based questioning by children.* Unpublished manuscript. Toronto: Ontario Institute for Studies in Education.

Schiefele, U. (1991) Interest, learning, and motivation. *Educational Psychologist, 26,* 299-323.

Table 1

Content Categories of Problems Posed in Study One

Relationship to Problem Space	Category	Content Subcategories
Inside (188)	Hardware (35)	Fuel/Propulsion (8)
		Construction/Design (7)
		Ventilation/Power (7)
		Capacity (4)
		Communication (3)
		Capacity (4)
		Other (2)
	Mission (24)	Route/Configuration (8)
		Trip Length (7)
		Landing (5)
		Crew Size (3)
		Other (1)
	Health (53)	Illness (12)
		Social (10)
		Entertainment (7)
		Toilet (5)
		Cleaning (5)
		Fitness/Training (5)
		Sleep (4)
		Privacy (2)
		Long Term Effects (2)
		Other (1)
	Life Support (42)	Oxygen (11)
		Food (11)
		Spacesuits (5)
		Water (5)
		Cargo (5)
		Plants/Animals (2)
		Other (3)
	Surface Activity (14)	General (5)
		Transportation (4)
		Experiments (2)
		Danger (2)
		Tools (1)
	litical (10)	Cost (6)
		Politics (2)
		Other (2)

Table 1 (Continued)

Content Categories of Problems Posed

Relationship to Problem Space	Category	Content Subcategories
Outside (131)	Mars Conditions (37)	Atmosphere/Weather (11) Temperature (7) Gravity (6) Volcanoes/Earthquakes (6) Geology (7)
	Colonization (25)	Buildings (5) Plants/Animals (5) People (5) General (10)
	Life on Mars (14)	People/Aliens (8) Plants/Animals (6)
	Problems (30)	Maroon/Lost (4) Equipment Failure (11) Other (15)
	Other (7)	Unreadable (2) Misconception (2) What to tell on return (3)
	Frivolous (18)	

Table 2

Master Categories and "Most Important Problems" in Study One

Ship & Transportation	How much oxygen will it take?
	Did you see any people or aliens on Mars?
	How will gravity work?
	How much foold and fuel to take?
	Will there be enough technology to get there and come back?
	How long do you stay?
	Is it fun in space?
	You need a ship that would be able to withstand the heat.
	How far and how long will it take? They will have to know that to plan how much other stuff to bring.
Feelings About Mars	Is it hot or cold?
	Why do they go to Mars and what do they do?
	Is it scary?
	How does it feel in Mars?
	How long will you be there?
	Is this planet foggy?
Landform & Lifeforms	How will the surface affect landing?
	Are there any kind of volcanoes, mountains, or landforms like that?
	Will there be any life?
	Is the gravity going to be greater or less?
	How much space or room will be needed?
	Are there sattelites on Mars?
	Is there any water?
	Could we take lifeforms back to earth?
Safety	Is there insurance?
	If something happens to the ship what will they do?
	If you were stuck on Mars how many days will they live?
	If someone got lost would you find them?
	Will there be a doctor or a first aid kit?
	Are there any Mars quakes?
	Are there any volcanic eruptions on Mars?
	What will make a space ship blow up?
Fuel	If they had a solar powered ship it would same a lot of money and fuel.
	They would have to have a lot of gas and chemicals for the going and coming back from Mars?
	Also you'd need two sets of boosters. One to get out of the atmoshpere of earth and from Mars
	You'd Also need a cooling system for the engines so they wouldn't explode in the extreem heat of Mars and its atmosphere?
	And another cooling system in the ship and suits so the men and women that go don't get heat stroke, heat exhuastion, or anything else heat related.
Necessities	Do you need to take chemicals up there?
	What kinds of food will you take up there?
	How long will it take to train?
	You'd also have to have to have tools for picking up samples that would melt when picked some samples up with it?
	How much extra oxygen will they need?

Table 3

Problem Posing Results in Study Two

	Informational Video (n =14)	Generative Video (n = 15
Total Number Problems	113	112
Mean Number per Student	8.1	7.4
Problem Categorization (All Problems)		
Yes/No	21 (18.6%)	33 (29.5%)
Factual	56 (49.5%)	44 (39.3%)
Open-Ended	36 (31.6%)	35 (31.2%)
Mean Level of Inquiry[1]	2.10	2.17
Mean Proportion "Inside" Problem Space[2]	.46	.65
Number of "Text-based" Problems	20	3

---

[1] Based on each students mean ratings of problems ranking with *yes/no = 1, factual = 2, and open-ended = 3.*

[2] Based on each students proportion of problems rated as "inside" the problem space.

Table 4

Frequencies of Problems Posed in Specific Content Areas by Students in Informative and Generative Video Conditions[1]

Relationship to Problem Space	Category	Content Subcategories
Inside (66/*76*))	Hardware (10/*15*)	Fuel/Propulsion (3/*10*) Construction/Design (0/*1*) Ventilation/Power (1/*0*) Capacity (0/*1*) Communication (2/0) Other/General(4/*3*)
	Mission (13/*23*)	Route/Configuration (0/2) Trip Length (7/*4*) Takeoff/Landing (0/*5*) Crew Size (2/*4*) Other/General (4/8)
	Health (17/*11*)	Illness (1/2) Social (1/*0*) Entertainment (4/2) Toilet (1/2) Cleaning (2/*1*) Fitness/Training (2/*1*) Sleep (3/*3*) Pregnancy (3/*0*)
	Life Support (19/*24*)	Oxygen (3/*6*) Food (9/*8*) Spacesuits (2/*5*) Water (2/2) Cargo (1/*0*) Other/General(2/*3*)
	Surface Activity (7/2)	General (1/*1*) Transportation (2/*0*) Experiments (0/*1*) Danger (1/*0*) What to Return (3/*0*)
	Political (0/*1*)	Cost (0/*1*)

---

[1] Frequencies for Generative condition students given in italics.

Table 3 (Continued)

Relationship to Problem Space	Category	Content Subcategories
Outside (47/*36*)	Mars Conditions (9/*7*)	Atmosphere/Weather (1/*1*)
		Temperature (5/*1*)
		Gravity (0/*4*)
		Volcanoes/Earthquakes (1/*0*)
		Geology (0/*1*)
		Look/Size (2/*0*)
	Colonization (10/*1*)	Buildings (2/*0*)
		Plants/Animals (5/*0*)
		General (3/*1*)
	Life on Mars (6/*14*)	People/Aliens (2/*5*)
		Plants/Animals (1/*0*)
		General (3/*9*)
	Problems (12/*12*)	Maroon/Lost (9/*7*)
		Equipment Failure (2/2)
		Other (1/2)
		Human Failure (0/*1*)
	Other (10/2)	Other (10/2)

Table 5

Expertise Categories and "Most Important" Problems in Study Two

Expertise Category	"Most Important" Problems
Psychologist	How would they eat and sleep in space? How would the astronauts survive from sickness? Do they know what to do in case of an emergency? Are there enough oxygen tanks for the suits?
Meteorologist	How would you be able to take a shower in space? How much air do you need for space? What would they do if they ran out of food?
Chemist	How much oxygen would it take to get there and back? How much fuel will it take to get there and back? If there was a leak what would happen? What kind of fuel would you use?
Astronomer	Will there be any extra oxygen and food if the trip to Mars takes longer than planned? How long will it take to go and come back? Why is Mars the only other planet people can live on? How come nobody already lives on Mars? Was there ever running water on Mars? Was there ever life on Mars?
Medical Doctor	What kind of medicines would you use if somebody got really sick? If one of the women is going to have a baby, would the atmosphere change? How do you take a bath in space? What if they run out of food?
Aerospace Engineer	How would you keep the Space Craft from burning up when it enters Earth's atmosphere? How would you get gas if you ran out? How would you get water to Mars?
Mechanical Engineer	Data Lost
Electrical Engineer	Data Lost
Biologist	Data Lost

Appendix A

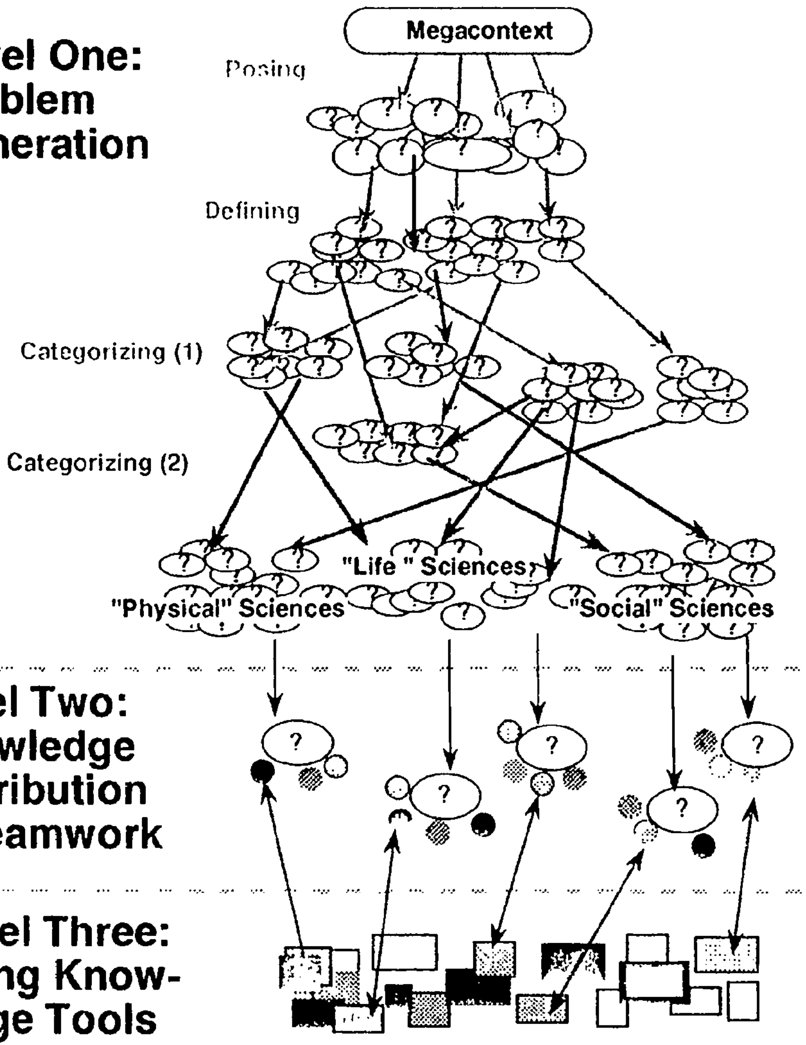
Task Instructions for Study Two

For the next few days, we will be thinking about travelling to Mars. In fact, we are going to help you solve some of the problems that will need to be solved before we can go to Mars. We want you to think up questions that would have to be answered and problems that might have to be solved for women and men to travel to Mars and get back home again. You don't have to know the answers to the questions, and it is okay to list problems which scientists still have not solved.

In a few more days, we will come visit you in your classroom to help you learn information that you might use to answer some of the questions and solve some of the problems that your class came up with. We will ask some scientists from Vanderbilt to help us figure out what we need to learn to solve the problems. So we need to come up with the best questions and problems we can think of.

Today you are going to watch a short video. After you watch the video we will ask each of you to write down as many questions and problems that you can think of. Then we will watch the video a second time. We would like to try out two different videos, so one half of you will go to one side of the room and the other half to the other side.

Figure 1
Conceptual Framework

Levels	Activities	Affordances	Materials
Level One: Problem Generation 	**Generate Problem Set**	**Investment in Topic**	
Posing	Pose problems individually	Generation of Problems in Megacontext	Problem Posing Video
Defining	Define problems in small groups	Opportunity to collaboratively redefine problems with group input	Teacher Guides
Categorizing (1)	Groups categorize problems according to surface features.	Surface-level understanding of interrelationships between problems	Teacher Guides
Categorizing (2)	Class categorizes the groups' problems according to types of experts	Deeper understanding of interrelationships and appreciation of different occupations	"Ask the Expert" disc
Level Two: Knowledge Distribution & Teamwork	Assemble into content area groups to work on preferred problems	Understanding the distributed nature of knowledge and expertise	Student Guides Problem Spreadsheets
Level Three: Using Knowledge Tools	Identify and use knowledge to solve problems.	Learning as problem solving and learning *through* problem solving	Text & Library Books NASA Print & Video E-mail access to Experts Hypermedia Info Base