Mediating Through Messages: Expert Knowledge in a Teleapprenticeship Project

Raoul CERVANTES

The development of computer networking technology has enabled the conventional classroom to participate in learning communities extending beyond classroom walls. These learning communities make possible the types of environments advocated in recent theories of situated learning, particularly the cognitive apprenticeship model. The cognitive apprenticeship model enables novices to learn conceptual and factual knowledge as it is applied to real problems and complex tasks in a variety of contexts. Within this practice, experts externalize and make explicit processes that are usually carried out internally. As a result, novices acquire a web of skills, practices and knowledge, available in various contexts.

Consistent with the cognitive apprenticeship model, Levin (Levin, 1990) introduced the teleapprenticeship model and argued that in addition to enhancing existing educational practices, electronic networks can be utilized to explore practices quite different from those found in conventional schooling. Levin' s teleapprenticeship model incorporates three innovative practices into its design. The first practice is that electronic networks enable students to engage in real problem solving. A second design practice, is that the electronic network should draw upon the diversity that exists throughout the network community. This diversity not only includes different communities and cultures, but different levels of expertise. A third design practice is that electronic networks enable teachers and students to establish contacts with resources beyond their classroom walls. These contacts can include researchers, graduate students, and particularly experts in fields of science and business. Levin suggests that it would be possible for students to read messages sent by experts to other experts, as a way of being socialized into the professional community.

The availability of computer equipment in schools and efforts of researchers and instructional technology developers have enabled students to participate in teleapprenticeship tasks advocated by Levin and his colleagues. Within this model experts can provide assistance and mediate learning as the novice pursues his or her goals. This raises the question of how do long distance experts and novices communicate with each other so that learning will occur. This type of relationship requires that the mentor have an understanding of the novice's states of knowledge and abilities.

Little is known about the nature of network pedagogical communication and how experts interact with novices. Network communication often lacks the history of face-to-face communication between teachers and students in which understandings of common knowledge would develop. In addition, there is no immediate mutual context to assist verbal communication. Experts and novices attempting to provide assistance through a network message must mutually construct the context in which communication occurs.

Given the limitations of network communication mentioned above, how do participants communicating through network messages construct a common focus of attention and shared presuppositions? This study explores how contexts of learning are constructed and how assistance is provided within these contexts. This study addressees the following questions:

1 How do experts construct contexts for learning in network projects?

2 What types of assistance to experts attempt to provide in network projects?

3 How do experts communicate assistance in network projects?

Background of study

The Zero-g Project, the network project which generated the messages in this study, was a year-long project in which participants designed activities for a zero-g environment, such as exists in the space shuttle or in space stations. Zero-g Project activities included the Collision Course Challenge, in which students generated solutions for a problem involving two people on a collision course in zero gravity; the Design Challenge, in which students addressed the problems of recreation and food in zero gravity; the School Design Challenge, in which students designed a school for zero gravity; and the Five Same and Different Challenge, in which students proposed five differences and similarities between conventional and zero gravity schools.

The designers and coordinators of the Zero-g Project attempted to create functional learning environments to provide a wide range of instructional opportunities for the participants in this study. The Zero-g Project and the activities it generated then provided a context for mediation. Within this context, experts assisted novices to achieve goals specified by the project.

Constructing the Context

The first step towards building a context in which experts and novices could mutually participate required the development of a network-based learning project. The network project director accomplished this by proposing the Zero-g Project, challenging participants to design living quarters for a space station. Proposing and coordinating this project included recruiting participants, both experts and novices, establishing goals and timelines, providing resources (software, hardware, video tapes, books, and bibliographies), and constructing problems and challenges. The two challenges discussed in this paper are the Collision Course challenge and the Design Challenge.

The Collision Course challenge was as follows:

> People in a zero-g environment can move from one place to another by 'flying' through the air, pushing off of their starting place toward where they want to go. What if you were 'flying' down a hallway and another person was coming in the other direction toward you on a collision course! What would the two of you do to avoid smashing into each other?

The Design Challenge asked participants to choose to tackle either recreation or food related problems.

> RECREATION
>
> If you choose to submit a proposal for a zero-g recreational activity, assume the following:
>
> 1. The recreation room or module is at least 27,000 cubic feet in volume.
> 2. The zero-g environment has normal air pressure and temperature.
> 3. The activity should involve more than one person at any giv-

en time.

Design a recreational activity that would keep two or more people actively engaged for at least 30 minutes. Some activities that fall within this design request are sports (either modifications of existing sports or totally new ones), dance (either modified or novel), and games (modified or new). These activities can be competitive and/or cooperative. Be sure to take advantage of the free-fall nature of the recreation room.

FOOD

If you choose to submit a proposal about the food process in zero-g, assume the following:

1. The space station is large enough to have a food growing area.
2. The zero-g environment has normal air pressure and temperature.
3. Food and water brought in from outside the station is considerably more expensive than food grown in the space station or water reclaimed from waste.
4. There is a high cost for transporting waste back to earth.

Select some part of the food process (growth, preparation, consumption, or disposal). Describe the steps in detail, providing supportive evidence that the steps of the process are both plausible and desirable.

The Zero-g Project provided a shared context for the network participants enabling them from the beginning of the project to discuss common problems and constraints. The challenges served as the background and context which was either referred to or implied in succeeding messages. Many of the issues and problems discussed by the experts were anchored in these first project proposals. This provided the beginnings of the common focus of attention and shared presuppositions required for communication and mediation.

Mediation as Assisted Performance

As students and other novices tackled problems generated by the Zero-g Project, experts from different fields and professions provided assistance. Experts included college professors, scientists, graduate students, and elementary and public school teachers. Forms of mediation included statements of knowledge and facts, explanation of concepts, feedback and critique, suggestions, and collaboration. Experts provided assistance when commenting of designs, answering questions, or participating in problem solving discussions.

Scientific Practice as Problem Locating

One of the most pervasive forms of assistance occurred when experts located problems in the novices' designs and solutions. Experts noticed problems that stemmed from a lack of knowledge about zero-g conditions and the design of spacecraft. Experts also informed novices when their designs or solutions would not perform as anticipated, would create new problems, or did not address their intended goals.

One problem experts pointed out to novices was that their zero-g designs did not address the goals set forth by the project director. For example, one of the goals of the recreation challenge was to provide physical exercise for astronauts. Many of the students' zero-g designs emphasized the entertainment aspect of recreational activities, rather than physical exercise. In the following message excerpt, an expert responded to a series of game designs by a team of second grade students, all using Velcro, which functioned to prevent them from moving in "free fall" (or floating). Since one of the goals of the project was to provide astronauts with exercise, the expert suggested that the students design a game which enabled the astronauts to exercise their legs. The expert informed the students of the fact that astronauts get ample upper body exercise, but have little opportunity to exercise their legs. Using this knowledge, she suggested that the students reconsider the goal of their design.

Student design:

VELCRO VOLCANO is played by standing in a Velcro suit waiting for the volcano to erupt. When it does, Velcro balls come out each worth a different amount of points. When attached you score points.

Expert's feedback:

One of the problems that the astronauts experience in space is that their legs do not get enough exercise. They use their arms a lot, so they really do not have too many problems with losing their arm muscles. It's their leg muscles that they have to worry about. The exercises that they now do have them strapped down in a row machine or on a stationary bicycle. Some of the exercises need to focus on the leg muscles. Maybe there is some way to get your legs moving more in this game.

It was not unusual for novice designs to not fully take into account a zero-g environment, tacitly assuming features of their gravity environment in their designs. This resulted in an inconsistent

> environment, in which some aspects of the design assumed gravity while others did not. The following message responded to a zero-g musical chairs game which was designed by a team of elementary schools students. The expert pointed out that chairs themselves would not be as useful in a zero-g environment as they are on earth.
>
> MUSICAL CHAIRS: in Skylab, they had a table and chairs. One of the first things they discovered was that chairs were worse than useless, and they unbolted them and threw them into a storage closet. In zero-g, your relaxed position is one that is sort of half way between being upright and sitting down. To actually sit in a chair takes effort. It is much easier just to float at a table, "sitting" in mid air! So while you might have a game sort of like musical chairs where people jockey for a decreasing number of "bases", the notion of "chair" may be as meaningless as that of a buggy whip, a razor strop, or a candle snuffer for us today.

The notion that chairs would not be useful in zero-g implies that gravity is a force which pulls one toward the earth, and the chair functions, in part, because it is an obstacle between a human and the earth. This, however, is not explicitly stated in the message. The focus is on the design of the game. This is common in many of the messages analyzed in this study, in that concepts are indexed by knowledge and facts expressed by the experts, but often the concept itself, or an elaborated explanation of the concept is not produced.

The Collision Course Challenge elicited a number of solutions that would not have been feasible aboard a present day spacecraft. This message responds to a solution offered by a group of second graders, who proposed that astronauts guide themselves in zero-g by grabbing on to handles fastened to interior of a spacecraft. The expert informed the students of the risks of reaching out to grab onto handles aboard a spacecraft. In addressing the students' design, the expert does not dispute the possibility that their solution would work, but describes the environment in which the solution would be implemented, which challenges the effectiveness of their solution.

> Although it's possible to grab onto handles, you'd have to be careful not to grab onto other things that would be along the way, like scientific instruments, power switches, and other things. What if there was no locker handle to grab onto at the time when you needed it?

Occasionally, novice designs reflected a lack of knowledge of the constraints and costs of sending materials into space. This message addresses this problem. The students asked if dinnerware could be washed and "recycled" aboard spaceflights (currently dinnerware is disposed of after one use). The expert responded by drawing the students' attention to the amount of water required for recycling, and the practicality of transporting that amount into space.

> I can't imagine that the quantities of water required to "recycle" dinnerware during a mission would make this idea very plausible. I'm sure that between wash and rinse water, the quantities would be impractical to take up with the shuttle. Also, I don't think that you could synthesize water up there very practically.

Experts' knowledge in a particular domain enabled them to locate problems unforeseen by novices. More importantly, experts revealed to novices that detecting problems was as much a part of the process as formulating solutions.

Contextual Knowledge and Knowledge as Context

The network messages constituted a broad body of knowledge, situated in concrete examples and instances of space habitats and the living conditions. This body of knowledge included facts and concepts related to space travel and technology, including the architecture, design, and materials used to construct spacecraft. Network experts also attempted to explain how and why the movement of objects and people in zero-g differed from that on earth.

This message responded to a suggestion that magnets be used to avoid the problem of "floating around" aboard a spacecraft. The author, an aerospace scientist, explained the unfeasibility of using magnets on a spacecraft. In doing so, she provided information about the design and constraints of space station architecture.

> Also realize that there will be no halls per se on the space station. There will be equipment just about everywhere, even in the nodes. This is because the modules are so expensive that all space must be utilized. Thus halls and corridors will double as work places.

The expert directed the student to reflect upon his solution by describing an actual space module. The phrase "also realize" points to presupposed knowledge that there are no empty halls in today's space vehicles, but modules filled with sensitive equipment. Providing this knowledge alters the problem space in which the student constructed his design.

The Collision Course Challenge, reported above, motivated a variety of solutions aimed at controlling human movement in zero-g. One participant suggested that a conveyer belt be used to move people through a space station. A university professor responded to this idea by uncovering some of the implicit assumptions embedded in this design. The expert explained that in zero gravity, mechanical locomotion would be unnecessary, since according to Newton' s first law of motion, an object in motion would continue to move until they encountered an obstacle.

> The idea of a conveyer belt in the middle of a hall is sort of like a ski tow rope. But I' m not sure why it needs to be moving. As long as the astronauts can push off on it, they don' t need to be pulled along, since they' ll keep moving once they push off of it. If it were moving, it would be hard for the astronauts to also use it to stop.

The expert begins by drawing an analogy between a conveyer belt and a ski tow, a more conventional means of moving people. Then the expert writes "But I' m not sure why it needs to be moving", directing the student' s attention to reflect on a problem with her design. The expert attempts to fill the knowledge gap by explaining Newton' s first law of motion, that astronauts would keep moving once they push off making a moving conveyer unnecessary. The final sentence "If it were moving, it would be hard for the astronauts to also use it to stop." reiterates the implied concept by explaining that astronauts holding on to a moving conveyer would find it harder to stop.

The project generated a range of questions about space and the nature of a zero gravity environment. This message excerpt responded to a question about how a zero gravity environment would affect the movement of objects with different masses — a nerf ball and a bowling ball. The expert explains that air resistance would affect the two objects differently, causing the nerf ball to slow down more quickly.

> If you threw the two balls with equal force for an equal time, they would not end up moving at equal velocity. Instead the bowling ball would end up moving much more slowly than the nerf ball. Another factor is air resistance — the nerf ball would start out flying quickly through the air, but since it is so light for its size, it wouldn't go very far before stopping because it would have a lot of air resistance compared to its mass. The bowling ball, on the other hand, would keep moving until it hit a wall (or a person, etc.), because it has much more mass.

These messages illustrate the nature of knowledge in scientific endeavors — applied knowledge becomes the context. In these messages, experts applied knowledge to assist novices in solving the problems set forth in the challenges. Once the knowledge is applied, it becomes part of the context. Knowing how spacecraft are designed and understanding the first law of motion as it is applied to a zero-g environment becomes background knowledge constraining further designs.

Understanding Scientific Concepts

Throughout the course of the project, experts provided explanations and definitions of scientific concepts and applied these concepts to problems. Experts explicitly discussed concepts when novices requested knowledge or when their designs and solutions indicated misconceptions. In this message, the expert answered an elementary school student who asked the question, "How does gravity hold you down?"

> The theory of gravity says that any object attracts all the others (in the universe!) toward it. The bigger the object, the stronger the attraction. But the further away the object, the weaker the attraction. So, since we're close to the earth (we're standing on it, usually), and since the earth is REALLY large (compared to us), it pulls us down.

One student responding to the food design challenge designed a container "that could hold gravity". An expert responding to this message addressed implicit assumptions in this design, particularly that gravity was not a substance but a force. In this message, the expert responded to the student by defining gravity.

> Gravity is one of the four fundamental forces which scientists have discovered are responsible for our universe behaving as it does. It is a basic property of all matter which causes the matter to have an attractive force. All objects have this force and so attract one another to some small extent. We usually think of the gravity associated with the earth and maybe the solar system, but we don't often think of gravity affecting smaller objects but it does ... just in a smaller way. In fact, the law of gravity tells us that all objects possess gravity and the larger the object the larger is the gravitational force of the object.

Scientific concepts and social languages

Experts participating in the Zero-g Project constituted a diverse community professionals each contributing knowledge and practices of their respective social environments. This diverse group expressed themselves through a variety of social languages. Bakhtin (1986) defined social languages as "peculiar to a specific stratum of society ... within a given social system at a given time" (Holquist & Emerson, 1981, p.430). Wertch (1991) has argued that social languages "provide an essential construct in a sociocultural approach for connecting intramental functioning with social life as organized by institutional, cultural, and historical forces" (Wertsch, J.V.; Tulviste, P.; & Hagstrom, F.; p.346, 1993). This diversity in social languages is illustrated in the following example in which a fifth grader sent a question over the network asking whether a tennis ball would go faster or slower when thrown in zero-g than on earth. The student received three responses written in different language registers:

First response:

> In space, there is no atmosphere or air to slow the ball down and the gravitational force would probably be weak (depending on what is near the ball when it is struck), so these counter-forces wouldn' t be the same as the ones which would apply on earth. So, while the ball would not necessarily travel any faster in space, it would hold on to the speed it had much longer than a ball on earth. In other words, it wouldn' t slow down as fast.

This response expresses scientific concepts in a non-technical, everyday language. The word "atmosphere" is paraphrased by the word "air". The phrases "slow down", "weak", "travel faster", "hold on to the speed" are used to express changes in velocity and forces that affect these changes. Everyday language is particularly apparent in the phrase "it wouldn't slow down as fast", which attempts to explain succinctly the effect of zero-g on a moving tennis ball.

> Second response:
> If you could throw the ball as hard as on earth it would go the same velocity if the air pressure in the space station were the same. The space shuttle has the same air pressure as on earth so the ball will travel at the same velocity in it. However, the Apollo space craft had an air pressure at about 1/3 that of on earth, so if the ball could travel very far (which it couldn't because the space craft was so small) it would slow down much slower.

The second response contains everyday language as well as a technical register commonly found in science textbooks. The non-technical phrases "as hard as", "the same", "slow down", "much slower" are used to express the concepts of force and change in velocity. This message also contains the science terms "velocity" and "air pressure", which are representative of science literacy at the secondary school level.

> Third response:
> Neither! F=ma both on Earth and in space. Assuming that atmospheric pressure in a space station is the same as on Earth, and that "wind resistance" is equal, the tennis ball will go only as fast as the force imposed on it will allow. The mass of the tennis ball is the same in both environments, i.e., v=Fxtxt/m.

This message contains very little everyday language to express scientific concepts. The register is representative of a high school or college physics textbook, incorporating both discourse and scientific equations. The phrases "atmospheric pressure", "wind resistance", "is equal", "force imposed", and "mass" are used to explain the effect that gravity would have on the tennis ball. In contrast to the previous two messages, the equations "F=ma" and "v=Fxtxt/m" express scientific laws, the underlying reasons for the phenomena.

Directing Student to the Source of knowledge

Experts also provided assistance by directing novices to information sources. Experts directed participants to books, and resources provided by the Zero-g project coordinators or available on the Internet. One widely used resource was a video tape, titled the Free-Fall Video Tape, in which astronauts could be seen working and moving in the space shuttle and Skylab, both Zero-g environments. Copies of this tape were provided to the participating sites. It tape became a useful point of reference when responding to questions and designs. In this message excerpt, the project director responds to two students who proposed a Zero-g lunchroom design. The message directs the students to view the eating facilities shown in the Free-Fall video tape.

> I'm glad you tackled the design of lunchrooms. In Skylab, they had tables to eat on, but in the Space Shuttle they ate with no tables (see the Free-fall Video Tape, 7:55-8:36), just floated in a sort of hallway with trays that clipped to their legs that held the various food packets. Which do you think worked better?

In one of the Zero-g project challenges, students were asked to list differences between Zero-g and conventional earth schools. Students wrote that going to the bathroom would be different in a zero-g environment. The project director sent this message to the Zero-g conference, directing the participants to a book which addressed this issue as well as other living design problems in space.

Both lists mentioned that bathrooms would be quite different. One of my favorite books on space is a paperback by William Pogue, an American astronaut who spent 84 days in space, called "How do you go to the bathroom in space?" The book contains the most frequent questions he was asked when giving talks on space, and he says that the most frequent question was: "How do you go to the bathroom in space?" I recommend that you look at his book (Tor Books, 1991, $5.99) for the answers (there were several techniques — my brief summary of his answers is "with difficulty").

Requesting Cognitive Action

Most if not all messages to students in the Zero-g Project either implied or explicitly asked novices to carry out cognitive actions. Experts asked novices to think, solve problems, perform experiments, seek knowledge, and give examples. In the first message excerpt, the author first gives the reader one example of how gravity effects our universe. Then the author asks the reader to provide additional examples of the effects of gravity.

First message:

Gravity plays an important part in the universe. The sun, for example, has gravity. The gravitational force on the sun is what keeps the planets rotating in an orbit around the sun. These are just some examples of the effects of gravity. Can you think of others?

In the second message the expert answers a novice who asked how astronauts find their way home from space. In doing so, the expert attempted to build a bridge between the student's background knowledge and space navigation. The expert guides the novice on a mental excursion seeking a path from her house to school, then explains that astronauts perform a similar task when finding their way back to earth.

Second message:
In space they have special navigation instruments to find your way around. Think about how you find your way to school each day. Can you see the school from your house? If not, you must walk down one street, turn in some direction, then walk some more until you find your school. Astronauts do similar things except they travel longer distances.

In the following message, the expert assists a group of students in designing a space station library. The expert restructured the problem by proposing that books need not be stored and used in the same form that they are on earth. The expert then asked the students to think of other forms books can take for space transportation then offers help in solving the problem.

Third message:
Can you think of any other way that the books might be transported

> to space. Is there some way to send them? In their hard back form they could weigh a lot. What other form could they be put in. If you would like suggestions we can try to come up with some alternatives.

Inculcating Scientific Practices

Another mediation strategy employed in the messages was applying scientific practices to solve a specific problem or achieve a goal. These practices included logical thinking, consideration of all relevant information, obstacles and problems, and testing hypothesis. This message is a response to the student who proposed blocking magnetic force with a lead plate. The author of the message proposed that the student conduct an experiment to test his hypothesis.

> Here's a key thought that will apply here and to other situations. To check out ideas such as this try a little experiment. That's what science is all about! You'll need a strong magnet, a paper clip, a piece of sheet lead and some cardboard of similar thickness. Place the cardboard between the magnet and the paper clip. Now do the same, replacing the cardboard with the lead. Is their any difference. Try the same thing using a sheet of steel. Remember — scientists check ideas by trying them out. You can talk and speculate about ideas like this forever. But without experimental confirmation, it's not science, its science fiction!

In this message, the author describes in detail how to conduct the experiment, in which the students tests several substances for their ability to block magnetism. The text "Here's a key thought that will apply here and to other situations. To check out ideas such as this try a little experiment." attempts to teach the student that this is not only a course of action for this specific problem but also a general practice central to scientific exploration and hypotheses testing.

Mediation as Communication

Pedagogical communication is always problematic, particularly so when using computer network message systems. There is no immediate shared context, no access to gestures, facial expressions, and tone of voice. In many cases, the interlocutors have little or no mutual personal history, and can only guess at what background knowledge they share. Even constrained by these limitations, communication occurs. What is required are strategies to communicate meaning and the construction of a mutual context. As reported above, the Zero-g Project provided functional tasks to serve as communicative contexts. The following section, I will report several communication strategies experts used to provide effective assistance to other participants.

Using Examples

The Zero-g Project motivated the exploration of scientific concepts as they are applied to specific problems and instances. This led to the widespread use of examples as a vehicle for communicating difficult concepts. The following two message extracts illustrate this. Both of these messages address the problem of what happens to objects after a force is applied. In both cases, the designs implied to the expert that the students held misconceptions about the nature of zero-g and its effect on objects in motion. Also, in both these messages, as was the case in many messages, the students provided the example as a context, enabling the expert to assist the students within that context.

In these two messages, the expert provides examples of Newton's first law of motion. The first message is a response, to students who had designed a zero-g baseball game in which a tube was required to guide the trajectory of the ball. The expert comments that such a tube would be unnecessary, since the ball would travel in the direction it was thrown. The second message is a response to students who had designed a basketball game which implied that spinning around repeatedly would be challenging in zero-g.

> First message:
> Why would you need a tube to get the ball to the batter? It would be easy to throw a ball straight to a batter, since it wouldn't fall down along the way but would go straight in the direction it was thrown.

> Second message:
> To the designers of the Super Slam Dunk Challenge: Since you don't fall in zero-g, you could spin forever before you push the ball through the hoop. So a 720 spin wouldn't be much of a challenge — you could do a spin that took you around 720 times if you had the patience. What kinds of tricks could you think of that would be a challenge to players in zero-g?

In this next message, the expert uses the example of dribbling a basketball in zero-g to illustrate Newton's third law of motion.

> What happens if you "dribble" a ball in zero-g? Well, if you're in a room and throw a ball, you'll move in the opposite direction

(that' s how rockets work-Newton' s 3rd law). The ball bounces, and then comes back to you and you catch it. Then you move even faster in that same direction (when you catch the ball, it transfers its momentum to you). So dribbling is a way to go from being stationary in a zero-g room to moving across it to the other side. So, if you were going down a hall on a collision course with someone coming toward you and you had a ball with you, you could "dribble" your way to the side (throw the ball out sideways and catch it after it rebounds off the side wall), then "dribble" you way back to being in the middle again (throw it in the other direction and catch it)!

The message begins by constructing a scene in which some dribbles a basketball in a room. The message states that if a person threw a basketball "you' ll move in the opposite direction", as an example of Newton' s third law. Then, the writer continues, "The ball bounces, and then comes back to you and you catch it. Then you move even faster in that same direction (when you catch the ball, it transfers its momentum to you)". This example illustrates Newton' s second law, that a ball in motion will transfer its momentum to someone who catches the ball.

Linking Author and Reader Ideas

Message authors typically made attempts to link ideas expressed in messages by other participants to those expressed in their own responses. In these responses, the author typically briefly referred to another participant' s ideas at the beginning of the message, then continue by addressing those ideas.

One device for this type of response was to insert text from the message being addressed into the message response. In this example, the author responded to a solution to the Collision Course challenge mentioned above. In the solution, sent by a group of second graders, the students propose that kicking one' s feet would enable the person to change their direction. However, they did not clearly describe how the body would move as a result of kicking which would in turn cause a person to change their course of movement. In the response, the expert appropriates the proposal of kicking ones feet, then proceeds to explain what effect this would have.

> Student solution:
> You could kick with your feet to change your course and go around them.
>
> Response:
> Kicking your feet would rotate you. If you weren' t on an exact collision force, if you both rotated at exactly the right time, you could get by each other.

Second message

In this message exchange, the expert refers to the novice' s expressions, “shapes of rooms in the spaceship, that are the most easy to facilitate movement in” with the expression “using different shapes of rooms to help you move”. The expert refers to the expression “hexagon or octagon shaped room” with the expression “walls not perpendicular to your direction of movement, like most hallways here on earth. If there were surfaces at an angle to your direction of movement." By using similar or identical language to refer to the novice message, the expert attempts to construct a response which is a continuation of the novices point of view. The expert's response, following the novices message, elaborates on the consequences of different shaped rooms and how rooms could be constructed so that different shapes would provide a useful means of movement.

Student message:
I want to know if you've done any research on the shapes of rooms in the spaceship, that are the most easy to facilitate movement in. I mean would it be easier to move around in an hexagon or octagon shaped room than in a square room. I would really appreciate your response and a few suggestions for problems that need to be solved.

Expert's message:
One nice point you've made is the possibility of using different shapes of rooms to help you move. There would be a big advantage to having a hallway with walls not perpendicular to your direction of movement, like most hallways here on earth. If there were surfaces at an angle to your direction of movement, you could push on them to speed up, to slow yourself, and to turn corners.

Refer to experience

Explaining complex scientific concepts thorough textual network message exchanges does not allow for the use of gestures or a mutually perceptible physical environment to illustrate abstract knowledge.

One strategy used to provide concrete, real-life contexts to assist the understanding of abstract ideas was to refer to the reader's experience. In the following message exchange, a group of students asked why objects that are thrown in zero gravity appear to move slower than those thrown on earth. In attempting to explain the perceived difference, the author asks the reader to refer to their experience when ice skating (in fact, the author has no basis to assume that the students have ice skated). The author asks the students to consider how difficult it is to throw and catch objects the first time on ice, then asks them to extend that experience to attempting this in zero- gravity.

> Students' questions:
> In the video we observed the paper airplane and food being thrown. Neither seemed to reach the speed that similar thrusts would yield on earth. Is it because the astronauts weren't throwing too hard or is that just the way things get propelled forward from human effort in zero-g?
>
> There are probably several reasons for this. I think the main one is that the astronauts were not very experienced with living in zero-g. Think of how you behaved when you first got out onto the ice with ice skates. Think about trying to play a game of catch during your first time out on the ice. Anyone watching would think that things move more slowly on the ice than on the ground. Now on the other hard, imagine watching a professional ice hockey game. You would draw exactly the opposite conclusion. My guess is that once people have spent a long time in zero-g,

then they would throw and catch things with astonishing (to us) rapidity and accuracy. Astronauts routinely report that throwing and catching is a problem because they automatically take into account gravity, and so throw too high and try to catch too low!

Analogy

Analogy was used to explain difficult and abstract concepts to the elementary school and high school network project participants. In this next message, the author makes an analogy between the pull of gravity, an invisible force, and the physical pull of a friend, a concrete example.

> First message:
> First of all, gravity is a force that attracts things to each other. You can think of a force as someone or something trying to pull you. Say for example a friend is in a swimming pool and she takes your hand and pulls you into the water. She is forcing you into the pool. We have gravity on earth. One way to think about gravity on earth is something inside the earth holding or forcing you to the ground. This is why people walk instead of fly through the air (without an airplane). If you throw a ball in the air, it is gravity that makes the ball fall to the ground.

Use of Imagery to Explain Scientific Concepts

Applied linguists have argued that imagery is an effective means of communicating ideas and concepts (Tannen, 1989). Tannen argues that images involve the listener or reader in the communicative exchange and through the construction of details enabling the creation of a mental image. By communicating through images, the reader and writer are able to share memories and scenes allowing them to engage in recognizable activities.

The construction of verbal images was essential to the Zero-g Project. At the time of the project, most sites were unable to send graphics, so verbal images carried the burden for describing the designs and zero-g settings. Much of the feedback relied on descriptive images, rather than explicit conceptual explanations. These three messages illustrate how images were constructed to mediate novices' understanding of zero-g related concepts.

In the first message, the expert responded to an idea for eating a pie in zero-g. The novice wrote "If I was in space and I needed to eat a piece of pie I would use a dull knife because if you lost control of the knife you wouldn't get cut. Then I would just flip in into the air and eat it. You couldn't bake it in a bowl or a pan because it wouldn't stay in it".

The expert inferred that the novice had not fully understood how adhesion would not be affected in zero-g. Also, the expert inferred that the novice had not fully understood that zero-g meant less force attracting a knife. The expert uses images of pie crusts sticking to pans, pie crust tops, sticky pie fillings, and dropping knives to illustrate his point, rather than engaging in an explanation of adhesion, forces and gravity.

First message:

You raise some interesting issues about how to bake and eat a pie in zero-g. If the pie crust stuck to the pie pan to some extent, that would keep it in the pan. And if it had a pie crust top,

> that would keep the contents inside the pie. So I think that standard pies with pie crust tops would work in zero-g, assuming your oven had a way of holding onto the pie pan. As far as dull vs. sharp knives, don't we have the same problem here — the danger of dropping a sharp knife is here is worse than the problem of losing control of one in zero-g. Yet we deal with it enough to continue to use sharp knives. Something as sticky as pies and their fillings would probably not be too hard to eat in zero-g, but if it made crumbs, you'd have to worry about them floating around in the air currents — a mini-vac might have to be placed at each place setting instead of a napkin!

In the following message, the expert responded to a novice solution to the collision problem. The novice suggested that motion could be achieved by moving the arms in a swimming motion. The expert challenged the notion that swimming through the air was possible in zero-g by constructing a scene of attempting to move on slippery ice using swimming movements. At the end of the message, the expert mentions using a cape, inviting the novice to consider how this would affect the ability of locomotion.

> Have you ever tried "swimming" through the air when you were on slippery ice? If your experience is like mine, you didn't move very far. Air is much thinner than water, so swimming with your arms wouldn't move you anywhere very quickly. Perhaps if you wore a cape?

In the next message, the expert responded to a question asking about the nature of gravity. The expert constructed a scene in which the novice is asked to imagine standing next to a friend, the sun, and Jupiter.

> If you're standing close to a friend, is the force on you bigger or smaller due to gravity than the attraction that the moon has on you? How about your friend vs. the sun? Your friend vs. Jupiter? I don't know of any way to directly measure to answer this question, so I'll try to carry out the calculations to answer these (and other) "heavy" questions!

Conclusion

The analysis of these messages reveals multiple levels of mediation written into each message. These levels each mediate different forms of knowledge, both conceptual and social. The messages themselves should be viewed as a whole representation of the respective communities of each expert participant. However, this whole is comprised of rules, norms, assumed knowledge, and conventional forms of communication, represented by the messages.

One level mediated by the messages is functional in nature. The experts attempted to provide some functional mediation to the novices to assist them in achieving their stated goals. At a functional level, these messages answered questions, solved and located problems, offered advice, and suggested improvements in novice designs. It is at this functional level that the knowledge expressed in these message was applied and judged for their usefulness.

At another level, messages were epistemic in nature, mediating the knowledge of the novices. Experts provided facts, explained concepts, corrected misconceptions, located and filled in knowledge gaps, and directed novices to knowledge sources. In most cases, epistemic mediation occurred in service of functional mediation, however, while functional mediation was expressed in a specific instance, like designing a game, epistemic mediation is more abstract, like defining gravity. Intersubjectivity was attempted in many cases by experts uncovering implicit knowledge suggested by novices' designs and solutions to problems. Making the implicit explicit not only revealed hidden thought processes of the experts, but also of novices. Also, epistemic mediation was indexed by the text, for example, explaining that letting go of a knife in zero-g would not be as dangerous as on earth, indexes the Newton's second law, but does not explicitly state it.

A third level of mediation is semiotic in nature. Semiotic mediation fulfills two functions, one, making knowledge accessible to novices, through the use of examples, metaphor, and imagery. And secondly, by educating the student in the linguistic, rhetorical, and epistemic norms of scientific social language or languages. Descriptions of balls flying through the air, equations, cause and effect sequences, logical arguments, assertions with supporting arguments, stating hypothesis, and speculating, are all within the scope of scientific discourse expressed in these messages.

A fourth and subtler level is affective in nature. Each message carries a distinctive tone. Message can be interpreted as expressing praise or criticism, tolerance or intolerance, help or impatience. These messages often praised novices, offered help, but as is often characteristic in science, did not accept or tolerate a violation of truth. Falsehoods and inadequate knowledge were not accepted but instead were corrected.

These messages provide a wide spectrum of mediation within the context of a scientific/pedagogical endeavor. The promise often offered of network communication, of multiple perspectives from the variety of participants, is demonstrated here, as well as conventions of the scientific community. The problem facing these experts is to construct a context, or mutually construct a context, in which novices can participate and will weave together the ideas and knowledge of all participants. These contexts are often concrete descriptions of specific instances as in a description of a zero-g baseball game or ice skating, that serve to construct abstract principles of science.

These specific, concrete instances and examples also provided experts with evidence of the novices' states of knowledge. By attempting to understand the thought processes underlying novices' designs and solutions to problems, experts inferred what the students believed and conceptions they held.

Through participation in the Zero-g project, experts and novices collaborated to construct workable designs and solutions. Through this collaboration process, experts were able to attain a glimpse of the novices thought processes, and what assistance would be useful. Expert assistance came in the form of explicit teaching of concepts, but more often, assistance was directed through the work novices created.

References

Levin, J. (1990, April). *Teleapprenticeships in globally distributed electronic network*. Paper presented at the Annual Meetings of the American Educational Research Association, Boston MA.

Mediating Through Messages: Expert Knowledge in a Teleapprenticeship Project

Raoul CERVANTES

The development of computer networking technology has enabled the conventional classroom to participate in learning communities extending beyond classroom walls. These learning communities make possible the types of environments advocated in recent theories of situated learning, particularly the cognitive apprenticeship model. The cognitive apprenticeship model enables novices to learn conceptual and factual knowledge as it is applied to real problems and complex tasks in a variety of contexts. Within this practice, experts externalize and make explicit processes that are usually carried out internally. As a result, novices acquire a web of skills, practices and knowledge, available in various contexts.

Little is known about the nature of network pedagogical communication and how experts interact with novices. Network communication often lacks the history of face-to-face communication between teachers and students in which understandings of common knowledge would develop. In addition, there is no immediate mutual context to assist verbal communication. Experts and novices attempting to provide assistance through a network message must mutually construct the context in which communication occurs.

Given the limitations of network communication mentioned above, how do participants communicating through network messages construct a common focus of attention and shared presuppositions? This study explores how contexts of learning are constructed and how assistance is provided within these contexts.