RECOGNIZING AND RESPONDING TO STUDENT PLANS IN AN INTELLIGENT TUTORING SYSTEM: CIRCSIM-TUTOR

BY

FARHANA SHAH

Submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy in Computer Science
in the Graduate College of the
Illinois Institute of Technology

Approved _____
Advisor

Chicago, Illinois
July 1997

ACKNOWLEDGMENT

This thesis emerged as the fruit of labor and an unwavering determination to step down or back. In the process I experienced the loss of many flowers. What we lose in flowers, we may gain in fruit. With this belief I did not remove my gaze from my goals and my commitment to integrity, trust, values and ideas.

It is said that behind the success of every man there is a hand of a woman. Let me add the word woman and restate that behind the success of every woman and man, there is a hand of a woman. Professor Martha Evens has been a ray of hope and great source of understanding and encouragement. I am grateful to her for the time, considerable energy, creativity, and positive suggestions, she has invested in me. Her helpful spirit has helped me do what could have been impossible otherwise.

I feel proud of my children Sher, Portia, and Babar for being so supportive and understanding. I love their fine elements. Especially the role performed by Babar in such an unpleasant and unfavorable state has been commendable. I had been trying to recuperate from the abnormal and unnatural situation, and there were moments when I found it hard to keep myself stable at the pivot of motherhood and authorship. Our geographical separation was a test and tough experience for both of us.

I acknowledge a number of useful suggestions and feedback received from Dr. Joel Michael and Dr. Allen Rovick. My thanks are due to Dr. Charles Merbitz, for his helpful discussions. I appreciate the nice job of classification done by Stefan Brandle and Bruce Mill. I also heartily thank Drs. Cynthia Hood, Chow Lam, Ilene Burnstein, and of course Martha Evens for serving on my dissertation committee.

Life appeared sometimes like a glass half full and other times like that half empty. On occasion, it would remind me of the stories of the Ugly Duckling and Cinderella in the sense that one had to go through tough time due to misrecognition and the other had trials due to negative forces around. But amazingly…

I am thankful to all those unforeseen forces which unexpectedly would appear and assist me to beat the odds. The tussle between quality life and survival has brought me to the point where I am thinking is it worth what my children and I have experienced and what we have or don't have as a result? Yes, indeed!!! The essential thing is the struggle–fighting well.

Finally, I am indebted to Government of Pakistan for the award of a scholarship to achieve my academic goal. Humble Gratitude!

F.S.

TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

ABSTRACT

The focus of this research is to analyze the ingredients in recognizing and responding to student plans in an intelligent tutoring system called CIRCSIM-Tutor. It is necessary to understand student plans in order to formulate appropriate responses. It happens occasionally that the student attempts to change the course of dialogue by asking a question, or by giving a self explanation, or by taking some other action different from giving an expected answer. We call any action of this kind a student initiative. The tutor is obliged to respond to student initiatives. We call this reaction a tutor response.

We began by analyzing keyboard-to-keyboard transcripts of human tutoring sessions to understand the issues regarding natural language interaction. We introduced a new classification of student initiatives and tutor responses. The student initiatives are classified with respect to four dimensions: surface form, communicative goal, focus of attention, and degree of certainty. The tutor responses are classified along three dimensions: surface form, communicative goal, and delivery mode. We have confirmed the validity of these categorization schemes with inter-rater reliability studies.

We have identified eight communicative goals in student initiatives and ten in the tutor responses. Some of the student goals are: request for information, request for confirmation, and conversational repair. Some of the tutor goals are: explanation, acknowledgment, conversational repair, and teaching the problem solving algorithm. Using the chi-square test, we have found significant dependency relationships between some initiative-response pairs including (request for confirmation, acknowledgment), (conversational repair, conversational repair) and (request for information, explanation).

In order to detect whether the student input is an answer or an initiative, we need to understand the student plan. We are convinced by Carberry's claim that to achieve this behavior, it is necessary for a system to recognize and reason about the goals and plans motivating its human user. Sometimes the presence of certain clue words give enough information about the communicative moves. At other times the context of the each initiative is needed to identify the goal related to the student plan. We have identified some clue words to aid in recognition of the discourse goals.

CHAPTER I

INTRODUCTION

1.1 Overview

CIRCSIM-Tutor is an intelligent tutoring system for cardiovascular physiology with a natural language interface. This system is intended to provide a first year medical student with an interactive learning experience. Important subgoals include teaching problem solving as a causal reasoning task, teaching the sublanguage of cardiovascular physiology so that students can express these new ideas correctly, prompting students for self-explanation, and making students feel comfortable with the keyboard and screen environment.

We cannot make a machine tutor that can replace a human tutor, but we can try to make one that works the way a human tutor does. We study human-to-human keyboard sessions as our major source of ideas for system design. In these sessions, the student spends most of the time answering questions from the tutor, but occasionally the student tries to alter the flow of discourse and take control of the session by typing something other than an appropriate answer to the tutor's question. Any contribution by the student that attempts to change the course of the session, is called a "student initiative." We are convinced that the recognition of initiatives depends on identification of student plans.

My goal is to design a module capable of understanding the student plan in order to recognize student initiatives, and to generate more appropriate tutor responses. My work is based mainly on analysis of human tutoring sessions. The analysis of naturally

occurring dialogues indicates that in a fruitful conversation it is essential that the participants understand each other's utterances and believe that their responses are being understood. I have been involved in trying to understand some basic questions. What kinds of plans do students make? How does the tutor plan a response or develop a goal in the tutoring session? How can we characterize the intention of the student and the expectation of the tutor participating in the tutorial dialogue?

I strongly agree with Pollack [1987] that instead of enforcing a number of restrictions on allowed student input that limit the ability of the system and add an unrealistic touch to it, the tutoring system must be able to detect the student's misconceptions and recognize the user's plans whether valid or invalid. She identified the assumptions underlying previous plan inference systems, and proposed a different approach to plan recognition. She emphasizes the importance of the ability of the system to reason about the validity of user plans that are not explicitly represented in the system's plan library. These are important problems underlying text understanding and text generation in a robust intelligent tutoring system.

I looked at critical issues found in the design of the current running member (CIRCSIM-Tutor v.2) of the CIRCSIM-Tutor family, and explored the aspects that influence smooth, interactive human/machine discourse. Whenever the student takes any initiative that violates the system's view of the domain, the system is unable to understand; it either responds with "I'm sorry I don't understand you. Please rephrase." or crashes. I find this very unsatisfactory. This led me to the classification of student initiatives and tutor responses in transcripts of human tutoring sessions by examining the interaction between them. We have classified student initiatives in terms of four

dimensions: the surface form, the communicative goal, the content area, and the degree of certainty expressed (Does the student hedge or not?). The tutor responses are classified in three dimensions: the surface form, the delivery mode, and the communicative goal. My analysis of student initiatives and tutor responses represents a stepping-stone on the path to mixed-initiative dialogue in our system.

We have identified eight communicative goals in student initiatives and ten in the tutor responses. The student goals are: request for information, request for confirmation, inability to answer/time delay, challenge, support, conversational repair, and other. The tutor goals are: explanation, acknowledgment, help in response to pause, instruction in the rules of the game, probing the student's inference process, teaching the problem solving algorithm, teaching the sublanguage, brushing off, conversational repair, and summary. Inter-rater reliability studies described in a later chapter have confirmed the validity of these categorization schemes. Using the chi-square test, we have found significant dependency relationships between some initiative-response pairs including (request for confirmation, acknowledgment), (conversational repair, conversational repair), (request for information, explanation), and (pause, help in response to pause).

1.2 Mixed-Initiative Tutoring

A good learning environment in which the learner is an active participant, rather than a passive observer or receiver, can break the monotony of passive learning and the students will find the session to be a more interesting and satisfying learning experience [Hume, 1995]. Active learning promotes the acquisition of problem solving skills. Much

learning that goes on in the real world occurs through interacting and collaborating with others [Preece et al., 1994, p. 170].

In a mixed-initiative interaction, direction and control of the action shifts between the tutor and the student. The information and abilities needed to solve a problem are shared and distributed between the participants. My research work on understanding the student plan is an essential step in preparing CIRCSIM-Tutor to take part in mixed-initiative dialogues.

In the human-to-human keyboard sessions that we have studied, student initiatives were found to be of various types and natures. Most of them are either simple questions or explanations by the student followed by requests for confirmation. For example, in saying "But I'll bet that's not right…" the student is asking for confirmation implicitly, i.e., asking whether what the student is thinking is right or wrong. Let me illustrate it with a somewhat different excerpt from the transcript obtained from keyboard-to-keyboard session number one.

EX. 1.1.

K1-tu-26-2: Why would there be an increased amount of blood coming into it?
K1-st-27-1: I guess there would not be increased RAP, but would the TPR increase because of the increased CO?
K1-tu-28-1: Were dealing now with the DR period.
K1-tu-28-2: That's before there are any neural, reflex changes.
K1-tu-28-3: The TPR is neurally controlled.
K1-tu-28-4: So what do you think would happen to it?
K1-st-29-1: During the DR period it would remain unchanged.
K1-tu-30-1: Correct.

The student is unsure that his explanation is correct and is expressing uncertainty producing a hedged answer followed by a question. The question hides a request for confirmation about the causal relation. The tutor sees that request and also recognizes that the student is forgetting the phase of problem solving. He teaches the problem solving algorithm by guiding the student through the solution.

When these concepts are developed in CIRCSIM-Tutor, these communicative goals will be defined in the planning system as operators. The operators will have the effect that the tutor believes that the student is requesting confirmation of her theory.

Any tutor, machine or human, needs to distinguish student initiatives from student answers to tutor questions. Furthermore, we need to recognize whether an initiative taken by the student is a request for an explanation, or clarification, or repair, or a request for confirmation. The tutors' responses to students' initiatives change with the nature of the initiative and the tutor's perception of the student. The number and depth of initiatives vary with the student's learning about the subject.

These phenomena can be explained further by considering a fragment of a dialogue extracted from a human tutoring keyboard-to-keyboard session. In all these sessions the tutors are our research collaborators, Dr. Joel Michael and Dr. Allen Rovick, Professors of Physiology at Rush Medical College. The students are first year medical students at Rush.

The session transcripts that are the basis of my research were made using the Computer Dialogue System. The Computer Dialogue System [Li et al., 1992] was designed to allow two PC users to communicate with each other via a telephone line with Hayes modems while typing at computer keyboards. The input is communicated through

the keyboard and the output is seen via the computer screen. The content of the conversation is saved as a transcript file on the hard disk of one of the computers.

EX. 1.2.

K12-tu-75-5: Now let's get back to TPR.
K12-tu-75-6: Do you have any new thoughts about it?
K12-st-76-1: I am thinking that tpr is a measure of pre-load force to the right heart and that if you increase pre-load force you will increase sv, something we don't want for this patient.
K12-st-76-2: So I think that tpr goes down.
K12-tu-77-1: Your answer is right but for all the wrong reasons.
K12-tu-77-2: Let's get back to this reflex.
K12-tu-77-3: What is it trying to do in this patient?

The identifiers such as "K12-st-76-1" are produced by running a numbering program on the raw transcript. They are used for recording information such as the fact that this sentence comes from the twelfth keyboard-to-keyboard session, the student's turn, the seventy-sixth turn in the session, and the first sentence in that turn. A turn is a continuous stretch of the dialogue where one participant, the tutor or the student, types. Each turn consists of one or more (communicative) acts. The number K12-tu-77-1 can be interpreted on a similar way except for one difference; "tu" stands for tutor. The underlined in sentences are student initiatives.

The student flags her uncertain thinking with "I am thinking ...." Knowledge of the discourse context is essential for tracking the student goal and determining the focus of attention. The tutor understands and recognizes the student's plan to find out whether her reasoning is correct and handles the situation accordingly. Chi et al. [1994] show that eliciting self-explanations promotes greater learning and deeper understanding. Even an incorrect self-explanation can provide the student with an opportunity for self-repair to

resolve the conflict. This suggests that CIRCSIM-Tutor must take into account the nature and coherence of the student's conceptions in order to give better hints. CIRCSIM-Tutor (v.2)'s lack of ability to respond to self-explanation definitely limits its effectiveness. For instance, if the student poses a question or proposes some theory, the system reveals its limitations mostly by ignorant responses like the one mentioned earlier.

Human tutors perform multiple roles when tutoring, as an expert in the domain, an expert in the process of tutoring, an expert in the process of diagnosing the student's misconceptions, an expert in communicating her/his responses to the student. In the tutoring system, when the tutors ask some question, they are interested not only in knowing what the answer is, but also in how it was obtained. The tutors estimate the student's understanding of the material to be taught as the tutorial dialogue progresses.

We need to incorporate these roles as components in an ITS so that it reflects the effective tutoring behavior that we want to model. The major work still lies ahead, in specifying the design and organization of these components, their rules of operation, and how they are interconnected.

1.3 Intention and Plan Recognition

Maintaining a mixed-initiative dialogue requires the understanding of the intentionality behind an action [Lehnert, 1978]. Participating in a conversation and producing an utterance can be viewed as problems in plan construction where the problem is to create an utterance that satisfies goals involving the transmission of certain contents or intentions [Wilensky, 1983]. Carberry [1990 a, b] has played a major role in the growing understanding of the significance of plan recognition. She puts it this way:

> As research on intelligent tutoring systems and computer consultants progresses and more complex problem situations are attacked, recognition of the student's problem-solving plan will become more and more important [Carberry, 1990b, p. 72].

Planning deals with the process by which people select a course of action: make a decision about what they want to do, formulate and revise plans to accept this goal, and eventually perform some actions. Understanding concerns the way in which a person comprehends a situation, infers implicit components, develops a coherent picture of an episode, structures events in meaningful units, and finds explanations for other people's actions [Wilensky, 1983]. Goal analysis is needed to understand the intent behind speech acts or many kind of conversation. A plan is typically a partial solution to the problem of achieving a goal.

I believe that human tutors make use of many knowledge sources including the student's goal. Both the focus of attention, and the form of input are exploited to infer the student's intention, and identify the student plan. By recording both user plans and system plans in a tutoring history, the system will be able to reason about previous utterances, both to interpret and to answer the user's queries. Thus, to realize that the student's utterance "I still don't understand", is a request for explanation, the student's probable goal of understanding clearly needs to be inferred by the tutor by going back from the utterance to the underlying goal.

1.4 Student Initiatives

A student initiative interrupts the normal flow of dialogue, and enables the transfer of control of the session from the tutor to the student. This transfer of control takes place by

asking a question or making a statement that demands that the attention of the tutor move to some other topic. This kind of act on the part of a student is called a "student initiative." The student initiative may be a simple question asked by the student, or a request for confirmation, or a request for repair or some other category. A request for clarification is a conversational tool that functions to allow the student to bring a misunderstanding in the conversation to the attention of the tutor. Once the tutor becomes aware of the misunderstanding, he may attempt to repair it. Different types of repair need to be done depending on how soon after the comprehension problem it is initiated. The realization of the error in the student knowledge at different points gives rise to misconception, or misunderstanding, or not understanding. The error in the knowledge of the student initiates "nth-turn" [Schegloff, 1992] repair in response to misconception and misunderstanding. Let's analyze the student misconception and tutor response from the following excerpt taken from keyboard-to-keyboard session. It depicts the 2nd-turn repair corresponding to the student misconception recognized by the tutor.

EX. 1.3. Misconception, nth-Turn Repair, n

K16-tu-41-2: Does sympathetic stimulation change during the DR phase?
K16-st-42-1: Does dr mean diastolic relaxation?
K16-tu-43-1: NO!
K16-tu-43-2: The DR occurs during the period of time before any reflex response to the perturbation of the system takes place.

EX. 1.4. Misunderstanding, nth-turn Repair where n >=3

K1-tu-72-1: Only missing one -- -RAP.
K1-tu-72-2: What happens to it?
K1-st-73-1: RAP d
K1-tu-74-1: No.

K1-tu-74-2: RAP is still inversely related to CO as described in the vascular function curve.
K1-st-75-1: RAP i
K1-tu-76-1: Tghat's correct.
K1-tu-76-2: Do you think that you really understand it?
K1-st-77-1: I am still unclear about RAP.
K1-tu-78-1: We better talk about it at some other time.
K1-tu-78-2: Either make an appointment X26567 or catch me in the PLATO room when we are doing CIRCSIM.
K1-tu-78-3: Thanks a lot for your help.
K1-st-79-1: Thank you.
K1-st-79-2: Good-bye!

As the study of transcripts shows, the student initiatives are of various types and are treated differently. It was clear that we needed to categorize the student initiatives. Sanders [1995] worked on identifying and classifying the student initiatives and came up with different categories discussed in Chapter V. After finding it hard to classify some of the initiatives using Sanders' scheme, we decided to invent another scheme that could not only classify those initiatives but also help in understanding the tutors' responses.

When we were studying the transcripts of twenty eight tutoring sessions involving various student initiatives, we discovered a new category of initiative which is "Pause", when the student does not type anything and a complete silence prevails. The students use this stop-and-go strategy to gain time. Skinner likens the pause after reinforcement to the inability to expend effort [Bower and Hilgard, 1981, p. 181]. The tutor recognizes this initiative, sensing the time delay. He offers his help knowing that the student is facing some problem. Thus the immediate response to the "Pause" initiative is asking the student if s/he is stuck or needs any help. Here is an example of this category:

EX. 1.5.

K1-tu-38-1: What would change first and in what direction?
{PAUSE}
K1-tu-38-2: Need help?
K1-st-39-1: Yes

We worked more on the student initiatives to get a more sophisticated and useful categorization scheme so that it can cover the true sense of the content correctly, and so that we can hope to build a model or write a feature checking program that will help in distinguishing the initiatives and enabling the correct responses to be generated.

1.5 Tutor Responses

In order to cover the research track from "student intentions" to "tutor expectations", I thought it would be better and more productive if the direction of the path is reversed. I started my research by observing tutor responses and using them as a guide in investigating the corresponding student initiatives. Our analysis revealed various strategies that the tutors implement in their responses to initiatives. Some tutor responses are very brief, like "yes". Others are elaborate and may include many other tutoring strategies in the form of multiturn dialogues, questions, hints, and acknowledgments. Multiturn structures such as Directed Lines of Reasoning (DLRs) serve various roles in tutoring: as summaries, as extended hints, and as examples of causal reasoning. Causal reasoning helps in making explicit what is left implicit at the level of interconnected thought (or text) by explaining a chain of cause and effect. We can see causal reasoning at work in the following transcript:

EX. 1.6.

K17-st-67-1: Would you please explain how a change in CO manifested because of a change in SV causes a change in RAP.
K17-st-67-2: I picture an increasing in SV because of increased contractility as resulting in a greater ejection fraction, but not in changing RAP-- -well, I guess I do see your point, because if a higher fraction of the volume is ejected from the ventricle, then more volume will have to leave the atrium to refill the ventricle and this will cause a lower RAP.
K17-st-67-3: Is this right?
K17-tu-67-1: Yes.

There are many variations in tutor responses as shown in the complex example below with nested initiatives:

EX. 1.7.

K12-st-62-2: I am just hesitant to say what comes first.
K12-st-62-3: I'll go with tpr I to slow blood flow back to heart (I don't really like this idea)
K12-tu-63-1: Well let's see if we can get at the first question I asked and then we'll come back to TPR.
K12-tu-63-2: With regard to SV, what are it's determinants?
K12-st-64-1: Ventricular volume prior to onset of systole and cardiac contractility
K12-tu-65-1: Sure.
K12-tu-65-2: Now considering that we are in the RR period, i.e., the first things that are going to change are the things that are under neural control, which of these determinants would be the first affected?
K12-st-66-1: Cc
K12-tu-67-1: Of course!
K12-tu-67-2: And in what direction?
K12-st-68-1: Decrease
K12-tu-69-1: Right again.
K12-tu-69-2: And how would that affect SV?
K12-st-70-1: Decrease
K12-tu-71-2: And what affect would that have?
K12-st-72-1: Decrease co
K12-tu-73-1: Yes again.
K12-tu-73-2: Then what?
K12-st-74-1: Map d
K12-tu-75-1: Yes, again.

K12-tu-75-2: And in this regard.
K12-tu-75-3: It is MAP that is regulated by the baroceptor reflex.
K12-tu-75-4: That's why it is called that.
K12-tu-75-5: Now let's get back to TPR.
K12-tu-75-6: Do you have any new thoughts about it?
K12-st-76-1: I am thinking that tpr is a measure of pre-load force to the right heart and that if you increase pre-load force you will increase sv, something we don't want for this patient.
K12-st-76-2: So I think that tpr goes down.
K12-tu-77-1: Your answer is right but for all the wrong reasons.
K12-tu-77-2: Let's get back to this reflex.
K12-tu-77-3: What is it trying to do in this patient?
K12-st-78-1: Adjust for an unadjustable hr.
K12-tu-79-1: what do the receptors measure?
K12-st-80-1: Stretch and some measure chemical comp.
K12-tu-81-1: I mean the BAROCEPTORS.
K12-st-82-1: Pressure
K12-tu-83-1: WHAT ARE THEY TRYING TO ACCOMPLISH WITH REGARD TO PRESSURE IN THIS PATIENT?
K12-st-84-1: Decrease it
K12-tu-85-1: How will TPR have to be affected to lower MAP?
K12-st-86-1: Decrease
K12-tu-87-1: Correct.
K12-tu-87-2: How does the reflex manage to lower TPR?
K12-st-88-1: Dilation of blood vessels
K12-tu-89-1: And how does it accomplish that?
K12-st-90-1: Either decreased symp.
K12-st-90-2: pr increased para.
K12-st-90-3: (did I reverse it)
K12-tu-91-1: There is practically no parasympathetic enervation of blood vessels (erectile tisse and a few other fun places).
K12-tu-91-2: Most-- --almost all of the enervation to blood vessels is sympathetic and the primary effect is norepi acting on alpha receptors to cause vasoconstriction.
K12-tu-91-3: Now what do you say about what the reflex does vis-a-vis TPR?
K12-st-92-1: I am sorry I just got lost.
K12-st-92-2: Are you saying it is not vasodilatation
K12-tu-93-1: no. I'm agreeing with you the vessels are dilated.
K12-tu-93-2: I was just giving you information that you could use to determine how the reflex accomplished that.

The variety of these responses utilizing different types of tutoring patterns gives rise to different categories of tutor responses, each of which can further be subdivided into subcategories. An extensive study of the transcripts led us to classify the responses along three dimensions. These categories are described in Chapter IV.

Obviously identifying and then responding to student initiatives are not simple straightforward processes. The overall absorbing question now becomes:

Q 1 What category of responses is considered to be appropriate in order to answer a particular class of initiatives and how is the actual response chosen?

The search for an answer to this overall question sparked more linked questions like:

Q 2 On what dimensions should we categorize student initiatives?

Q 3 What would be a proper tutor response? and ultimately

Q 4 What makes the tutor's response a perfectly satisfactory one?

This thesis describes my attempt to answer these questions.

1.6 Organization

This thesis contains nine chapters. The first chapter we have just gone through. The second chapter deals with the background of the CIRCSIM-Tutor project including historical highlights of computer based instruction systems developed at Rush Medical Center: from HEARTSIM to CIRCSIM-Tutor Version 3. The third chapter provides a review of theories or formalisms developed in the context of understanding in natural language systems, and examines intellectual discoveries by other researchers in planning

and understanding. The fourth chapter presents our classification of tutor responses to student initiatives. The fifth chapter closely examines regularities (patterns) in human tutoring sessions to recategorize the student initiatives. The sixth chapter investigates the relationship between initiatives and responses, with the goal of developing some rules for generating appropriate responses in CIRCSIM-Tutor. The seventh chapter sheds some light on the factors influencing the behavior of students in performing a task/goal in certain learning environments. These steps correspond to the "understanding" dimension of student plans. Different models of student plan recognition and their representational structures are discussed in the perspective of the CIRCSIM-Tutor. The eighth chapter raises some promising ideas for future research. The final chapter presents our conclusion, including a summary and a discussion of the significance of our research.

CHAPTER II

BACKGROUND AND HISTORICAL CONTEXT OF THE CIRCSIM-TUTOR PROJECT

Bloom [1984] argues that one-to-one tutoring is the most effective learning environment. He observed that students taught individually by a human tutor were found to learn better than those taught in a class situation. But there are not enough human tutors to do all of the necessary tutoring and pay special attention to each and every student. Therefore with the development of computers, our world dreamed of a remedy in the form of a machine tutor that can not only tutor the students on the subject matter but also help them learn the skills necessary to solve problems in the real world. The students can access the machine any time they want and receive training through hands on practice. Computer Aided Instruction (CAI) systems were introduced in education. Adding artificial intelligence led to the term Intelligent Computer Aided Instruction (ICAI). Systems of this type are also called Intelligent Tutoring Systems (ITS) [Sleeman and Brown, 1982]. Hence, ITS are tutoring systems that function as individualized problem-solving guides with qualities of flexibility.

CIRCSIM-Tutor was developed as the most recent of a series of computer-aided instruction systems. The knowledge domain of our tutoring system is cardiovascular physiology, concentrating on the baroreceptor reflex, which is responsible for maintaining a more or less constant blood pressure. The end users are mostly first year medical students. The goal of this intelligent tutoring system is to assist students to understand the causal relationships between the components of the circulatory system; to reason about

the complex behavior (negative feedback) that stabilizes blood pressure; and to apply this understanding to solve problems about this system. CIRCSIM-Tutor starts with a perturbation of the blood pressure and asks the student to make predictions about the effects of the perturbation on seven cardiovascular parameters. Based on the predictions made by the student, CIRCSIM-Tutor identifies possible misconceptions and then takes remedial action. If there are no errors, the system asks questions to gauge the student's cognitive state further. The development of ITS requires a multidisciplinary approach, which must combine the features of knowledge based systems with an instructional system in a single framework. In order to design a more sophisticated version of CIRCSIM-Tutor, we are analyzing transcripts of human tutorial sessions, produced by professors of physiology working with students from Rush Medical College.

2.1 Domain of Cardiovascular Physiology

Knowledge in one domain may be organized according to principles different from knowledge in another. The storage of knowledge is linked with the nature of the problem. Medical students must not only acquire a great deal of information but also learn how to use available information to solve problems in real life situations. They need to practice using the language of physiology as well.

2.1.1 Heart as a Pump. The heart is an intermittent pump. William Harvey (1578-1657) was the first to correctly identify the heart as a pump that repeatedly moves a small volume of blood forward in one fixed direction in a circular path through a closed

system of blood vessels (the circulatory system). The intermittent pump puts out a volume of roughly 100 ml per second, but pumps the entire volume at a steady rate over 0.5 seconds and then pumps nothing during the next 0.5 seconds. During the pumping phase of the cycle (systole/ contraction and emptying) the flow of 200 ml/s through a resistance of 1 mm Hg/ml/s would produce a pressure of 200 mm Hg in a rigid system. During the filling phase of the pump (diastole/ relaxation and filling) the pressure would be 0 mm Hg in a rigid system [Berne and Levy, 1992]. The cardiac output (CO) is the amount of blood pumped out per minute from the central venous compartment of the heart. It takes approximately one minute to get back to the heart. So medical students need to visualize what is happening to the pressure and volume in the central venous compartment (CVP, CBV) during that minute so that they can understand the complex behavior of the baroreceptor reflex.

2.2 Evolution of Computer Aided Tutoring at Rush/ IIT

Rovick and Michael started to develop Computer Aided Instruction (CAI) systems in this area because medical students are particularly confused by negative feedback systems. They have built a number of systems in various areas but their first effort was intended to help the student understand the negative feedback process that maintains blood pressure in the cardiovascular system and to apply these concepts correctly in clinical problem-solving using the correct language.

The use of CAI systems in physiology at Rush Medical College evolved from MACMAN [Dickinson et al., 1973], which was a mathematical model (computer simulation) of the blood pressure regulation system. HEARTSIM, developed by Rovick

and Brenner [1983], at Rush Medical Center, was a PLATO program that was used at Rush Medical College for several years. It included a pedagogical component besides MACMAN. Formal mathematical descriptions of the circulatory variables and the relationship between them were replaced by qualitative expressions. Although HEARTSIM provided the students with an opportunity to design and run their own experiments, the access of the students to PLATO was very limited.

CIRCSIM by Rovick and Michael [1986] came into existence as a stand-alone Basic program for DOS machines. It does not incorporate the mathematical model that was a major part of HEARTSIM. HEARTSIM and CIRCSIM both assume that the students have acquired facts and concepts about the baroreceptor reflex from their reading, attendance at lecture, and participation in other scheduled problem solving exercises. CIRCSIM has been in use at Rush Medical College for many years. It has been shown to successfully assist students in learning to predict the behavior of this complex negative feedback system that controls the blood pressure [Michael et al., 1992]. This way, the students have a chance to interact directly and practice their skills with hands-on experience that gives them real mastery in the subject domain and problem solving skills. Although the effectiveness of CIRCSIM has been demonstrated, Michael and Rovick felt that a program that required the student to give explanations in natural language would be even better. CIRCSIM-Tutor came into existence. The time-frame of the development of CIRCSIM and CIRCSIM-Tutor can be seen in Figure 2.1.

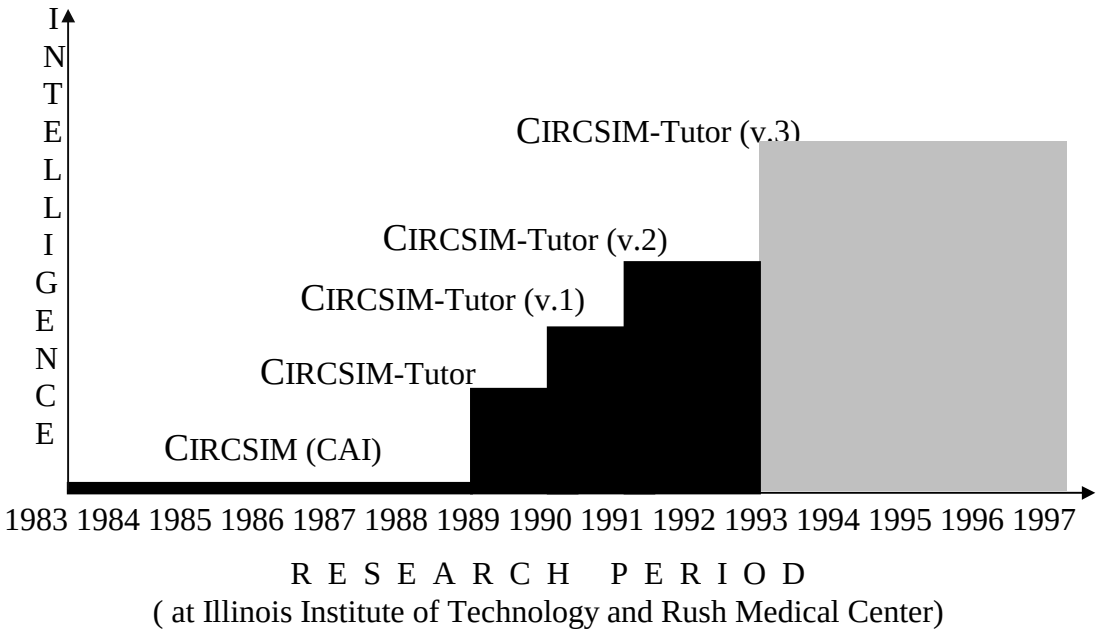


Figure 2.1 Development Stages in the History of Intelligent Tutoring Systems at IIT/Rush

2.3 CIRCSIM

CIRCSIM is a BASIC program for machines running DOS [Rovick and Michael, 1986]. It was created with the intent of teaching medical students to solve problems in cardiovascular physiology effectively. CIRCSIM has been an effective instructional system that can identify bugs in the student thinking and give explanations to help the student correct misconceptions.

2.3.1 A Prediction Table. The curriculum for CIRCSIM is a set of predefined experimental procedures. CIRCSIM starts by defining different perturbations to the cardiovascular system and inviting the student to pick one. Then it asks the student to make qualitative predictions (increase/ decrease/ no change) about the responses of seven

cardiovascular parameters to that perturbation (something causing a change in blood pressure) in the Direct Response (DR) phase, the Reflex Response (RR) phase, and the Steady State (SS) phase. The immediate response of the system to the perturbation is called the Direct Response (DR), and it always results in a change in Mean Arterial Pressure (MAP). This change triggers a Reflex Response (RR) that takes place in order to bring MAP back closer to its normal state. Eventually, a Steady State (SS) is achieved, which is the "total effect" of the DR and RR phases [Michael et al., 1992].

The system variables are: the procedure variable, which is the one changed by the perturbation, the primary variable, which is the first variable in the prediction table to be affected by the change in the procedure variable, the neural variables, which are under the control of the nervous system, and the haemodynamic or physical variables.

Each procedure commences with a description of a certain clinical problem, say for example, a mechanical heart pacemaker suddenly failed, decreasing the heart rate (beats/ minute) substantially. The student is asked to predict the direction of change, if any, of the seven fundamental cardiovascular parameters in three phases and enter these predictions in a worksheet, i.e., the Prediction Table as shown in Figure 2.2.

The Prediction Table contains the names of the parameters controlling the blood pressure and cells to be filled out by the student with the qualitative effect of the perturbation on the parameters. The symbols '-', '0', and '+' represent 'decrease', 'no change', and 'increase' in the value of the corresponding parameters. The procedure variable and the primary variable are the same in this problem; both are the heart rate (HR).

Phases: / Parameters	DR	RR	SS
Cardiac Contractility (CC)	0	+	+
Right Atrial Pressure (RAP)	+	-	+
Stroke Volume (SV)	+	+	+
Heart Rate (HR)	-	0	-
Cardiac Output (CO)	-	+	0
Total Peripheral Resistance (TPR)	0	+	-
Mean Arterial Pressure (MAP)	-	+	-

Phases: DR= Direct Response, RR= Reflex Response, SS= Steady State

Figure 2.2 The Prediction Table. Example entries are indicated by 0 (no change), + (increase), and - (decrease) for an artificial pacemaker failure that forces the heart rate down.

Each column represents a different stage in stabilizing the blood pressure. The first column corresponds to the first stage of direct response to the perturbation. The second column gives predictions about the second stage, the stage when the reflex responses kick in. The third column, the steady state, contains predictions about the changes in the variables after the situation has stabilized.

When the student is done with filling the entries in the first column, the entries are matched with the correct answers. The errors are used to choose one of more than 240 files of canned remedial text to display to the student.

2.4 CIRCSIM-Tutor

By the late 80's as Rovick and Michael [1992] used CIRCSIM in classes at Rush Medical College, they realized that although CIRCSIM has many useful features, it has problems as well. It was unable to keep track of changes in the student's concepts and misconceptions over time or to help the student in mastering the language of physiology. It lacked the ability to model the student knowledge and could not react flexibly to different student needs. CIRCSIM just recognizes patterns of prediction errors and rolls out canned text in response. At this point Rovick and Michael recognized the need for a natural language interface that would require the students to make explanations and teach them the sublanguage. They turned to IIT for help in building a more intelligent system, an ITS or Intelligent Tutoring System. The result was CIRCSIM-Tutor, designed to hold a dialogue with the student while s/he is busy in solving a problem.

A Prolog prototype of CIRCSIM-Tutor was designed and implemented by Kim et al. [1989]. This system used canned language like CIRCSIM, but, on the other hand, it made explicit the domain model, the student model, and instructional planning issues.

2.4.1 CIRCSIM-Tutor (v. 1). CIRCSIM-Tutor (v. 1) was the next step. It was developed using InterLisp on a Xerox Lisp machine. These modules implemented the natural language processing aspects of CIRCSIM-Tutor. The real work on the natural language interface started from this version. Lee [1990] worked on the problems pertaining to handling ill-formed natural language input for an ITS. Zhang [1991] focused

on interactive discourse generation in a machine tutoring environment. She addressed three issues: how to represent domain knowledge and tutoring context information to support tutoring discourse generation, what strategies should be used to plan tutoring discourse based on the knowledge representation, and how to implement the planned discourse in natural language.

2.4.2 CIRCSIM-Tutor (v. 2). Later CIRCSIM-Tutor (v. 2) was built using a Macintosh based LISP system, extending the natural language capabilities and expanding the conceptual model. CIRCSIM-Tutor (v. 2) uses the same architecture as Kim's prototype but includes improved student modeling, instructional planning, and natural language understanding and generation facilities [Woo, 1992]. It has two sets of tutoring rules: instructional planning rules and discourse planning rules, which are interpreted by the system planner. Using these rules the tutor can plan and replan in response to the dynamic student model. The instructional planning rules determine the goals. The discourse planner plans the discourse to accomplish the goals of the tutor and responds to the student errors dynamically. It uses natural language for both input and output. It has the feature of correcting misspelled words besides handling fragmentary answers from the student.

One goal of the system is to teach the student certain problem-solving algorithms in making predictions about variables. The student is expected to follow these algorithms. For example, s/he must predict the primary variable first, follow the correct sequence, and may predict neural variables in any order. Otherwise s/he may be warned by an error message.

2.4.3 Concept Map. The main objective of CIRCSIM-Tutor is to assist medical students to understand the concepts of the negative feedback system that regulates blood pressure along with acquiring problem-solving skills to be applied in solving any related clinical problem facing them. The crux of the knowledge that Version 2 of the CIRCSIM-Tutor system wants the student to internalize is expressed in the concept map shown in Figure 2.3. It is a qualitative causal model of the baroreceptor reflex. This diagram was developed by the physiology experts Rovick and Michael [Khuwaja et al., 1992].

Here RAP is Right Atrial Pressure, SV is Stroke Volume, CC is Cardiac Contractility, HR is Heart Rate, MAP is Mean Arterial Pressure, CO is Cardiac Output, TPR is Total Peripheral Resistance, BR is the Baroreceptor Reflex, and CNS is the Central Nervous System. CBV, BV, RV, and PIT stand for Central Blood Volume, Blood Volume, Venous Resistance, and Intra Thoracic Pressure.

The concept map depicts the causal relationship between parameters involved in regulating the blood pressure. Each box in the map represents a physiological variable. An arrow from one parameter to another means the first variable directly determines the second variable. A plus sign on an arrow means that the causal relationship is a direct proportionality. A minus sign on an arrow means the causal relationship is an inverse proportionality.

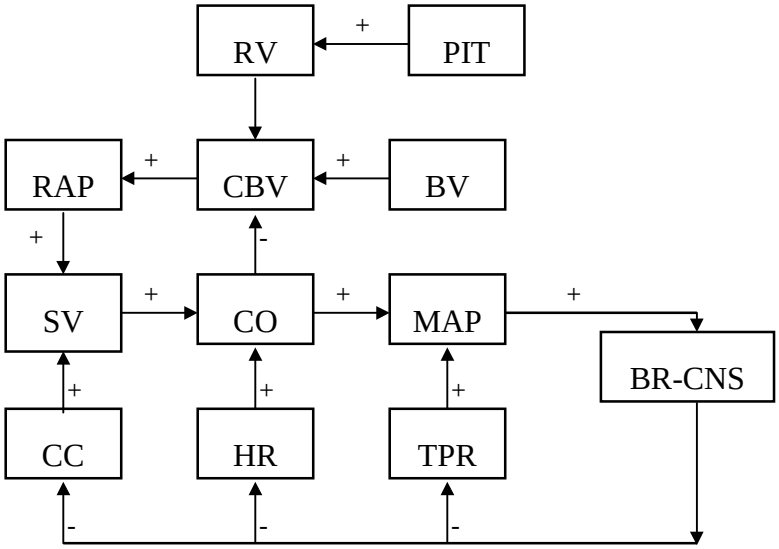


Figure 2.3 Surface Level Concept Map

The graphical representation of the core variables and relationships between them provides the student with the concepts of what determines what and how. Some variables are determined by more than one variable, and the relationship between the variables may be direct or inverse. For example, stroke volume is determined by right atrial pressure, cardiac contractility, and mean arterial pressure. It also shows the control of the nervous system, which acts to stabilize the blood pressure, using the neural variables.

2.5 CIRCSIM-Tutor (v. 3)

CIRCSIM-Tutor (v. 3) is the current version that we are working on. The architecture envisioned for CIRCSIM-Tutor Version 3.0 is illustrated in Figure 2.7. The

components are divided into two major classes: modules and information stores. The shared information stores include the domain knowledge base, a lexicon, and a student model. They are kept separate as information stores that may be freely accessed by all modules of CIRCSIM-Tutor. The domain problem solver makes heavy use of the domain knowledge base [Khuwaja et al., 1992]. The knowledge base development framework was mainly influenced by the KADS (Knowledge Analysis and Design Structure) methodology. Portions of this system have been implemented: the domain knowledge base and the student modeler. Others are in progress.

The system initiates a tutoring session with one of pre-defined perturbations to the cardiovascular system. The problem-solving behavior of the subject is partitioned into three phases: Direct Response, Reflex Response, and Steady State. The student picks one of the procedures or possible perturbations of the cardiovascular system that involves the baroreceptor reflex. The regulated variable is the variable that the reflex system controls. In the case of the baroreceptor reflex the regulated variable is Mean Arterial Pressure. Neurally controlled variables are the ones that are under direct control of the nervous system: Heart Rate, Total Peripheral Resistance, and Inotropic State (Cardiac Contractility). The other variables are under physical/chemical control; they are sometimes called haemodynamic variables. When the student finishes filling a whole column of the prediction table, the tutor makes a diagnosis [Michael et al., 1992] of the student's errors and tailors the tutoring to remediate them.

The Top Level Concept Map (shown in Figure 2.4) represents the knowledge that Rovick and Michael want their students to internalize and use in problem-solving. It is

the minimal map to simulate the baroreceptor reflex. Note that the parameter RAP is replaced by CVP and CC by IS to avoid confusion.

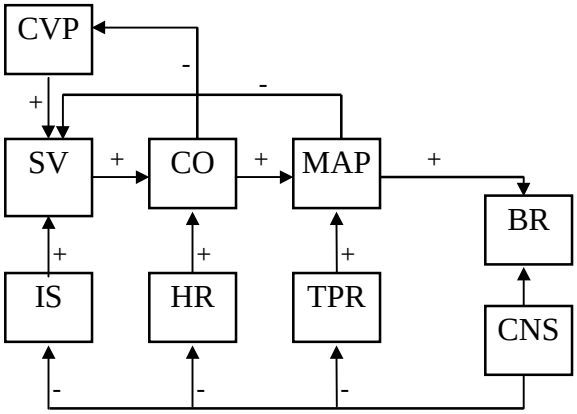


Figure 2.4 The Top Level Concept Map

The Intermediate Level Concept Map (shown in Figure 2.5) contains supporting knowledge that appears to be particularly useful in eliciting responses from the students. It is used particularly in giving hints and explanations.

The Deep Level Concept Map (shown in Figure 2.6) represents all the knowledge that the system posseses. If the student reveals some serious misconception about the subject matter, then the system refers to this level for teaching the core concepts. It is used in responding to student questions and explanations.

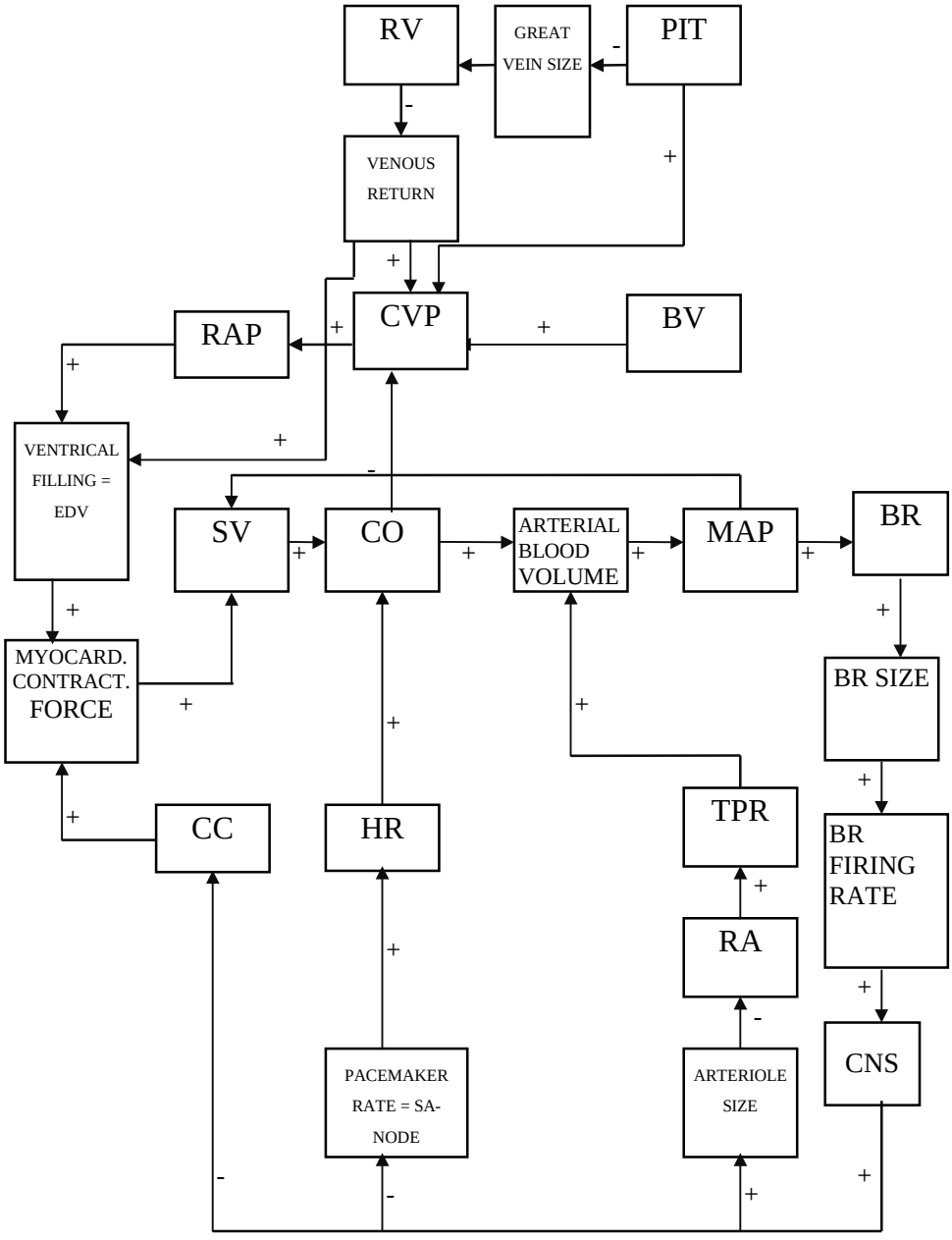


Figure 2.5 The Intermediate Level Concept Map

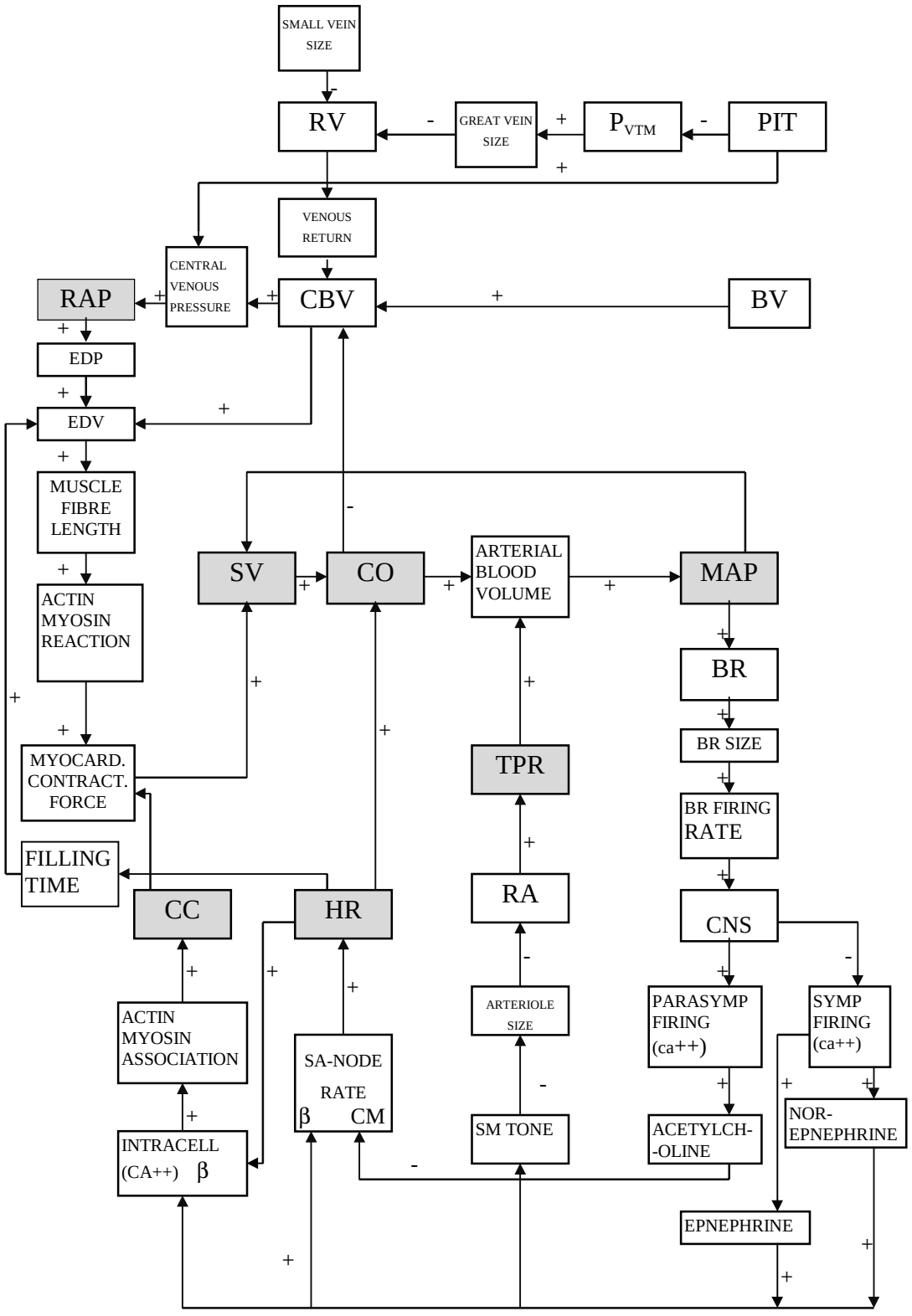


Figure 2.6 The Deepest Level Concept Map

2.6 Components of CIRCSIM-Tutor (v. 3)

Eventually CIRCSIM-Tutor (v. 3) will be made up of a number of modules: a domain knowledge base, a problem solver, a student modeler, an instructional planner, a controller, an input understander, a judger, a discourse planner, a text realization component, and a screen manager. The architecture of the system is shown in Figure 2.7

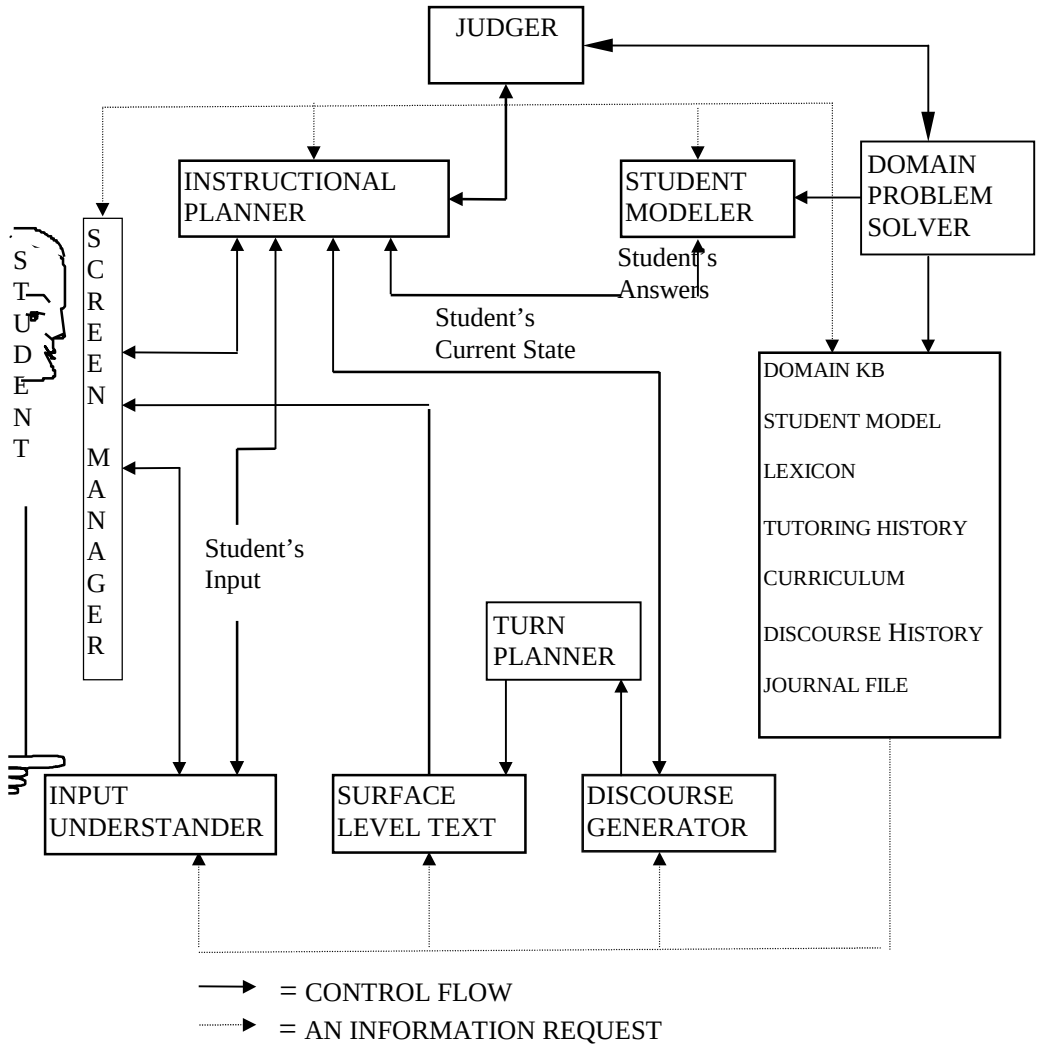


Figure 2.7 The Architecture of CIRCSIM-Tutor (v. 3)

The tutoring system needs to understand the student input, however ill-formed, in order to craft an appropriate response. This is done by parsing and translating the input into a logic form. The logic form is used to present the literal meanings of sentences more clearly. The problem solver is invoked to check whether the logic form is correct or not. Then the logic form is passed on to the student modeler, to update the student model. The planning component decides what to do next. It develops an instructional plan and then a discourse plan. The discourse plan is sent to the text generator. The discourse generator generates a turn plan that is passed to the surface text generator to be expressed as a series of sentences. The functionality of each component of the system is described below:

2.6.1 Domain Knowledge Base. It is a reservoir of information. The ability of the system to reason about the multiple causal relationships between various components of the CV system is based on the “concept map”. The amount of knowledge that must be imparted depends on the levels of student misconceptions. The system may switch over to the other two deeper levels of the concept map at the discretion of the instructional planner.

2.6.2 Cognitive Modeling. The student modeler builds the student model, an information store that can be accessed by all the other modules. So far the student model constitutes the basic knowledge about the student available to the system. However that model describes the tutor’s perception of what the student does or does not know about cardiovascular physiology. The model is consulted heavily by the instructional planner and the discourse planner. The student modeler uses two information stores: the Student

Model and the Domain Knowledge Base. It also calls the Domain Problem Solver. It interprets the student's cognitive performance, and records or updates it in a student model that describes the current stage of the students' knowledge from the tutor's point of view. The student modeler interprets the student's errors as well as correct responses. This represents the set of hypotheses formulated about the student's acquired skills and misconceptions identified by the system during analysis of the student's predictions and during the tutoring dialogue. Based on this information, the tutor can give appropriate instruction to the student.

There are two major approaches used for student modeling: the overlay model [Carr and Goldstein, 1977] and the buggy model [Brown and Burton, 1978]. The buggy model was developed to explore a modeling scheme using bugs in arithmetic algorithms. The scheme represents the in-depth analysis both of the domain and of the actual performance of the student. Bug libraries have been used to record common student misconceptions so that they can be checked by the system later on in order to plan to fix them [Shim, 1991]. The overlay model is designed to represent the student's knowledge state as a subset of an expert's knowledge state. Typically this approach has been used to detect declarative errors, while the buggy model is designed to represent the student's misconceptions as a variant of the expert knowledge rather than as a subset of an expert's knowledge state. The research team working on CIRCSIM-Tutor has come to feel that this distinction is not valid in our complex domain. Instead we have tried a unified approach to all errors. The integration of overlay and bug techniques redefines the errors in terms of misconceptions graded in order of importance and difficulty rather than the

declarative/ procedural division. There is ongoing research on student modeling [Hume, 1995].

2.6.3 The Instructional Planner. The Instructional Planner is the central component of this architecture. This module decides what, when, and how to teach the student. It is responsible for determining the course of action at each point during a tutoring session and building a tutoring history. It measures how often the parser/understander fails to understand and falls back on "I am sorry I did not understand you. Please rephrase." It interacts with the input understander, the text generator, the student modeler, and the screen manager in order to carry out the tutorial activities, e.g., planning the curriculum and teaching the selected goals, answering student questions or responding to other student initiatives, planning, monitoring and critiquing, depending on the state of the model.

The Instructional Planner decides what subject matter to focus on, how to convey it to the student and when to intervene when the student is busy problem-solving. It is a dynamic instructional planner that carries out a mixed initiative strategy. It monitors current plans in progress. If there is any plan that does not seem to be working, the planner drops it and replans rather than repairing it. Domain knowledge, knowledge about the student from the student modeler, and pedagogic knowledge are all factors in making decisions. Analysis of human tutoring sessions shows that when human tutors come across initiatives while teaching some lesson plan, they respond to the initiative, which may be a multiturn segment of dialogue, and come back to the execution of that lesson

plan. The system behaves like an operating system that services an interrupt first and then resumes the flow at the point where it was left before.

The system controller coordinates actions/ applies plans. It allows access to any procedure at any stage, whether direct response (DR), reflex response (RR) or steady state (SS).

2.6.4 The Judger. The judger evaluates the response from the student encoded as a logical form, and declares whether it is correct or not by examining the response, the question, and the correct answer provided by the Problem Solver. The information about the student reply is then stored in the student model.

2.6.5 Problem Solver. The problem solver solves all procedures on an expanded list. Right now it consists of two components: the main problem solver and the subproblem solver. When the screen manager takes qualitative predictions from the prediction table and sends them to the planner, it is the problem solver that generates correct predictions for all parameters in the prediction table and gives a solution path to be used to monitor the student's problem solving approach. The subproblem solver is used for solving problems from any other module of the system or problems raised by a student query. The intelligence of an ITS comes from its ability to solve problems [Clancey, 1987].

2.6.6 Input Understander. Modifications are under way in the input understander. In CIRCSIM-Tutor (v.2), the input understander produces an internal representation from the student's natural language responses. It handles not only well formed but also ill-formed inputs [Lee, 1990]. It uses lexical functional grammar as a basis for the parser.

As intelligent tutoring systems grow and become more robust, they rely more on information exchange using natural language dialogue with users [Fox, 1993]. As the input understander is based on natural language, so parsing the input efficiently is very important to the system. The study of the tutoring dialogues shows that medical students hardly ever respond to questions with complete sentences. Mostly, they respond with a noun phrase, or an adjective, or an adverb, or some other fragment. They also make spelling errors all the time. Lee [1991] developed a spelling correction module as a tool to help correct the spelling errors without user intervention. The unavoidable use of the fragments supports a bottom-up parsing approach.

Lee [1990] developed our original bottom-up chart parser. The module depends on two information stores: the Discourse History and the Lexicon. Elmi [1995] introduced an efficient parsing algorithm for lexical, syntactic, and semantic analysis of the user input. The advantage of interaction among the three components (lexicon, syntax, and semantics) is in early detection of spelling errors, or syntax errors, or semantic errors, or a simple sentence fragment.

The input understander parses the input keyed in by the student and produces a logical form. The logical form is used for the interface between the planner and the text generator and/or between the planner and input understander. The logical form of the

student input, if it is an answer, will be sent to the judger. The student may not always answer the question asked by the tutor, but sometimes s/he may ask a question, or generate an explanation and ask the tutor for confirmation. If the student seizes the initiative in this manner, the logic form will be sent to the instructional planner.

2.6.7 Text Generator. The text generator is responsible for translating the plan formulated by the discourse planner into natural language output. It generates a natural language sentence or sequence of sentences. For example, if the text generator is given a logical form from the planner, (question (affected-by SV ?)), then it produces the English sentence, “What are the determinants of SV?” The text generator is divided into two parts: the Discourse Planner and the Surface Generator. In Version 3 the Discourse Planner keeps track of the discourse content and conveys a discourse plan to the Turn Planner. It uses the Lexicon, the Discourse History, the Domain Knowledge Base, the Domain Problem Solver and the Student Model. The Turn Planner organizes sequence of subplans into a plan for a content turn. The Surface Level Text Generator takes the resulting plan and turns it into a sequence of English sentences. This module provides many lexical choices to help in conveying the underlying context. Ramachandran and Evens [1995] introduced a new strategy for lexical choice called User-Driven Lexical Choice, in which the user vocabulary is used as the basis for text generation. It uses both the Lexicon and the Discourse History.

2.6.8 Screen Manager. The screen manager acts as the actual means of communication between the system and the student. It displays and echoes the responses

of the tutor and student. It provides a center of attention and interaction for the student. It supports consistent use of the mouse and the keyboard. It keeps track of the variables and the time that the student and system take in responding. It receives the student's input via the keyboard and passes it to the input understander that processes this raw information. It displays text and graphics on the computer screen for the student. We are now combining the student window that receives the student's natural language input and the tutor window that displays natural language output, so that the dialogue is interleaved in a natural fashion.

2. 7 A Sample Tutorial Dialogue Carried on by CIRCSIM-Tutor

Before they are tutored students have already acquired some level of domain knowledge through attending regular class lectures and reading the text. The main task of the system is to teach the correct use of the language and useful problem-solving skills and help students correct their confusions. Let me illustrate the roles of the components through a portion of dialogue taken from a machine tutoring session. This dialogue was generated by a student using CIRCSIM-Tutor Version 2 developed by Woo et al. [1991]. Most of the system was developed on a Macintosh IICi. It has been ported to the SE-30, IISi and PC machines for the Rush Medical College environment and other situations. It requires 5MB main memory.

The user interface or screen interface includes windows for instructional dialogue, a procedure description, a prediction table, and a scratch area. When the students start CIRCSIM-Tutor, they see a list of procedures on the right top corner window of the

screen. The student picks one and then enters the changes caused in the seven variables in the DR column. When the whole column is done, the tutoring system initiates a natural language dialogue.

2.7.1 A Piece of Dialogue in CIRCSIM-Tutor (v. 2). In this section, I provide an example illustrating how the working version CIRCSIM-Tutor (v. 2) handles input from the student after the predictions are made.

EX. 2.1.

Tutor: What are the determinants of SV?
Student: SV is determined by RAP and CO.
Tutor: RAP is correct, but CO is not a determinant of SV.
Remember SV is the amount of blood pumped per beat.
What is the other determinant of SV?

Suppose the goal at hand is to explain the causal relation between the parameters, RAP and SV. The instructional planner generates a lesson plan based on an analysis of the student errors in making predictions. This information is also sent to the modeler along with the student's answers to tutor questions. The generated subgoals such as determinant, actual determinant, relation, value are pushed onto a stack, which is used by the discourse planner to pick the next topic. The planner determines the next move and sends this information to the text generator encoded in the logic form (question (affected-by SV ?)). After producing the semantic-form, f-structure (to express the content of a logic form) and c-structure, the text generator produces the English sentence, "What are the determinants of Stroke Volume?"

The student's input here is an answer to the tutor's question. The planner passes the input to the understander. The input understander parses the answer, and uses the logic form of the question as well to build the logic form, (answer (determinant SV (RAP CO)). The planner takes the student answer, (RAP, CO) and passes it to the student modeler to diagnose it. The student modeler analyzes the logic form version of the answer given by the student. If the answer is correct then the planner asks the tutoring system to give a positive acknowledgment and then starts in on the next topic on agenda. If the answer is wrong, then the planner refers to the tutoring tactics and decides to provide "a hint". It then asks a follow-up question with the expectation of receiving a complete answer. If the student makes a mistake again then another tutoring tactic will be applied. If the student fails to come up with the correct answer twice in a row then the direct answer to the question is generated by the tutor.

The overall processing of this dialogue [Woo et al., 1991] is described in detail below:

1. Instructional Planner: Pops the current topic from the stack, and decides what to teach next depending upon the nature of the topic. It passes a primitive logic form to the discourse planner. The discourse planner does the job of incorporating some more information like the mood of the sentence, the type of the sentence, and the main verb of the sentence.

   current topic: (determinant SV) discourse tactic: question
   logic form: (question (determinant SV))

2. Text-Generator: Generates a sentence from the logic form produced by the planner. The final sentence is: “What are the determinants of SV?”
3. Screen Manager: Displays the sentence in the Tutor window.
4. Student: Answers “SV is determined by RAP and CO.” in the Student window.
5. Input-Understander: Parses the student’s answer using a bottom-up chart parsing. It, then, passes the form to the planner as “student answer: (RAP, CO)”
6. Planner: Passes the current topic and student answer to the student modeler in logic form.

   current topic: (determinant SV) Student answer: (RAP, CO)
   logic form: ((determinant SV) (RAP, CO))

7. Student Modeler: Calls the problem solver, gets the correct answer: (RAP, CC), compares the correct answer with the student answer, and updates the student model.

Thus steps one through three generate the piece of dialogue:

Tutor: What are the determinants of SV?

Suppose the student responds as follows:

Student: SV is determined by RAP and CO.

Steps four through seven accept and evaluate the student’s answer, and record the results in the student model. At this point the planner checks the student model and decides the next response. For example, in this case the student’s answer is partially wrong, so the

planner comes up with the positive acknowledgment for the correct part and negative acknowledgment for the wrong part as given below:

Tutor: RAP is correct, but CO is not determinant of SV.

The planner, then, refers to other didactic rules and opts for giving "a hint" followed by a question.

Tutor: Remember SV is the amount of blood pumped per beat.
What is the other determinant of Stroke Volume?

If the student makes an error again, then a different tutoring strategy is adopted or the right answer is released. The tutoring rules or strategies vary with different situations.

Right now CIRCSIM-Tutor (v.2) responds to just a couple of student initiatives in a very simple way. In the following example it handles the first two initiatives, but it is totally confused by more complex initiatives.

EX. 2.2a

Tu> By what mechanism is Heart Rate controlled?
St> I don't know.
Tu> Heart Rate is controlled by the nervous system.
What is the value of Heart Rate in DR?
St> I don't understand.
Tu> The value of Heart Rate is unchanged in DR.
Please change the value of 'HR' in the Prediction Table.

EX. 2.2b

Tu> By what mechanism is Heart Rate controlled?
St> I am not sure.
Tu> I'm sorry I don't understand you.
Please rephrase.

EX. 2.2c

St> perhaps CC increases…
Tu> I'm sorry I don't understand you.
Please rephrase.

We notice from the examples given above that these are not good ways to respond to student initiatives. Human tutors respond in much more flexible ways.

2.7.3 Interaction of Modules in CIRCSIM-Tutor (v. 3). In Version 3 the components are implemented as packages in the Common Lisp Object System (CLOS). They communicate with each other by message passing. The common data stores are: the Knowledge Base, the Student Model, the Curriculum, the Lexicon, the Discourse History, the Tutoring History, and the Journal File, which keeps the account of tutor-student interaction. The later versions of CIRCSIM-Tutor are expected to improve the planning, coherence, lexicon, user interface, portability, dialogue handling, tutoring techniques, text generation, and dealing with mixed-initiative discourse.

Version 3 is being implemented in Lisp compatible with both Allegro Common Lisp for Windows and Macintosh Common Lisp. New approaches are being explored to implement varied and more sophisticated language. Work is going on to make the system more interactive. Briefly speaking the present and future packages are:

1. Planner: The curriculum planning decides on the problem to give the student. The planner asks the student to make predictions and decides how to remedy the errors. It pops the current topic from the stack. It chooses a pedagogical rule about how to teach the topic. It passes a primitive logic form representing the

list of instructions. The discourse planner makes multiturn plans to translate content into discourse. As soon as it figures out what the tutor should say in the next turn, it calls the turn planner to organize the next turn. When the turn planner has determined what should be packaged into the next sentence. It passes it on to the Text Realization Module. Text Realization picks the type of the sentence, and the main verb of the sentence. The resulting form is now called a shallow semantic form.

2. Text Realization: Generates functional dependencies (FDs) and passes them on to FUF (a text generator software developed by Michael Elhadad). FUF generates corresponding sentences and pass them over to the Screen Manager, which simply displays them on the screen. The sentences may be questions, short explanations, parts of more complex explanations, positive acknowledgments, negative acknowledgments, hints, or definitions, depending upon the type of input.
3. Screen Manager: Displays procedure text, receives student input in the prediction table and the text window. The system output is also displayed in the text window.
4. Student: Makes predictions in the prediction table and types text in the text window.
5. Input Understander: When the student types some natural language utterance, it is processed by the Input Understander, which carries out spelling correction and parses the input. The output is in the form of a logic form which is passed on to the Student Modeler.

6. Student Modeler: Calls the problem solver, gets the correct answer and passes the information to the Judger. The Judger compares the correct answer with the student answer, and updates the student model.
7. Problem Solver: There are approximately 70 problems describing different perturbations of the cardiovascular system. The problem solver is the real expert part of the system. It uses the algorithms and the data in the knowledge base to solve the problem.

The system analyzes the student input, and records the result in the student model for evaluation purposes. At this stage the planner checks the student model, and decides what to do next. The planner refers to the tutoring tactics and decides to provide "a hint" or DLR.

The discourse planner and the turn planner use Young and Moore's Longbow planner [1994]. Thus their planning rules are expressed in terms of Longbow operators. Thus much Lisp code can be replaced by operators that are much easier to read and update. This is just a skeletal plan of CIRCSIM-Tutor Version 3 architecture and its expected functionality.

2.8 A Future Look at the Technology

We are aiming at having a version of the system with a comparable level of understanding for the spectrum of student initiatives. More work is required to expand the modules especially in generating and understanding natural language to understand the

student behavior with the goal of responding effectively. Students will only produce self-explanations if they believe that the system can understand them.

My work is a link in this connection that involves understanding the student plan and developing the strategies to distinguish a hedged answer from an initiative. I have tried to figure out how to recognize student initiatives and how the system should respond to them. I have searched for concepts and AI technologies that can be combined to produce a tutoring system with a natural touch. All this is essential for making the system a resilient system which is capable of supporting student questions and self explanations. Some of this research is discussed in the next chapter.

CHAPTER III

APPROACHES TO NATURAL LANGUAGE UNDERSTANDING

Let's examine different approaches to natural language understanding from different but related disciplines. These disciplines include computational models, psychological models, linguistic processes, philosophical analysis, and logic. The long tradition of Intelligent Tutoring System (ITS) research really started as a distinct approach with a dissertation by Carbonell [1970] and with his classic system called SCHOLAR. Carbonell emphasized the need of anticipating not only unexpected answers from the student, but also unexpected questions the student asks. He was stimulated by the idea of representing knowledge by semantic networks, which he thought are much like the way people store and retrieve information. He envisioned a system that can hold mixed-initiative dialogues with students. In an effort to extend SCHOLAR's reasoning abilities, Carbonell and Collins [1973] adopted techniques that allow the knowledge base to support an inference engine. Collins et al. [1975b] did some analysis on human tutorial dialogues with the hope of implementing the findings in the system design. This further led to research on the Socratic method for teaching reasoning through successive questions. WHY [Stevens and Collins, 1977] was launched as a result. The design is still a challenge as this line of research continues.

Newell introduced the term "cognitive architecture" when he was working on computer architectures [Bell and Newell, 1971]. Anderson's work [1993] on rules of the mind in the form of ACT-R theory is an example of a cognitive architecture that has played a remarkable role in the world of intelligent tutoring systems. It provides good

ground to proceed in neural network terms, and sets a direction for research in the possible neural network implementation of ACT-R components.

3.1 Plans and Understanding

Constructing plans is a matter of intentions. Adopted plans are stored as intentions. In the simplest case, a plan for achieving a certain goal is just a sequence of acts that, when performed in that order, will result in that goal's being achieved. The analysis of keyboard-to-keyboard expert tutorial dialogue indicates that a single utterance may be used to carry out several communicative goals. Intention can be viewed as force of commitment. An agent is a planning mechanism that has beliefs and goals. A goal is a logical expression representing a proposition. The agent's beliefs are logical expressions and are manipulated in complex ways by the planning mechanism. Recognition of intention and cooperation at the discourse level is required to enable the system to distinguish if the student is merely experiencing communication problems or some fundamental misconceptions about the underlying physiology.

An approach to understanding plans was developed by Schank and Abelson [1977]. Plan understanding involves inferential knowledge of a large number of actions and goals. They treat plan creation as problem solving. Schank and Abelson inquired into the nature of knowledge and how this knowledge is used from the perspectives of cognitive science. Their work provides a meaning representation for events, and also intentional and contextual connections between events. They call this level of conceptual entities the Knowledge Structure (KS) level. Realizing the fact that intellectual history,

like political history, is full of shifting alliances between different interest groups, they comment about the KS level this way:

> It deals with human intentions, dispositions, and relationships. While it is possible computers can not actually experience such intentions and relationships, they can perfectly well been programmed to have some understanding of their occurrence and significance, thus functioning as smart observers [p. 4].

The contribution of linguistics to understanding is based on the methodology of mapping deep representations into surface representations. Statements in prose are related by causal conceptualizations. The events described form a causal chain on the basis of which the comprehender constructs an underlying causal conceptualization [Graesser, 1981].

Most researchers even in linguistics now agree that pragmatics is as important as semantics, and semantic features are as important as syntactic ones. Context is essential in the interpretation of text including literal as well as non-literal aspects of communication such as assumptions about the speaker's intentions. It is important to consider the speaker's goals in interpreting natural language. Hayes [1980, p. 71] predicts that without dealing with the non-literal aspects, man-machine interfaces will be uncooperative, unfriendly, and appear stupid to their users. This will obviously cause users frustration and ultimately make them give up using the machine. He believes that people can adopt more easily to interactions in which their communicative needs are satisfied.

3.2 Philosophical Approaches to Understanding Speech Acts

Austin, Grice and Searle, working from the tradition of philosophy of mind and action, addressed the questions of the nature of meaning, of actions, and indirectness in their own ways. Austin [1962], Grice [1957, 1969], and Searle [1975] have all made major contributions to plan recognition. Austin noticed that there are situations in which to say something is to do something. and thus the term “speech act” was coined. He introduced the distinction between the truth value of a proposition (constative) and the use of that proposition (performative) within an utterance that is the result of a speech act performed by some speaker for some hearer(s). He claimed that the notions of truth and falsity cannot be applied to performative utterances that involve actions and these actions cannot be true or false. For example, stating “I confer a degree of M. D. upon you.” under appropriate circumstances results in the candidate becoming a doctor, is not open to a true/false analysis. In Austin’s view [1962] the conditions that are required to perform a speech act successfully, are as follows:

(A. 1) There must exist an accepted conventional procedure having a certain conventional effect, that procedure to include the uttering of certain words by certain persons in certain circumstances, and further,
(A. 2) the particular persons and circumstances in a given case must be appropriate for the invocation of the particular procedure invoked.
(B. 1) The procedure must be executed by all participants both correctly and
(B. 2) completely.
(Γ. 1) Where, as often, the procedure is designed for use by persons having certain thoughts or feelings, or for the inauguration of certain consequential conduct on the part of any participant, then a person participating in and so invoking the procedure must in fact have those thoughts or feelings, and the participants must intend so to conduct themselves, and further
(Γ. 2) must actually so conduct themselves subsequently [p.15].

As Austin says (B.2) the procedure must be executed by all participants completely. For example: my attempt to sit in a class by saying ‘I want to learn’ is abortive until the teacher says ‘I let you come in’. The procedure must be executed by all participants correctly. For example, suppose the student says ‘I bet my answer is correct’ when more than one answer is given.

An imperative may be an order, a permission, a demand, a request, an entreaty, a suggestion, a recommendation, a warning, or it may reflect some condition or concession or definition. To say ‘I shall’ may be a promise, or express an intention, or predict my future. Thus, when I say ‘I shall’, it means forecasting if the adverbs ‘undoubtedly’ or ‘probably’ are present. It expresses an intention if the adverbs ‘certainly’ or ‘definitely’ are there. It reflects a promise in the presence of the adverbial phrase ‘without fail’, or the context I shall do my best to’. Sometimes performatives may be mistaken for descriptives or constatives [Austin, 1962, p. 77]. A statement that is either true or false, is called descriptive.

The violation of any of the conditions will result in an unhappy performative utterance, which means the act is void or without effect. For example suppose that ‘I divorce you’, is said to a wife by her husband in a Christian country, both being Christians rather than Muslims. Here the utterance is classed as a misfire because the procedure invoked is rejected. On the other hand the whole code of procedure is accepted if it is invoked in circumstances where both spouses are Muslims. Also the particular persons and circumstances in a given case must be appropriate for the invocation of the particular procedure invoked. For example, ‘I pick XYZ for my side’, will only be in order if the object of the verb is a player.

There are many ways in which we use speech. The three main kinds of speech act are: the locutionary, e.g., ‘she said that...’, the illocutionary, e.g., she argued that...’, and the perlocutionary, e.g., ‘she convinced me that....’ An illocutionary act is a conventional act. The locutionary act is defined as something that has meaning. A perlocutionary act is the achieving of certain effects by saying something. The illocutionary act has a certain force in saying something. The formulas:

> ‘In saying x I was doing y’, ‘I did y’, for example:
> ‘In saying I would shoot him I was threatening him’, depicts the force of an illocutionary act. In contrast,
> ‘By saying x I did y’ or ‘I was doing y’, for example
> ‘By saying I would shoot him I alarmed him’, depicts the achievement of a perlocutionary act.

These formulas are not authentic tests for deciding the type of an expression, and need more scrutiny. Any speaker who uses a sentence with an intention of communication in a context of utterance means to perform an illocutionary act, such as a request or an assertion.

Many of Austin’s insights about the nature of speech acts, happiness conditions, and modes of failure were derived from a study of communicative actions. His *How to Do Things with Words* [Austin, 1962], and work in pragmatics have inspired other researchers to address somewhat similar problems in speech acts, though using different methods.

The fundamental notions in Grice's theory [1957, 1969] are belief, intention, and plan recognition. It was Grice who first saw the distinctively reflexive character of communicative intentions (that is, he emphasized the importance of speaker meaning). Grice's philosophical interests led him to develop very striking and powerful ideas for understanding meaning in the theory of implicature.

Grice [1975] finds the source of conversational implicatures in the "cooperative principle" that demands the conversational contribution to be as much as is required by the direction of the talk exchange in which the participants are engaged. A participant can convey (communicate) more than what is strictly said (implied). This "more" is called implicature [Levelt, 1989]. For example, in our transcript analysis we see it enough on the part of the tutor to hint at a certain piece of information; the student interprets that information as relevant to the ongoing interaction and infers the tutor's goal.

Grice [1957] gives an account of what a speaker means when performing an act of communication in terms of the speaker's intention that the hearer should recognize certain intentions of the speaker. According to Grice's theory [Grice 1957, 1969] the criteria for judging linguistic intentions are very like the criteria for judging nonlinguistic intentions. The word "mean" especially connected with an utterance is the effect that the speaker intends to produce in his listener by virtue of the listener's recognition of that intent; otherwise the speaker would not have made the utterance.

Austin explains that language ought to be viewed as actions (including actions performed with an utterance). Grice's maxim of relations shows that in the absence of clue words indicating a topic shift, the listener should believe that the speaker's ill-formed utterance is relevant to the established dialogue context. The Gricean picture of

"conversational implicature" has been helpful in addressing the question of indirectness. "Conversational implicature" describes inferences about speaker intention that arise from the recipient's use of both logical meaning and conversational principles. He argues that just given a knowledge of the English language is not enough to identify the phrase (plan) of the speaker. One would need to know the identity of the referent, the temporal information, and the interpretation of utterance on that particular occasion. Grice emphasizes meaning in context; this not only allows a distinction between semantic and pragmatic meaning but also takes into account that part of human communication that focuses on intentions. A speaker may intend to create in a hearer a recognition of the intention to convey certain propositions about the world. Speaker-meaning need not be code-related and may be inferred through processes different from the encoding and decoding processes used in the model of communication.

Schiffrin [1994] quotes Grice distinguishing the meaning of natural language utterances from the logical propositions this way:

> It is a commonplace of philosophical logic that there are, or appear to be, divergences in meaning between, on the one hand, at least some of what I shall call the formal devices-~, ∧, ∨, ⊃, (x), ∃(x), ∫(x)...and, on the other, what are taken to be their analogs or counterparts in natural language-such expressions as not, and, or, if all, some, or (at least one), the [p. 193].

Thus in Grice's terms the broader interpretations of an utterance are what someone "implicates" and the added meanings are implicatures that are due to the cooperative principle underlying communication. The cooperative principle is to make one's conversational contribution such as is required, at the stage at which it occurs, by

the accepted purpose or direction of the talk exchange in which one is engaged [Schiffrin, 1994].

Searle [1970] focused on Sense and Reference in his Ph. D. thesis in 1959. His work is based on the conviction that anyone speaking a language is engaging in a rule-governed form of behavior. His line of thought was strengthened by trying to answer questions like “how do the words relate to the world?” and other such questions forming the subject matter of the philosophy of language. People do communicate, they do say things, and they sometimes mean what they say. They ask questions, issue orders, and give apologies. Peoples’ utterances relate to the world in ways we can describe as being true or false or meaningless, stupid, exaggerated or what not [Searle, 1970].

Searle [1975] emphasizes that the meaning of indirect speech acts is based on inferences by the hearer, with some conditions, and on “conversational implicature,” described by Grice. Fundamental to the speech act theory is an emphasis on the “functionality” of language and the need to distinguish between the force of an utterance and its literal content. Associated with all speech acts are a set of felicity conditions, preconditions and effects. Felicity conditions mainly refer to the speaker’s psychological state; preconditions refer to the functioning of the real world and a speaker’s social status; and effects refer to changes in the external world, including the mental states of others, created by the speech act. For example, the “conferring a degree” act can only have its intended effect of the candidate being so honored if its precondition that the person granting the degree has authority to do so is true. A major felicity condition of all speech acts is a sincerity condition [Reichman, 1985]. Reichman refers to Searle [1969] stating that:

> ...to assert, affirm, state (that P) counts as an expression of belief (that P). To request, ask order, entreat, enjoin, pray or command (that A be done) counts as an expression of a wish or desire (that A be done). To promise, vow, threaten, or pledge (that A) counts as an expression of intention (to do A) [p. 190].

Utterance acts consist simply in uttering strings of words. Illocutionary and propositional acts consist characteristically in uttering words in sentences in certain contexts, under certain conditions and with certain intentions. Searle claimed that recognizing the meaning of an indirect speech act requires inference by the hearer using knowledge of speech acts, principles of cooperative dialogue, and background knowledge shared with the utterer. The characteristic intended effect of meaning is understanding, but understanding is not the sort of effect that is included in Grice's examples of effects. Searle's analysis of illocutionary acts is to unpack what constitutes understanding an utterance in terms of some rules concerning the elements of the uttered sentence and in terms of the hearer's recognition of the sentence as subject to those rules. The key problem that Searle addresses is the relationship between the collective intentions and individual intentions causing the individual actions responsible for the collective behavior. He argues that discourse is a joint accomplishment, and the difference between the collective behavior and a summation of individual actions resides in the intentions of the actors. He points out that collective intentions are primitive and collective goals are achieved by the effect of contributions of individual intentions [Cohen et al., 1990]. The differences between Grice's analysis of meaning and Searle's concepts are as follows:

Grice's analysis	Searle's analysis
(a) Speaker intends the utterance of X to produce a certain perlocutionary effect in hearer.	(a) Speaker intends the utterance of a sentence to produce certain knowledge in hearer which is obtained under the state of affairs by the rules of sentence.
(b) Speaker intends the utterance to produce a perlocutionary effect by means of the recognized intention.	(b) Speaker intends the utterance to produce an illocutionary effect by means of the intention.
	(c) Speaker intends that intention will be recognized in virtue of hearer's knowledge of the rules governing the elements of the sentence.

3.3 Discourse Research in AI

Researchers in Artificial Intelligence (AI) were the first to treat discourse as a planned activity that requires theoretical and empirical notions of plan structure and plan recognition. They place strong emphasis on issues of intention. Cohen [Cohen et al., 1990] looked into the nature of intentions and plans. He was curious to know the constituents of the process by which one agent is able to recognize the intentions and plans of another agent participating in communication. Cohen examines some related computational questions such as data structures that allow finite representation of belief and mutual belief in a program that generates speech acts. He emphasizes that the

consequence can be based on rational interaction, caused by events changing the state of the world. Cohen and Levesque (both computer scientists) [1990, p.4] present another model of intention that is formalized in a temporal, first order logic. Utterance events are taken as a special case in which the change in the mental states of the participants in a dialogue is considered. They consider the properties that intuitively determine intention, and develop a logic that allows intention to be used for modeling rational behavior. The most important properties are: holding an intention unless the goal becomes true or the agent believes it is not possible to achieve, and including unintended consequences (side effects) as well as intended consequences (goals) from the plan.

Perrault [Cohen et al., 1990] also deals with questions of speech act theory from the angle of AI research on discourse understanding. He differentiates his work from the early work of other researchers by pointing out that the states of mind after an utterance depend on the mental states before the utterance. He prefers to consider a model of belief framed in nonmonotonic default logic where some of the consequences of speech acts are dependent on mental states treated as defaults, in the model of discourse. He considers changes in mental states more important than anything else in analyzing the illocutionary acts. Students of Perrault [Allen, 1979] and Cohen and Perrault [1979] adopt a plan-based approach to language generation, mainly based on Searle's formulation of speech acts. Cohen and Perrault [1979] suggest that speech acts (illocutionary acts) be defined in the context of a planning system, i.e., as a class of parameterized procedures called operators, whose execution can modify the world. Cohen formulated a planning system for modeling the possible intentions leading to the execution of a speech act [Cohen and Perrault, 1979]. Joshi et al. [1981] refer to Perrault and Cohen's discussion about the

logical, psychological or computational aspects of mutual belief, and quote Clark and Marshall who pointed out that virtually every other aspect of meaning and reference also requires mutual knowledge.

Allen [1983] has worked on the development of a hearer that can infer the speaker's plan and intention in order to give a cooperative answer. Pollack [1987] was the first to characterize some of the limiting assumptions that restrict the ability of models to handle naturally occurring dialogue. She analyzed these assumptions in order to see how they affect the system's capability to infer plans. Pollack [1990] correlates plans for a goal with a set of beliefs and intentions about how one is going to achieve the goal. Carberry [1990b] quotes Cohen, Perrault, and Allen as viewing users of question-answering systems as follows:

> [They] expect more than just answers to isolated questions. They expect to engage in a conversation whose coherence is manifested in the independence of their often unstated plans and goals with those of the system. [p. 1]

Allen extended Cohen's planning formalism and definition of speech act in terms of operators. Each operator is labeled with formulas stating its preconditions and effects. They use the operator termed "consequence-of-goals" as the basic building block for defining intention mainly for technical reasons. Allen addressed the problem of recognizing the intentions that a speaker intends to convey in making a particular utterance [Allen and Perrault, 1980]. He highlights the temporal aspects and thinks it an extremely difficult problem to relate one's future beliefs to one's present beliefs. The knowledge of the current situation is considered to identify the appropriate sense of a

word. He argues for logic forms thinking that a lot of semantic processing is independent of context. He uses abstract semantic relations to pinpoint ambiguities [Allen, 1987]. Allen's work on intended plan recognition has had a major impact on computational strategy for identifying the meaning of an utterance. His approach is based on ideas from Austin, Grice, and Searle, i.e., Austin's view of language by taking words as actions and modeling them with operators in a planning system. Grice's theory of meaning equates understanding with recognition of the speaker's intent. Searle views language as rule-governed behavior, he argues that the illocutionary force of an indirect speech act can be identified by inferencing on shared knowledge.

The limitations on Allen's work drew researchers attention to focusing. Focusing addresses problems of reference and generating text by developing focusing heuristics that ordered expectations about shifts in a speaker's focus of attention within the plan structure [Carberry, 1990b].

Briefly speaking, Allen, Perrault [1980] and Cohen et al. [1979,1990] mostly argue that discourse is a collective behavior or joint accomplishment and what is needed is a characterization of "joint plans" or "collective intentions." They based their work on simplifying the syntactic and semantic components as much as possible by restricting their domain to literal meanings. The indirect meanings are then handled at the plan level. This strategy of treating utterances as actions and equating the meaning of an utterance with the goals and plans that the agent intends to convey is based on work in philosophy by Austin, Grice and Searle.

Although plan-based approaches work well as long as the topic follows the task structure closely, they encounter difficulty in accounting for generated subdialogues such

as clarifications and corrections, and topic change. Litman and Allen [1987] introduce a set of discourse plans, each one corresponding to a particular way that an utterance can relate to a discourse topic, and distinguish such plans from the set of plans that are actually used to model the topics. They account for a wide variety of dialogue by incorporating knowledge about discourse into a plan-based framework. Domain and discourse plans are recognized by a context dependent heuristic plan recognition algorithm. The algorithm updates the stack of plans representing the current discourse context after every utterance.

Joshi et al. [1981] discuss the convoluted intricacies of “I believe that you believe that I believe...”. They think linguistic theories assume constraints, that they may be based on processing mechanisms involved in language production and comprehension, on the structure of language. They, therefore, make it a point to investigate the consequences of strong constraints for discourse processing, no matter if the constraints are invalid, in order to have insights into the structure and processing of natural language. These constraints are restrictions on the operation of rules of grammar [Marcus, 1981]. It is sometimes more than focusing on four themes: a) utterance meaning b) the participants’ evolving model of what underlies the discourse c) their evolving models of each other d) and situational characteristics that are used in the compilation of a discourse.

Joshi et al. [1984] point out that a cooperative respondent must prevent false inferences. If the tutor fails to notify the student that his/her queries are irrelevant to his/her motivating task, the student is justified in inferring by default that the tutor has pinpointed no discrepancy. A cooperative tutor will inform the student when the queries appear irrelevant and will suggest alternative information that may be useful in

constructing a plan for accomplishing a task. They worked to identify the appropriate content of expert responses by including additional information in the expert's plan that removes obstacles hampering execution of the correct plan or suggests better ways of achieving the information seeker's overall goal. Webber [1986] distinguishes between answers and responses. Answering a question (by asserting a proposition) is a logical type that is different from the everyday concept of response or reaction.

Bruce [1986] viewed utterances as a kind of social action that took into account and affected such mental attitudes as belief and intention. Hobbs and Evans [1980] pursued this paradigm and developed a plan-based model of conversation. A plan explains how a given state or event is a precondition for another state or event and also a postcondition from another state or event. With respect to causal chains, plans provide the reasoning by which one decides upon one or more actions, each of which can then lead to chains of results and enablements.

There are three important points to remember in planning. The first one is to allow the representation of states, goals, and actions, where states and goals are represented by sets of logical sentences, and actions are represented by specifying preconditions and effects. The second one is that the planner is free to add actions to the plan whenever they are needed. The third one is to expand conjunctive goals considering that most parts of the world are independent of most other parts [Russell and Norvig, 1995].

Charniak and McDermott [1985, p.557] claim that we recognize the intentions of others by attributing to them the same planning abilities that we have. They think of determining motivation as equivalent to synthesizing plans in reverse.

3.4 Planning and Intention in Communication

Barbara Grosz and Candace Sidner [1986] have surveyed the formalisms in the AI literature for modeling plans and intentions and used them in analyzing communication. Diane Litman [1986] worked on generated subdialogues like clarifications and corrections. Herbert Clark and Deanna Wilkes-Gibbs [Cohen et al., 1990, p. 463] have raised the issues of how very general collective intentions underlying dialogue become realized in fine-grained collective intentions underlying reference and proposed a principle of mutual responsibility for dialogue. Finally, Martha Pollack has analyzed plans as particular configurations of beliefs and intentions [Cohen et al., 1990, p. 77].

Analysis through a logical representation is a standard strategy in question-answering and message understanding. Such logical representations may sometimes express too little and sometimes too much, giving rise to ambiguities. Proper selection of a logical representation matters. The fact that sentences in context do much work that is not produced from the form of the sentences alone, makes us think about how to get accurate meaning [Kay et al., 1994]. KAMP (Knowledge and Modalities Planner) is a planning system that takes into consideration a goal and plan to achieve it [Appelt, 1982]. Appelt views linguistic actions at different levels. The highest level actions are illocutionary acts, for instance, informing, requesting, confirming, etc. The next lower level corresponds to performing these illocutionary acts as surface speech acts that consist of an intention-communication part and a linguistic-realization part. The lowest level actions determine the utterance of particular sequences of words. Fraser [1975, p. 194] points out that sentences containing modals typically contain more hedges than synonymous sentences without modals. The modals include: can, could, may, might,

must, shall, should, will, would, can/be able, must/have to, will/intend to, and the forms want to, would like to, and wish to which appear to function like the modals. He distinguishes strongly performative sentences from weakly (hedged) performative ones on the basis of some principles. He insists that all must sentences be interpreted strongly performative in spite of appearing as a hedged form in the literal meaning of the sentence. This is because we get the performative force from the speaker's intent in uttering the sentence.

Grosz [1986], Reichman [1985], and Sidner [1986] studied the use of clue words and phrases in structuring conversation and identifying the relationship of entities to one another. McKeown [1980] extended the concept of focusing to the generation of coherent natural language text**.** If we accept the analysis proposed by Carberry [1990b], we can say that in a tutor-student dialogue the tutor uses the context within which each initiative occurs to interpret the initiative, gets the desired information, and formulates an appropriate response. The context is built out of underlying knowledge of the domain as well as the history of previous questions and answers. Sidner [1979] considers it a challenge to choose appropriate elements of a context to be included in the structural description [p. 13]. Grosz and Sidner explain various linguistic and discourse phenomena as collective actions.

3.5 Recognizing Student Plans

A human tutor uses the information exchanged during the tutoring session in addition to his own knowledge of the domain to adjust his opinion about the student and updates his internal student model as the dialogue progresses.

In our machine tutor, when the screen manager receives input from the student, the input understander is invoked. It reasons about the input from the student and the last utterance from the tutor to identify the student's intended meaning and returns it to the judger for subsequent processing.

Once the student input is understood and judged, the student-modeling component must update the student model to reflect the effect of this new utterance on the system's beliefs about the student and the current dialogue context. Then the instructional planner is invoked: it reasons about the intended meaning of the student's utterance and the student model to construct a response that addresses the student's perceived needs. The discourse planner composes a discourse plan and the text realization component closes the system response in words.

How can we improve the system? We need to model the student plans and goals. We need to figure out whether the student is taking the initiative. Carberry [1990b] has shown that plan recognition is important both in understanding natural language utterances and generating cooperative responses. Plan recognition is also important in tutoring because effective tutoring requires identifying and evaluating the student's plan for solving the problem [p. 70]. She has provided a model of plan recognition that has been implemented in computer systems that communicate with their users. She has worked on this problem for several years [Carberry, 1988] and applied these ideas to such problems as interpreting ellipses [Carberry, 1989], understanding pragmatically ill-formed input [Carberry, 1990b], handling clarification subdialogues [Lambert and Carberry, 1992], and understanding indirect speech acts [Green and Carberry, 1994]. Her

work on response generation in a collaborative environment with Chu-Carroll [1994, 1995, 1996] is particularly notable.

Carberry classifies information-seeking dialogue as either top-down or bottom-up. In the top-down approach, the student response may begin with the underlying task and then proceed with the queries relevant to constructing a plan for accomplishing the task. I have found these naturally occurring top-down and bottom-up procedures, in examples from our transcripts of keyboard to keyboard tutorial dialogues:

EX. 3.1. Top Down

> K10-st-34-2: I was thinking about TPR intrinsically and extrinsically.
> K10-st-34-3: So ANS would affect the system extrinsically and control it but wouldn't there be more friction on the fluid going through the tube?

In the first utterance the student conveys her underlying task, which is to predict the change in TPR, and in the second utterance she tells the tutor what she knows about TPR and then formulates an (information-seeking query) initiative in order to construct a plan for accomplishing the task of predicting the change in TPR. The tutor directs his response to what he believes is the request underlying the student initiative, as follows:

> K10-tu-35-1: TPR is a function of the extent of contraction of the vascular smooth muscle.
> K10-tu-35-2: That determine the vascular radius, present in the resistance equation for each blood vessels as an inverse 4th power function.
> K10-tu-35-3: sure increasing the flow by increasing the pressure gradient would occur but the calculated TPR wouldn't change.

Top-down dialogue seems to occur when the student has little knowledge about how to proceed in the domain and is reluctant to take initiatives or has full command of knowledge and does not feel like taking control.

In a bottom-up approach the student does not communicate her/his overall goal but instead formulates queries relevant to subtasks (to elicit pieces of information) within the overall task (understanding), constructs plans for carrying out these subtasks, and builds her/his plan from the bottom up. The following is an example of naturally occurring bottom-up dialogue:

EX. 3.2. Bottom Up

K27-st-63-1: I have question on TPR?
K27-st-63-2: Doesn't flow affect tpr to any extent
K27-tu-64-1: It is true that the vessels are compliant and that if there is more blood in them they will expand and get larger.
K27-tu-64-2: But the flow (ml/min) through the vessel does not determine its size.
K27-st-65-1: Determinants for sv are cc and filling of lv..
K27-tu-66-2: Right.

Although the student does not communicate his overall task of making a prediction about SV starting with the determinants for SV, this was inferred by the tutor from the dialogue. This is indeed the next step in the algorithm that the tutor wants the student to use. He hints to the student, by the utterance in K27-tu-64-2 that the flow through the vessel does not have to do anything with the size of the vessel and can not be thought to be a determining factor in stroke volume. He directs the student to correct his line of thinking, and solidify the correct information. Bottom-up dialogues seem to occur when the student believes that s/he is knowledgeable about the domain and is apt to take initiatives and fill in those parts of a partially constructed plan that are not yet complete.

In both top-down and bottom-up dialogues the tutor seems to use the student's inferred task related plan in the subsequent dialogue. The plan inference system must build its model of the student's plan incrementally as the dialogue progresses.

3.5.1 Plans and Goals. Graesser [1981] quotes Stevens et al. [p. 20] arguing that cognitive representations of causally driven systems in technology and the physical world are incomplete, are often incorrect and may be internally inconsistent. Goals, plans, and actions are organized by virtue of intentional conceptualizations. Graesser [1981] also differentiates them and then puts them together:

> An important difference between goal-oriented conceptualizations and causal conceptualizations is that goals and actions are future directed, whereas events and states are driven by past occurrences in causal systems. The interface between the two systems is the behavioral aspect of intentional action. The character is satisfied when the causally driven outcome match the characters goals. Again, the social and physical worlds are not always that cooperative [p. 24].

3.6 Plan-based Models

One of the earliest planning systems was STRIPS [Fikes and Nilsson, 1971], which uses a state-space approach. In the state-space approach, a problem is represented by descriptions of the initial state, a desired goal state, and a set of operators that transform one state into another [Carberry, 1990b]. The planner is to search for a sequence of operators that transforms the initial state to a goal state. The identified sequence of operators constitutes a plan for solving the problem. However, the premature ordering of actions in the plan caused lots of problems of backtracking in STRIPS.

Carberry describes the work of Sacerdoti [1974, 1975, 1977] who resolved these problems in successive planning systems, including ABSTRIPS and NOAH, by introducing the hierarchical structure of the representation of a domain and problem in a compact manner. The focus of her work is plan inference in task-related information seeking dialogue. She favors the notion of using a plan recognizer to build the user plan and tracking the user focus of attention in the plan.

Carberry's work on incremental plan inference into plan recognition has been implemented in a system called TRACK [1993]. Currently her strategies on plan recognition are being combined in DIALS (Delaware Intelligent Advising Language System).

Linguistic behavior can be understood by considering plan based models of language. The progress of a dialogue is based on old expectations, and proper inference of plans. In the setting of a train station (TRAINS) and information seeking dialogue, the assumption is made that agents try to recognize the plans of other agents and use this plan in coming up with appropriate responses [Allen and Perrault, 1980]**.** Traum and Allen [1994] analyze the model using a set of social conventions. They claim that in the process of planning, an agent considers obligations besides other factors in order to determine an action. Their model allows for a mixed-initiative conversation and varying levels of cooperation. They say:

> Following the initiative of the other can be seen as an obligation driven process, while leading the conversation will be goal driven. [p. 7]

The idea that language can be viewed as action evolved from speech act theory. According to this theory, linguistic action is an action planned to satisfy specific goals of

the speaker. Effects of speech acts manifest themselves through the recognition of intention. Some goals are knowledge state goals, e.g., changes in beliefs and wants. Some are discourse goals, i.e., the ones changing or maintaining the state of the discourse. Others are concept activation and focusing goals, e.g., concepts of some object, state or event brought to hearer's immediate attention, and social goals, e.g., related to politeness. All these goals are reflected in the surface form and content of the utterance, and influence what to say and how to express it.

A considerable amount of work has been done by Searle [1969] on the level of informing and requesting. Cohen [1978] has blended most of this work in his planning system. Further investigation is required on the formal specification of focusing. Different strategies are proposed by Reichmann [1985] and Sidner [1979] though. Grosz and Sidner's [1986] work provides the basis for keeping track of the focus of attention in a dialogue and for finding the link between an individual utterance and task structure.

In traditional dialogues the participants require positive evidence as a closure mark of understanding. The utterance of a contradictory statement or negative evidence displays non-understanding or misunderstanding [Litman and Allen, 1987]. Misconception is due to an error in the prior knowledge of the student. Such errors can be recognized immediately in the case of misconception as compared to misunderstanding [McRoy and Hirst, 1995]. The symptoms of misconceptions include references to entities that do not map to previously known objects or operations [Webber and Mays, 1983] or requests for clarification [Moore and Paris, 1989]. Fox [1987] points out that such repairs involve, in effect, a reconstruction of the initial utterance [McRoy and Hirst, 1995, p. 437]. Further she adds that correction is a subtype of repair, covering repairs that arise out

of errors [Fox, 1993, p. 52]. Misconception causes misunderstanding. One does not know about her/his misunderstanding in the beginning.

According to Grosz [1981] and Reichman [1985], discourse analysis is done better when the discourse is partitioned into related but distinct discourse units. Grosz called these partitions "focus spaces," while Reichman called them "context spaces." Reichman [1985] marked different conversational moves using clue words like because, but , so, now, (no) but, and so forth. For instance, but marks the next proposal as a contrasting plan. The terms discourse operators [Polanyi, 1985; Redeker, 1986, 1990], cue words [Grosz and Sidner, 1986] are also signaled by clue words. Good surface cues are easy to identify, and when used in combination with others, can provide lexical semantic information [Light, 1996].

3.7 Environment-based Interpretations

We saw that mutual signaling of intent and its interpretation is central to conversational success. Different researchers have attempted to seek ways for using the computer as an interactive tool in an environment designed for exploratory learning [Papert, 1980]. Knowledge communication is a common intelligent behavior [Wenger, 1987]. For the design of an effective teaching tool, Skinner's notions (in contrast to cognitive orientation) of programmed learning/teaching provide some interesting perspectives [Skinner, 1968]. His views on purpose and intention of behavior in terms of controlling variables are given below:

> Purpose is not a property of behavior itself; it is a way of referring to controlling variables. [Skinner, 1953, p.88]

Catania, author of *B. F. Skinner, Organism*, illustrates the nature of response due to different roles and different situations. He uses an analogy that when a victim of a heart attack reports pain in the shoulder or in the small of the back rather than within the chest, the cardiologist is a better judge than the patient of the real source of the pain [1992, p. 1526].

Again Skinner spoke of the self as an organized system of responses, and of the individual as a locus in which many variables come together to produce an outcome. He reiterates:

> When someone says that he can see the meaning of a response, he means that he can infer some of the [potentially manipulable] variables of which the response is usually a function. [Skinner, 1957, p.14]

Behavior is the interaction between organism and environment. It is understood in terms of its relation to present and past evaluation. The discourse structure, its variability, and evolutionary origin enrich our understanding of the behavioral phenomena [Skinner, 1972].

In accordance with Skinner's point of view we need to simply describe the features of different shades of human behavior. Then we climb up to the next rung, which is explanation about what we have closely observed. This stage explains the conditions related to the occurrence of the behavior. After having identified and explained the properties, the next stage is to characterize the verbal behavior within a framework.

Response is an aspect of verbal behavior. Some responses are committed to particular functions and are generated by specific stimuli or their antecedents, others are

implicitly unrestrained in their potential interaction with the environment [Palmer and Donahoe, 1992]. Webber defines a response as:

> …respondent's complete informative and performative reaction to the question which can include…additional information or actions performed that are salient to this substitute for an answer. [Webber, 1986, p. 366]

The next chapter specifically investigates the responses crafted by the expert tutors while tutoring the circulatory system in one-on-one tutoring sessions. The tutor and student communicate with each other using PCs. The subset of tutor responses which come from responding to just student initiatives, provides us with a good source of data. Moreover the accessibility of the expert tutors is another invaluable resource for our analysis, as explained in Chapter IV.

CHAPTER IV

TUTOR RESPONSES TO STUDENT INITIATIVES

This chapter examines tutor responses to student initiatives in one hour and two hour sessions of keyboard-mediated tutoring recorded in the form of transcripts. We then use this analysis to propose an approach to generating such responses in CIRCSIM-Tutor. The need to generate adequate responses with respect to initiatives caused us to reanalyze the categories proposed by Sanders et al. [1992]. This study led us to the classification of student initiatives described in Chapter V.

To understand the student initiatives better we started off with studying the tutor responses to the student initiatives. The step was taken in this direction in order to gain insight through the tutor's reaction to the action taken by the student. Not only do the tutor responses tell us how they understood the student's initiatives, but we can also discuss and confirm the results with the real tutors. The knowledge about why and how the tutor is reacting to student initiatives provided us with some insight into the causes of the student's actions at least as the tutor perceives them. We went through the transcripts and tried to investigate the processes behind the generation of responses by the tutor. We noticed that tutors respond in different ways or with different rates and lengths to each of the student initiatives, but some particular response patterns occur. The student or tutor behavior can be understood according to distinct initiatives and different responses arranged into patterns.

The tutors respond to the student's changing needs and past performance. For current computer tutors, in which communication takes place through written text within a narrow bandwidth, the tutor response can better be rationalized if we look at it from three dimensions. These dimensions are the communicative intentions, the surface form of the expression to realize these communicative goals, and the delivery mode.

4.1 Classification of Tutor Responses to Student Initiatives

Cognitive structures are involved even in simple judgments, like discrimination. The sentence is regarded as the written realization of a meaningful idea. Our study of the keyboard-to-keyboard transcripts suggests that we can approach the problem of responding to student initiatives in CIRCSIM-Tutor from the perspective of communicative intention, delivery mode, and surface structure. The three aspects we consider are:

1. Communicative Goal
2. Delivery Mode
3. Surface Form

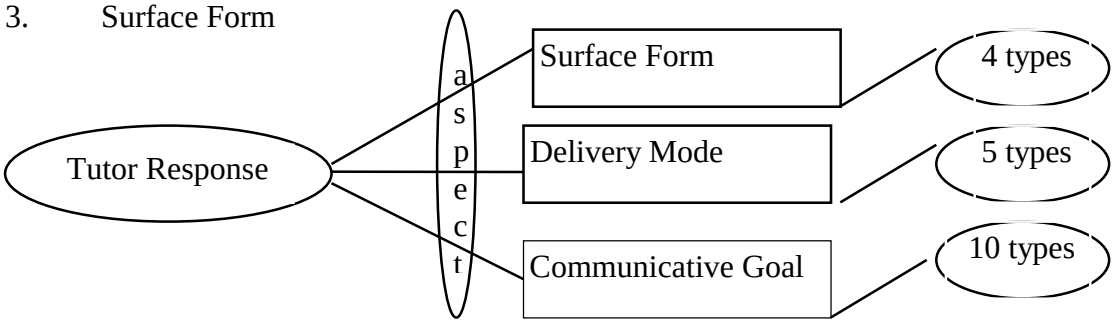


Figure 4.1 Potential Categories of Tutor Responses

As Figure 4.1 illustrates, the tutor performs a sequence of activities during the formulation of a response. Figure 4.2 looks at the response phenomenon as a function of three variables and mirrors the classification of responses associated with the variables.

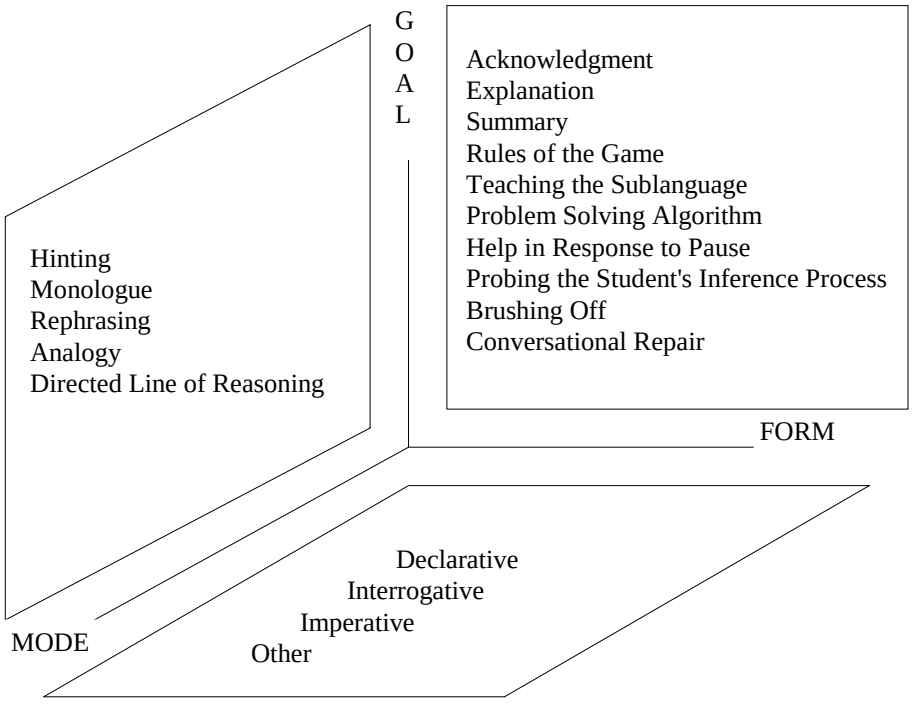


Figure 4.2 Classification of Tutor Responses in Three-Dimensional Space

The communicative goals are connected with what to teach, the delivery modes are associated with how to teach, and the surface forms are related with how to express the message. A more detailed discussion of the theory appears in the subsequent sections.

4.1.1 Communicative Goal. “The mother of each speech act is communicative intention.” said Levelt [1989, p.108]. In Chapter V, we also use the communicative goal of the student as one of the dimensions in the classification of student initiatives. Setting

of a communicative goal by the tutor is the first step in the generation of a response. This step is initiated by the conception of some communicative intention, which is the gist of the utterance. Grosz and Sidner [1986] relate most of the topics of conversation with the intentional structure of the discourse, that is, the hierarchy of goals and subgoals being developed.

We classified the tutor responses to student initiatives with respect to this axis using ten communicative goals as given below:

G1 Acknowledgment

G2 Explanation

G3 Summary

G4 Instruction in the "Rules of The Game"

G5 Teaching the Sublanguage

G6 Teaching the Problem Solving Algorithm

G7 Help in Response to Pause

G8 Probing the Student's Inference Process

G9 Brushing Off

G10 Conversational Repair

These goals motivate the tutor responses. They also support introducing discourse topics that are shared by the tutor and student. Let me illustrate them one by one.

4.1.1.1 Acknowledgment. An acknowledgment tells the student whether an explanation is correct or not. It provides evidence of understanding provided in

response to the student's act. The student presents an initiative to the tutor to recognize, and the tutor communicates that he understood what the student meant. The acknowledgment may be positive or negative depending upon the follow up question or theory presented by the student. It may be made in a very simple or complex manner.

EX. 4.1a

K6-st-60-1: Does the direct affect steady state more than the reflexes?
K6-tu-61-1: Yes.

EX. 4.1b

K4-st-48-1: How about the RAP, which may have an effect on how much blood is reaching the ventricle.
K4-tu-49-1: Definitely, RAP affects ventricular filling.

EX. 4.1c

K12-tu-33-1: By what mechanism will it increase?
K12-st-34-1: If you increase pressure will you momentarily increase resistance
K12-tu-35-1: No.
K12-tu-35-2: You may be thinking of autoregulation.
K12-tu-35-3: That's slow.
K12-tu-35-4: Remember that we're dealing with the short period before you get a reflex response.
K12-tu-35-5: Is this what you had in mind?
K12-st-36-1: Yes i guess i am not sure then what happens to tpr

EX. 4.1c illustrates a compound category of tutor response that is comprised of a negative acknowledgment, followed by an elaboration. The tutor generates an explanation usually after the negative acknowledgment. The explanation is ended with a question. It asks if the tutor has been successful in responding to student's query or if the student has received the information precisely transmitted by the tutor.

4.1.1.2 Explanation. The response to different requests may be an explanation of varying length. Appropriate explanations are constructed based on the conception of communicative intention and on the content of the student question or theory. Usually an act of commission or omission on the part of the student gives rise to this response. Often the explanation targets underlying parameters and causal relations between the predicted and predictor variables. The tutor manipulates other factors like interaction and mode of delivery in explaining the relationships. The explanation often ends with a follow up question. For example:

EX. 4.2a

K16-st-38-1: I think i am getting contractility mixed up with stroke volume...
K16-st-38-2: Contractility is the force of contraction that i think goes up with increased heart rate, but i am not sure how
K16-tu-39-1: Ok, let me explain.
K16-tu-39-2: The length-tension relationship of muscle says that as length goes up (as the ventricle fills more|) the force of contraction will increase.
K16-tu-39-3: Changes in contractility result in changes in force at the same fiber length or same filling.
K16-tu-39-4: What input to the heart causes contractility to change?
K16-st-40-1: Sypmathetic stimulation
K16-tu-41-1: Right.

EX. 4.2b

K12-tu-35-5: Is this what you had in mind?
K12-st-36-1: Yes i guess i am not sure then what happens to tpr
K12-tu-37-1: What is the primary mechanism of control of TPR?
K12-st-38-1: Radius of arterioles
K12-tu-39-1: Yes.
K12-tu-39-2: And what is the primary mechanism by which arteriolar radius is controlled?
K12-st-40-1: Sympathetics
K12-tu-41-1: Yes.

K12-tu-41-2: And we're dealing with the period before any change in nervous activity occurs.
K12-tu-41-3: So what do you think about TPR now?
K12-st-42-1: It stays the same.

In EX. 4.2a the student is requesting information to fill the gap. The hedged statement made by the student is an indication of her lack of confidence in her knowledge. She is unsure about the process that controls TPR. The tutor responds with an explanation using the mode of directed line of reasoning.

EX. 4.2b

K4-st-48-1: How about the RAP, which may have an effect on how much blood is reaching the ventricle.
K4-tu-49-1: Definitely, RAP affects ventricular filling.

Here the student is proposing a mini-theory and asking the tutor for confirmation. The tutor responds with an acknowledgment while launching an explanation, too. The amount of detail may vary.

4.1.1.3. Summary. The tutors choose to summarize often in all types of tutoring dialogue. They often use this strategy of reinforcing important concepts in responding to student initiatives.

EX. 4.3.

K34-st-171-1: OK.
K34-st-171-2: Now that I think about it, if afterload goes up (MAP), the heart will pump less blood out, so CO would go down.
K34-tu-172-1: THAT's correct, if MAP goes up CO goes down.
K34-tu-172-2: What determinant of CO goes d own?
K34-st-173-1: SV

K34-tu-174-1: Great.
K34-tu-174-2: Let me summarize that little bit.
K34-tu-174-3: When the agonist constricts the arterioles TPR I causing MAP I causing SV D causing CO D causing RAP I.
K34-tu-174-4: O K?
K34-st-175-1: Yes.

4.1.1.4 Instruction in the "Rules of the Game." In this response the tutor is telling the student about how to proceed. The student forgets or does not know the protocol, does not understand what the tutor expects. S/he is expected to be aware of the three different stages and of the setting of the procedure before applying her/his knowledge of the causal relationships to solving the problem at hand.

EX. 4.4.

K27-st-13-1: Predict using arrows?
K27-tu-14-1: You can fill out the prediction table i gave you using arrows or +/-/0.

4.1.1.5 Teaching the Sublanguage. The tutor is concerned about teaching the correct usage of the language of physiology. Indeed, this is one of the most important reasons for implementing a natural language dialogue in CIRCSIM-Tutor.

EX. 4.5.

K12-st-46-1: Does the rate of blood removal from the central veins mean that blood entering the right atrium, if so i think venous return does go up immed.
K12-tu-47-1: We need to get our terminology straight.
K12-tu-47-2: Venous return means blood returning from the systemic circulation to the heart.
K12-tu-47-3: That does not go immediately.

K12-tu-47-4: It takes about a minute after CO I.
K12-tu-47-5: Does more blood enter the ventricle for CO to I, Yes.
K12-tu-47-6: But it's coming from the blood content of the ventricles (end systolic volume -- reserve), pulmonary blood volume, central venous volume.
K12-tu-47-7: Immediately after CO I, the entire central blood chamber decreases in volume.
K12-tu-47-8: That's because CO exceeds VR.

4.1.1.6 Teaching the Problem Solving Algorithm. A major goal of the tutor is making sure that the student understands how to solve problems. The student needs to learn how to carry out a sequence of steps using causal reasoning. In the example below the tutor responds to the initiative by pushing the student to go back to the start of the causal reasoning process.

EX. 4.6.

K12-st-62-2: I'm just hesitant to say what comes first.
K12-st-62-3: I'll go with tpr i to slow blood flow back to heart (i don't really like this idea)
K12-tu-63-1: Well let's see if we can get at the first question I asked and then we'll come back to TPR.

4.1.1.7 Probing the Student's Inference Processes. The tutor encourages the student in active learning through self explanation. This provides the tutor with feedback that helps him in student plan recognition. This also helps the tutor to update his model of the student and generate justifications of his own reasoning and behavior. For example:

EX. 4.7.

K5-st-102-2: But I'll bet that's not right.

K5-tu-103-1: Well you're right in your bet.
K5-tu-103-2: SV D because CC D.
K5-tu-103-3: That doesn't mean that RAP has to be D!
K5-tu-103-4: Let me remind you again of the vascular function curve.
K5-tu-103-5: Does that help?
K5-st-104-1: RAP I.
K5-tu-105-1: Would you explain.
K5-tu-105-2: You're right but I just want to hear what you'r thinking.

4.1.1.8 Extending Help in Response to Pause. When the tutor notices a delay on the student side, he intervenes to offer his help. This is another tutor tactic to assist the student in active learning. This kind of response is used whenever the student seems to be lost, or reaches a dead end, or wants to disengage, or feels too exhausted to expend effort. This tactic works as a response for the pause initiative. (The label on the last line of this example contains "ti" instead of "tu" to indicate that this is a tutor interruption.)

EX. 4.8.

K5-st-42-1: Yes, MAP=CO * TPR.
K5-tu-43-1: Right.
K5-tu-43-2: We went through that before.
K5-tu-43-3: How about yet another variable.
K5-st-45-1: I don [big pause here]
K5-ti-46-1: Need help?

4.1.1.9 Brushing Off. Sometimes the tutors decide to avoid or put off discussion and bring the dialogue back to issues of higher priority. The same kind of response is used when the tutors do not understand what the student is driving at. In the following example the tutor seems to take control of the dialogue, pursuing his own goals rather than responding to those of the student.

EX. 4.9.

K16-st-46-2: Is sympa stimulation the only factor influencing cc?
K16-tu-47-1: It is in the experiment we are discussing today.
K16-tu-47-2: All of your other DR predictions were correct, so please read page 6 so we can go on.

4.1.1.10 Conversational Repair. Repair is done to avoid misunderstanding and correct misconceptions. As McRoy and Hirst [1995] say:

> Misconceptions are errors in the prior knowledge of a participant. Some such errors can be recognized easily when an expression is not interpretable with respect to the computer's knowledge of the world. In misunderstanding, a participant obtains an interpretation that she believes is complete and correct, but which is, however, not the one that the other participant intended her to obtain [p. 436].

If the misunderstanding is not noticed at once, the conversation may break down at a later stage. So it is very important to make an attempt to resolve the issue immediately. Presently we are restricting ourselves to conversational repair most of the time with respect to the language issue. The extracts of conversation taken from various transcripts of tutorial sessions shown in the following examples depict some forms of conversational repair.

EX. 4.10a

K5-tu-79-2: Now, where do you want to go?
K5-st-80-1: CO D.
K5-tu-81-1: Right.
K5-tu-81-2: Why?
K5-st-82-1: Because CC D.
K5-tu-87-1: So?
K5-st-88-1: I don't understand.
K5-tu-89-1: How does CC D affect CO?

EX. 4.10b

K2-st-29-1: I am not familiar with a "curce" relationship
K2-tu-30-1: Sorry I mistyped it should be "curve", the vascular function curve.

EX. 4.10c

K2-st-9-1: What do you mean by "pass the effect"?
K2-tu-10-1: I mean that the system behaves as though the left ventricle was filling from the right atrium.
K2-st-11-1: Ok

Notice the mark of understanding where the interpretations (beliefs) of the two participants converge.

4.1.2 Delivery Modes. The tutor uses different delivery modes like explanation, hinting, directed line of reasoning, analogy, and rephrasing to express different communicative goals [Hume et al., 1996]. These styles are used to increase the adequacy, smoothness, manner and productiveness of the interactive dialogues. We studied how the tutors engage in a conversation, sustain it, and disengage from it. Hinting is a frequently used tactic. Hints prompt the student to remember and organize the information that s/he already possesses. A directed line of reasoning is a series of questions and answers that push the student through the problem solving process. The different types of delivery modes used by the tutor are discussed as follows:

- ➢ Hinting
- ➢ Directed Line of Reasoning
- ➢ Monologue
- ➢ Rephrasing

➢ Analogy

4.1.2.1 Hinting. The tutors' desire to encourage active learning convinces them to prompt the student with hints. Hinting or reminding is a strategy that stimulates the recall of inert knowledge or activates the inferences needed in the completion of a task [Hume, 1995]. Recall or remembering involves the reactivation of a given memory trace that revives the same conceptual processes that correspond to the original perception. In recall, a hint triggers and amplifies the intensity of a particular trace to raise it over the threshold of cognizance [Bower and Hilgard, 1981, p. 311]. Hume noticed different types of hints in various forms embedded in the tutor's response. We have also used Hume's categories:

a. Convey Information Hint (CI-Hint) and

b. Point to Information Hint (PT-Hint)

The CI-Hints convey information directly to the student. For example:

EX. 4.11a

K3-tu-51-2: And how might RAP change in the DR period?
K3-st-52-1: The RAP would not change in the Dr period.
K3-st-52-2: The RAP will not increase for about 1-2 minutes-the time it takes for the blood pumped out of the left ventricle to return to the right atrium.
K3-tu-53-1: The venous return may not change for a couple of minutes but what about the rate at which blood is being removed from the central blood compartment?
K3-st-54-1: That rate would increase, perhaps increasing RAP???
K3-tu-55-1: You are correct the rate of removal of blood would increase because CO is going up.

K3-tu-55-2: But if you take blood out of the central venous compartment faster than it is returning, what happens to the central venous (I.E. RAP) pressure?

The PT-Hints point to pertinent information but do not explicitly convey information to the student. How the tutor points to a piece of information can be seen in the following example (in K5-tu-103-3):

EX. 4.11b

K12-st-76-2: So i think that tpr goes down
K12-tu-77-1: Your answer is right but for all the wrong reasons.
K12-tu-77-2: Let's get back to this reflex.
K12-tu-77-3: What is it trying to do in this patient?

The tutor understands the nature of the student initiative that contains a hedge and reflects the misconception of the student. He recognizes the error in her previous knowledge, i.e., the situation of RAP during a minute or two. The tutor responds by acknowledging the correct part of the student answer and pointing to a hint on the incorrect part he thinks is a source of her mistake.

4.1.2.2 Directed Line of Reasoning. A Directed Line of Reasoning (DLR) is a dialogue segment in which the tutor prompts the student in small steps through the reasoning process toward the solution of the problem. A DLR is most often a series of questions and answers, but clearly the tutor plans this sequence as a coherent multiturn dialogue. A DLR serves sometimes as an interactive explanation or as an interactive summary process. This style is adopted in order to lead the student toward a good mental model of reasoning needed for correct knowledge.

EX. 4.12.

K12-st-36-1: Yes i guess i am not sure then what happens to tpr
K12-tu-37-1: What is the primary mechanism of control of TPR?
K12-st-38-1: Radius of arterioles
K12-tu-39-1: Yes.
K12-tu-39-2: And what is the primary mechanism by which arteriolar radius is controlled?
K12-st-40-1: Sympathetics
K12-tu-41-1: Yes.
K12-tu-41-2: And we're dealing with the period before any change in nervous activity occurs.
K12-tu-41-3: So what do you think about TPR now?
K12-st-42-1: It stays the same
K12-tu-43-1: Correct.

4.1.2.3 Tutor Monologue. Based on the tutor's assessment of student understanding, when the tutor thinks that the student has no clue about what is going on, the tutor may give a long or brief explanation.

EX. 4.13a

K2-st-41-2: Now I am having a hard time visualizing the concept of RAP from the previous section.
K2-st-41-3: I would guess that an increase in right atrial volume would increase the pressure due to the equation relating tpr, co, and p.
K2-tu-42-1: Agreed, SV would decrease -- because of the fall in CC.
K2-tu-42-2: I don't know what equation you're referring to.
K2-tu-42-3: Maybe you could write it out for me.
K2-tu-42-4: But first let me explain the sequence of events visa vis RAP.
K2-tu-42-5: The increase in CC raises SV but the reflex can't also raise HR.
K2-tu-42-6: Hence, the change is SV is the only way in which CO canbe affected.
K2-tu-42-7: The fall in CO (from the fall in SV) causes RAP to rise.
K2-tu-42-8: But its rise can only limit the fall in SV, it can't completely override it.
K2-tu-42-9: That would be like pulling yourself up by the bootstraps.
K2-tu-42-10: Any question about this.
K2-tu-42-11: If not go on making your predictions.

EX. 4.13b

K20-st-35-1: I THOUGHT I GOT THIS ONE WRONG!!
K20-st-35-2: DETERMINANTS ARE END-DIASTOLIC VOLUME, AFTERLOAD I. E. MAP, AND I THINK TO A SMALL DEGREE, HEART RATE.
K20-st-35-3: SO I THINK THAT SV GOES UP.
K20-tu-36-1: Well that's partly correct.
K20-tu-36-2: EDV is certainly a determinant.
K20-tu-36-3: Afterload (I. E. aortic pressure is important but only when it (MAP) is very high.
K20-tu-36-4: Otherwise MAP has little effect on SV.
K20-tu-36-5: HR????
K20-tu-36-6: It affects SV but only through its effect on CC.
K20-tu-36-7: CC is the second important determinant of SV.
K20-tu-36-8: So what do you think happens to SV, given this info?

4.1.2.4 Rephrasing. The tutor often rephrases what he said earlier when the student signals a need for conversational repair, with the goal of helping the student or clarifying the issue. This tactic is also used to correct the student's use of the language of physiology.

EX. 4.14a

K4-tu-79-2: Now we've got a decrease in TPR and a decrease in CC.
K4-tu-79-3: And a resultant decrease in MAP during this reflex period.
K4-tu-79-4: What would happen next?
K4-tu-79-5: {PAUSE} Let me add something.
K4-tu-79-6: How are the falls in TPR and in CC connected to the decrease in MAP?
K4-st-80-1: I don't think I understand the question.
K4-tu-81-1: What are the determinants of MAP?

EX. 4.14b

K5-st-84-1: CO D.
K5-tu-85-1: Right.
K5-tu-85-2: Why?
K5-st-86-1: Because CC D.
K5-tu-87-1: So?
K5-st-88-1: I don't understand.

K5-tu-89-1: How does CC D affect CO?

4.1.2.5 Analogy. Sometimes the tutors use analogy for catching the attention and interest of the students. Analogy transforms knowledge from one situation to another that is somewhat similar. It gives a framework for understanding and organizing the concepts of the domain knowledge.

EX. 4.15.

see EX. 4.13a

The tutor is using the analogy of "pulling oneself by the bootstraps" to make the concept of RAP and its relation with other parameters clear. Similarly other terms like elastic, pump, gravitational pull, and balloon are used as analogies in response to student's trouble in understanding. Black says that analogies are a frequently encountered kind of comparison network in which two or more episodes, mechanisms, descriptions, or arguments are compared and contrasted by highlighting similarities and differences [Britton and Black, 1985, p. 258].

4.1.3 Surface Form. Grammatical encoding of communicative goals in a certain style of presentation produces a surface form. Some frequent sentence forms are: an imperative, a declarative, an interrogative (question), a fragment or a combination of these forms grouped together as a segment type.

EX. 4.16.

K15-st-68-1: Im not sure; I think an increase in rap would increase preload and therefore increase co, but then would an increased co lower rap?
K15-tu-69-1: You are correct; co and rap are inversely realted to each other.
K15-tu-69-2: Let's think about this situation this way. [imperative]
K15-tu-69-3: By what means would you expect the reflex to decrease map?

EX. 4.17.

K2-st-9-1: What do you mean by "pass the effect"?
K2-tu-10-1: I mean that the system behaves as though the left ventricle was filling from the right atrium. [declarative]

EX. 4.18.

K16-st-36-1: Do you mean the number of cross-bridges that are able to be formed b/w actin and myosin depending on the length of a cardiac muscle fiber
K16-tu-37-1: No.
K16-tu-37-2: Does changing the length of the muscle change its CONTRACTILITY? [Interrogative]

EX. 4.19.

K20-st-39-1: YES BUT IT DEPENDS ON WHICH VARIABLE IS INDEPENDENT.
K20-st-39-2: I THOUGHT THAT WHEN C. O. WAS THE INDEPENDENT VARIABLE, RAP VARIES INVERSLEY.
K20-st-39-3: BUT WHEN RAP IS THE INDEPENDENT VARIABLE C. O. VARIES DIRECTLY
K20-tu-40-1: Correct again. [other]

A segment is a sequence of sentences grouped together. How they are dealt with in the current approach is discussed in Section 4.2. A good survey of the work in discourse segment structure can be found in Allen's book [1987, pp.398-424].

4.2 A Specific Example

We have discussed a pattern for classifying tutor responses. The examples in this section illustrate the utilization of this pattern in the context of tutor responses to student initiatives.

EX. 4.20.

K3-tu-53-1: The venous return may not change for a couple of minutes
but what about the rate at which blood is being removed vfrom the central blood compartment.
K3-st-54-1: That rate would increase, perhaps increasing RAP???
K3-tu-55-1: You are correct the rate of removal of blood would increase because CO is going up.
K3-tu-55-2:But if you take blood out of the central venous compartment faster than it is returning, what happens to the central venous (I.E. RAP) pressure?

The tutor response to the student initiative (in K3-54-1) spans two sentences: K3-55-1 and K3-55-2. This adds to the complexity of the language part. Section 4.3 sheds some light on this issue.

K3-tu-55-1, K3-tu-55-2

Surface Form: Declarative, Interrogative

Communicative Goal: Acknowledgment + Explanation

Delivery Mode: Monologue + Hinting

4.3 Formulating Responses

How can we make CIRCSIM-Tutor produce the desired responses to student initiatives? We observed that most of the time some cue phrases or words help in

classifying not only the tutor responses but also provide us with the hint to classify student initiatives. Reichman says that in discourse some types of constituents can appear in isolation, whereas the interpretation of others is contingent on the presence of some other constituents. For example we can not support a statement without a claim or we can not explain a theory without some topic to be explained [1985, p. 24]. Further discussion can be found in Chapter VII. The distinctions used to classify responses are summarized in Table 4.1.

Table 4.1. Clue Words used for Response Generation

Clue Words	Responses
Question, guess, perhaps, how about, also, so, bet, think, thinking, may be, but with decl., would?	Acknowledgment + Explanation Probing the Student's mind Teaching: Rules of the Game, Sublanguage, Problem Solving
Question, unclear, still, would, hard, hesitant, not sure, ask, discuss, explain, but with declarative statement, though, trouble, let, confused, thought, but (if) with ?, just, see, i.e., sort of, I don't know	Explanation Brushing Off Teaching: Rules of the Game, Sublanguage, Problem Solving
Pause,	Help in response to Pause
Question, mean, familiar, previous, understand,	Conversational Repair

The system needs to recognize the student's plan, and identify the impasses in her/his plan of execution. Once the repair is made or any other misconception is removed

by providing the information requested or needed from the student. It, then, can continue with its topmost uncompleted plan on the plan stack. The lexical items like OK, understand from the student side are taken as tokens of alignment or coming closer to the same lines of thinking. They mark the state of acceptance of a response from the tutor side.

4.3.1 Response Generation. Figure 4.3 gives an outline view of how responses may be generated.

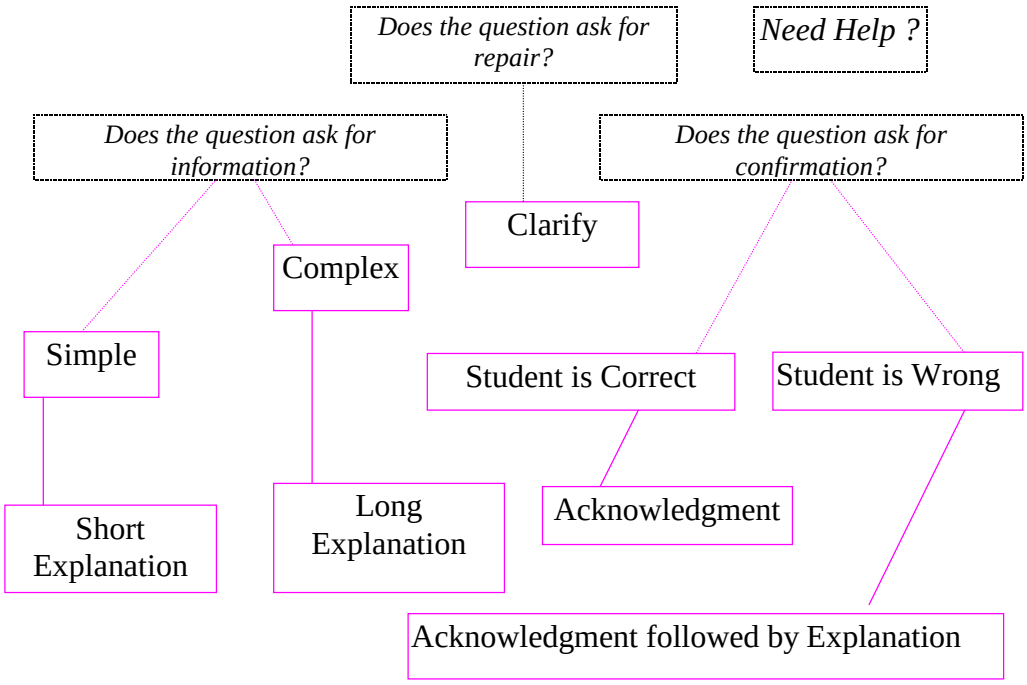


Figure 4.3 Output Synthesis

The output is synthesized in response to an initiative analyzed by the input understander.

4.4 Some Phenomena in the Formulation of Responses

It is perceived that sometimes the tutors just ignore or brush off the student. Our experts tell us that they usually choose this response when they do not understand the students goal. On the other hand the tutors may go on at great length while responding to student initiatives.

EX. 4.21.

K15-st-84-1: Cc d, but i really still dont understand why
K15-tu-85-1: You're right and we'll talk about it further if there is time.
K15-tu-85-2: what next?

The tutors use complete sentences much more than the students, yet they sometimes use elliptical language too. Sometimes we see complexities and subtleties in the structure of the surface forms, i.e., the sentences are in a compound form or a compound-complex form. For instance, sentence K15-tu-85-1 is a compound sentence with two independent clauses and a subordinate clause (introduced with the subordinating conjunction *if*) attached to one of the independent clauses.

EX. 4.22.

K16-st-38-1: I think i am getting contractility mixed up with stroke volume...
K16-st-38-2: Contractility is the force of contraction that i think goes up with increased heart rate, but i am not sure how
K16-tu-39-1: Ok, let me explain.
K16-tu-39-2: The length-tension relationship of muscle says that as length goes up (as the ventricle fills more) the force of contraction will increase.
K16-tu-39-3: Changes in contractility result in changes in force at the same fiber length or same filling.
K16-tu-39-4: What input to the heart causes contractility to change?
K16-st-40-1: Sympathetic stimulation

The tutor response to the student initiatives in K16-38-1 and K16-38-2 is an explanation consisting of four sentences. The delivery mode is tutor monologue. The communicative goal is teaching the problem solving algorithms. The first one begins with the adverb (single-word modifier) “ok”, followed by an imperative sentence. The rest of the sentences are:

K16-tu-39-2	Surface Form: Declarative
K16-tu-39-3	Surface Form: Declarative
K16-tu-39-4	Surface Form: Interrogative

Here the tutor responds by opening an explanation and ending with a follow up question. Generally the response pattern to a student request for confirmation is an acknowledgment followed by an explanation followed by a question. The length and the style adopted in the explanation varies. Often the explanation is delivered as a directed line of reasoning.

EX. 4.23.

K11-st-18-1: Let me restate my question.
K11-st-18-2: What do you mean by, "predict the changes in the variables in an order that would b
K11-tu-19-1: Let's see if I can lead you through it.
K11-tu-19-2: In this problem, what is the first variable that's going to be affected by the pacemaker malfunction and in what direction will it change?
K11-st-20-1: Hr
K11-tu-21-1: Yes.
K11-tu-21-2: In which direction?
K11-st-22-1: I
K11-tu-23-1: Yes.
K11-tu-23-2: Now, if HR I, what would it directly affect NEXT.?

Tutors end with a follow up question very often. This is to make sure that the student has understood well before moving on to the next remediation effort. If the student indicates some evidence of understanding then the tutor ends an explanation with a prediction question. For example:

EX. 4.24.

K11-st-58-1: But, it is ALSO under intrinsic control
K11-tu-59-1:You are confusing Starling's Law with a change in contractility.
K11-tu-59-2: The length/tension relation of the heart is not a change in contractility.
K11-tu-59-3: A change in contractility moves the length/tension curve from one location to another.
K11-tu-59-4: Increased contractility means that at a given EDV you get more contractilty performance out of the ventricle.
K11-st-60-1: Ok
K11-tu-61-1: So what's your prediction about CC?

The tutor, in the above examples coming from session K11, is Allen Rovick.

Joel Michael often seems to be probing the student's mind at the end of an explanation, and wants the student to think and come up with the right answer if possible. For example:

EX. 4.25.

K12-st-34-1: If you increase pressure will you momentarily increase resistance
K12-tu-35-1: No.
K12-tu-35-2: You may be thinking of autoregulation.
K12-tu-35-3: That's slow.
K12-tu-35-4: Remember that we're dealing with the short period before you get a reflex response.
K12-tu-35-5: Is this what you had in mind?

EX. 4.26.

K16-st-78-1: One question first.
K16-st-78-2: Does ss indicate that the reflex mechs have completely kicked in?
K16-st-78-3: If so, my next prediction is co i
K16-tu-79-1: In the ss period, the reflex is as active as it is going to be and the cv system is operating in a new steady state level.
K16-tu-79-2: with this in mind what do you want to predict now?

The tutor tends to hint instead of delivering the whole information or the complete answer [Hume, 1996].

Time is a critical factor, and if the tutors notice some pause or impasse on the student side, they prefer to intervene and keep the dialogue going. They plan the response in such a collaborative fashion that they mostly reach the solution by working together. The tutors recognize the student misconceptions and respond with the words and style that lead the student on to the right track in the subject domain.

After having classified the tutor responses along three dimensions (surface form, communicative goal, delivery mode), the next task is to build a classification scheme for student initiatives. This scheme is described in the next Chapter V.

CHAPTER V

RECATEGORIZING STUDENT INITIATIVES

This chapter introduces a revised taxonomy of student initiatives in tutoring dialogues. We define a student initiative as any attempt by the student to take control of the dialogue and change its course. The need to generate adequate responses with respect to distinctly classified initiatives caused us to reanalyze the categories proposed by Sanders et al. [1992].

We describe our categories of student initiatives with examples from the keyboard transcripts of the sessions. A category "Pause" is included to signify lengthy pauses in a tutorial dialogue. Two of our colleagues have used these guidelines to classify the student initiatives in twenty eight tutoring sessions. We have compared the results with the categories agreed on by Martha Evens and me. The next step was to test the inter-rater reliability. These results are given in Chapter VI. This work will be used eventually in modeling and understanding cooperative dialogue, enabling CIRCSIM-Tutor to understand and respond to more initiatives on the part of the student. The goal is ultimately to achieve effective mixed initiative problem-solving interactions with students of physiology.

5.1 Previous Work

Sanders [1995, p. 65] worked on identifying and classifying the student initiatives and came up with eight different categories with some subcategories as follows:

Class 1: The student asks a question

1a = Student asks a non-sequitur question

1b = Student is not requesting repair, but unaware of the "instructional rules"

1c = Student request for confirmation

1d = Student asks other sorts of questions

EX. 5.1a K6-st-30-1: Does it relate co and mean arterial pressure inversely?

EX. 5.1b K13-st-24-1: Cc i maybe

EX. 5.1c K5-st-51-1: So, when CO I, the CVP will D?

EX. 5.1d K4-st-80-1: Would the CVP also fall if the MAP is decreased?

Class 2: The student is having trouble "seeing" something or another (the student is not mainly requesting repair)

2a = Student is having trouble in perceiving the topic under discussion.

2b = Student gets confused with concepts and can't see the difference clearly.

EX. 5.2a K4-st-84-1: I don't think I understand the question?

EX. 5.2b K16-st-38-1: I think i am getting contractility mixed up with stroke volume...

Class 3: The student requests repair (the student did not understand the tutor)

3a = Student requests repair, not familiar with the lingo of physiology

3b = Student requests repair

EX. 5.3a K13-st-6-1: What does dr rr and ss stand for

EX. 5.3b K2-st-31-1: I am not familiar with a "curce" relationship

Class 4: Do repair (the tutor did not understand the student)

4a = Student does repair thinking tutor did not understand her/him.

4b = Student does repair thinking tutor has overlooked what s/he said before.

EX. 5.4a K22-st-79-1: May be i should clarify what i mean by hr o.
K22-st-79-2: I mean that the body has no control since it's artificial so it will still be d

EX. 5.4b K25-st-87-1: Didn't you let me do co before sv in dr?

Class 5: Hedging by the student

5a = Student hedges by making defensive statement.

5b = ..., perhaps, , ...??{?}*or equivalent explicit surface flags etc.

EX. 5.5a K7-st-40-1: Sort of

EX. 5.5b K3-st-54-1: That rate would increase, perhaps increasing RAP???

Class 6: Explicit backward reference to some earlier topic, event, time, etc. The reference could be to something talked about earlier in the current session ("Could we talk about X some more?) or it could be to previous sessions, conversations, class sessions, etc.

6a = Explicit backward reference in the same session (shift of focus)

6b = Explicit backward reference to some other previous session

EX. 5.6a K2-st-33-2: In your previous question were you looking for a change in position from supine to erect (that will trigger a decrease in filling?)

EX. 5.6b K20-st-93-1:YEAH, IT IS FROM ANOTHER CIRCSIM PROGRAM THOUGH.

Class 7: Initiatives specific to the keyboard-to-keyboard environment used in these sessions (asking about something that is now off the screen)

7a = Student asks something reflecting a deficiency in the human interface.

EX. 5.7a K17-st-61-1: May I type the entire seven entries at once in the

order of the table?

Class 8: Administrivia

8a = Administrative trivia

8b = Student wants permission to bring changes in some entries.

8c = Student wants permission to ask a question.

EX. 5.8a K12-st-58-2: Do I have to finish by 4, or just get as far as I can

EX. 5.8b K14-st-68-1: Can I change my last prediction?

EX. 5.8c K16-st-72-1: Can i ask you something...

5.1.1 Issues. The main issues faced in this classification were:

A) How can it help in understanding the student plans?

B) How can one discriminate class 1 from classes 2, 3, and 5?

C) How can one classify the initiatives left unclassified by Sanders [1992]? Some of them are given below.

EX. 5.9.

K3-st-54-1: That rate would increase, perhaps increasing RAP???
K3-tu-55-1: You are correct the rate of removal of blood would increase because CO is going up.
K3-tu-55-2: But if you take blood out of the central venous compartment faster than it is returning, what happens to the central venous (I.E. RAP) pressure?

EX. 5.10.

K5-st-45-1: I don {PAUSE}
K5-ti-46-1: Need `help?
K5-st-47-1: Yes.
K5-tu-48-1: Do you remember the vascular function curve?
K5-st-49-1: No.

EX. 5.11.

K5-tu-50-1: The vascular function curve shows the relationship between CO and central venous pressure, when CO is the independent variable (i.e. when it changes first).
K5-tu-50-2: Now do you remember?
K5-st-51-1: So, when CO I, the central venous pressure will D?
K5-tu-52-1: Absolutely correct.
K5-tu-52-2: What variable is essentially the same as central venous pressure?
K5-st-53-1: RAP.
K5-tu-54-1: Right.

We observed that several different kinds of initiatives are hedged. Students seem to ask for help in many ways. These facts and the many initiatives remaining unclassified convinced us to try a multidimensional classification system. We began by classifying the tutor responses to student initiatives, and then we stepped into designing a new classification scheme for student initiatives.

We note that Sanders left more than a third of the initiatives (35%) unclassified. He also obtained very poor inter-rater reliability.

I agree with the argument of Dale and Reiter [1995, p. 237]:

> Any work in natural language generation is faced with the problem of deciding what kind of input representation to start from; it is this that determines in large part how hard or how easy the generation task will be.
>
> We consider it essential to define what kind of input must be taken care of and how.

5.2 Student Initiatives in CIRCSIM-Tutor Version 2

At the moment CIRCSIM-Tutor starts by trying to interpret the student input as an answer. If it cannot make a connection between the tutor question and the student input then it tries to interpret the student input as an initiative.

In Woo's [1992] version of a multilevel dynamic instructional planner for the tutoring system, there is an option for handling a limited mixed initiative strategy. When the student takes an initiative in the form of a question, the plan controller monitors the discourse planner to suspend the current plan and attend to the student request and resume the suspended plan by using the goal stack. The planner restricts the type of student initiatives to just a few. For example, if the system asks a question like what are the determinants of SV? and the student answers in return, I don't know about SV, then the input understander recognizes it as an implicit question and comes up with a logic form as follows:

Student Initiative: I don't know about SV.

Logic Form: (question (define SV))

The planner receives the logic form and acknowledges it as a student initiative. It stacks the current plan and attends to the student request by asking the problem solver to provide the definition of SV from the knowledge base, and then calls the screen manager to display it. The screen manager does its job by displaying the definition as a tutor response in the tutor window. The system responds in the same way when a student types: "What is SV?" or "I am confused about SV."

5.3 Classification of Student Initiatives

Looking at examples of student initiatives convinced us that we could classify both initiatives and responses better if we studied them together. We decided to try to categorize student initiatives along four dimensions:

- Surface Form
- Communicative Goal
- Focus or Content
- Degree of certainty expressed - Is the student hedging or not? (as in Lakoff, 1973)

The dimensions and types of initiative categories are shown in Figure 5.1.

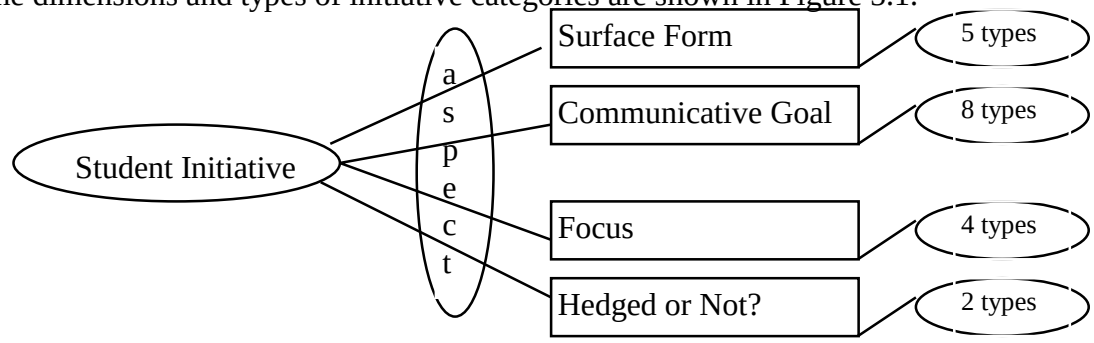


Figure 5.1 Conceptual Dimensions for Student Initiative Categories

Each of these dimensions represents an axis in a category space (see Figure 5.2), which is useful for distinguishing student initiatives.

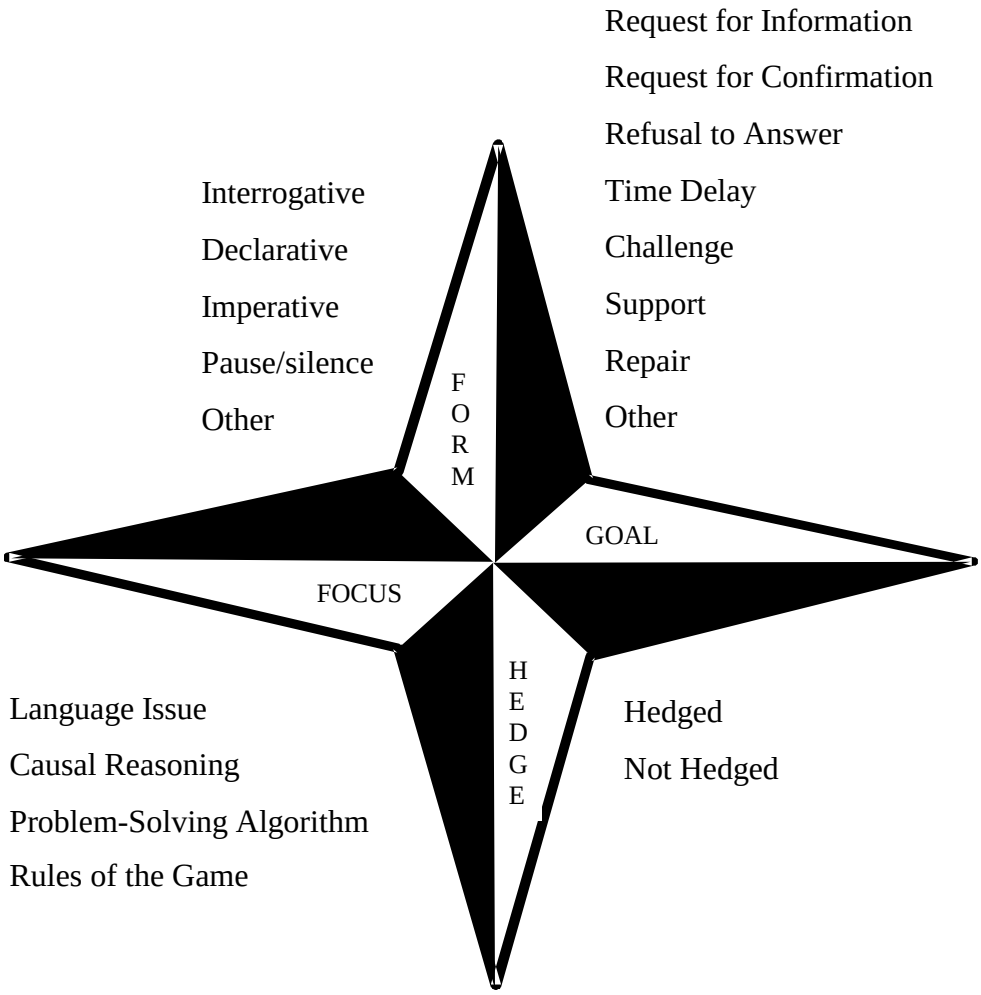


Figure 5.2 Student Initiative as a Four-Dimensional Phenomenon

We start with the surface form because it is the area in which we find it easiest to agree.

5.3.1 Surface Form. The student input comes in five forms: interrogative, declarative, imperative, pause, and other. Figure 5.3 shows the different forms of the input. The apparent type of a sentence or phrase can be determined by the word order, mood, and part of speech information. We have included pauses here because a long

pause on the part of the student causes our expert tutors to drop the current tutoring plan and offer help.

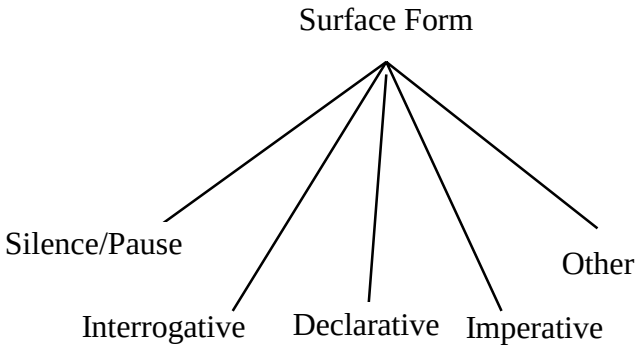


Figure 5.3 Classification of the Surface Form of Student Input

Let's look at the surface forms of the initiatives one by one with examples:

5.3.1.1 Interrogative. An interrogative form is a sentence mainly recognized by word order or wh-element. As an example of how this appears in an initiative, consider:

EX. 5.14.

K4-st-76-3: Would it be affected in a person who was not on an artificial pacemaker?

5.3.1.2 Declarative. A declarative form makes a statement. The statement may reflect an assertion or state ideas. For example:

EX. 5.15.

K4-st-84-1: I don't think I understand the question.

5.3.1.3 Imperative. An imperative form makes a request or proposes a theory. Like the declarative form the imperative sentence is usually followed by a period. Very strong requests may be given an exclamation point. For example:

EX. 5.16a

K11-si-18-1: Let me restate my question.

Sometimes students hedge even an imperative with a question mark.

EX. 5.16b

K22-st-89-1: Let me start somewhere else?

5.3.1.4 Other. These are the fragment forms comprising one word or more. We classify here strings that do not contain the syntactic structure of a sentence, with the exception of the type where the subject is elliptical. Carbonell's [1983, p.165] empirical study shows that users tend to be as brief as possible independent of typing ability. For example:

EX. 5.17a

K28-st-53-1: No

EX. 5.17b

K16-st-62-1: Co...

5.3.1.5 Silence/Pause. Silence/pause is a form of initiative that should be treated as a special case because of its various nuances. Let's take a look at various kinds of pauses:

EX. 5.18a

K1-st-73-1: The [big pause here]
K1-ti-74-1: Stuck?

EX. 5.18b

K5-st-45-1: I don [big pause here]
K5-ti-46-1: Need help?

EX. 5.18c

K7-tu-91-3: What happens in the reflex next. [big pause here]
K7-ti-92-1: Need help?
K7-st-93-1: Y

EX. 5.18d

K4-st-46-1: Well, if SV is volume per beat, and we already know that the number of beats is increased [big pause here]
K4-ti-47-1: Are you stuck?
K4-st-48-1: How about the RAP, which may have an effect on how much blood is reaching the ventricle.

It is an interruption to an ongoing remark or an occurrence between remarks. Levelt [1995] defines different types of silence as: pause, gap, and lapse depending upon its point of occurrence and duration. The student initiative "pause" can be interpreted in many ways. The most significant ones in our case are that either the student is in trouble, though it is hard to tell what kind of trouble, or the student wants to gain time. The tutor recognizes a student pause or is informed by the student that the student needs help. Each of these is classified in the initiative class inability to answer.

We need to see which particular meaning can be associated with a pause. The foci of attention in case of 'pause' may be:

- student needs time to think over the task
- student gets engaged in some other activity
- student wants to disengage from the session
- student gets confused or has some comprehension problem
- student faces difficulty in reaching some information for expression
- student is hesitant to answer

The length of pause, the point where it takes place, and the nature of the topic might help in determining the right sense of pause. Most of the time the tutor offers help in order to sustain the communication.

5.3.2 Communicative Goal/Intention. It is observed that the student produces illocutionary act(s) with the intention of fulfilling particular goal(s), and that the tutor's understanding of the speech act depends on how he interprets the production(s) as a component of what he believes is the student's plan. Stampe (1975) argued that what makes a request a request is the intention with which it is made; and what determines its success is whether its recipient can infer the intention from the linguistic form in context. Agreeing with Stampe's notion we tried to come up with a set of goals. The different types of goals that the students have in their mind before making a conversational move, are illustrated with examples from the transcripts (see Figure 5.4).

We hope eventually to be able to recognize these goals in the student initiative automatically.

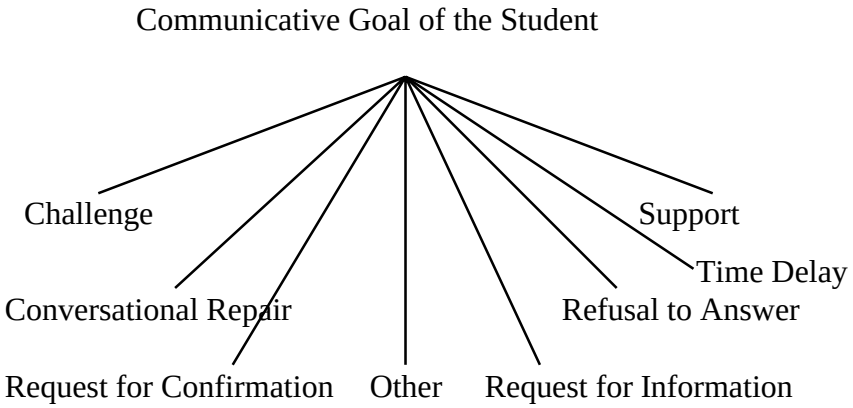


Figure 5.4 The Goal Hierarchy for Student Initiatives. Requests for Information and Confirmation are the Most Common Categories.

5.3.2.1 Request for Information. This plan/goal produces a direct interpretation of the initiative as a request that the tutor inform the student about the topic in focus. This can be satisfied by explaining the topic or releasing the information appropriate to the student's current goal. For example:

EX. 5.19.

K2-st-49-1: I think I would like to further discuss the idea of RAP.
K2-st-49-2: Unless compliance is involved, I still do not understand why the pressure in the right atrium decrease with an increase in right atrial filling.
K2-st-49-3: I will attempt to first find the answer in the monograph assigned.
K2-st-49-4: Thank you for this fulfilling session!
K2-tu-50-1: Wait
K2-tu-50-2: I apparently left you with the seriously wrong impression.
K2-tu-50-3: RAP goes up with the increased atrial filling and down with smaller central blood volumes.
K2-tu-50-4: The two do not go in opposite directions.
K2-tu-50-5: I think we do need to talk about this some more.
K2-tu-50-6: Please call me or drop into my office.

5.3.2.2 Request for Confirmation. The student generates an explanation and asks for confirmation of this theory. Sometimes a simple yes or no is a sufficient response. For example:

EX. 5.20a

K9-st-38-1: i.e. the change in sympathetic input changes the location of the Starling curve?
K9-tu-39-1: Yes.

More often the tutor responds more elaborately, especially when the student's explanation is wrong.

EX. 5.20b

K10-st-56-2: Does RAP increase initially with increasing CO and then taper off as CO continues to I?
K10-tu-57-1: no. When CO increases it transfers increased quantities of blood from the venous system into the arterial system, decreasing the CBV (central blood volume) and increasing the arterial blood volume (and pressure).
K10-tu-57-2: What would happen to the central venous pressure when CBV goes down?
K10-st-58-1: It decreases.
K10-tu-59-1: Yes.

In K10-st-56-2 the student reveals a serious misconception and the tutor tries to remediate this error.

5.3.2.3 Conversational Repair. Both the tutor and the student express their thoughts in a way that is not always perfect or clear. The repair initiative is often a request for clarification or it may be a request for rephrasing or correction.

The context of discourse and the task at hand are important determinants of the kind of repair construction. In our transcripts student requests for repair take several different forms. Presently I will restrict myself to just conversational repair pertaining to the language issue. Example (5.21a) shows a request for rephrasing.

EX. 5.21a

K4-tu-83-6: How are the falls in TPR and in CC connected to the decrease in MAP?
K4-st-84-1: I don't think I understand the question.
K4-tu-85-1: What are the determinants of MAP?
K4-st-86-1: MAP is determined by TPR and CO, so if the TPR is decreasing then the CO is decreasing too, given the act that CC is also decreased.

The student asks for repair in turn K4-st-84-1. Basically he asks for restatement of the question in a more precise or specific way. The tutor rephrases the question so that the student can understand it.

EX. 5.21b

K28-tu-104-2: I guess that weve cover your errors.
K28-tu-104-3: Is there anything else that you want to go over?
K28-st-105-1: I said that RAP would be down, wouldn't it be up in SS as a result of Co being down in SS
K28-tu-106-1: Yes, I had written it down wrong.
K28-tu-106-2: I'm glad that you caught it.

Example (5.21b) illustrates self correction. Actually the student predicted an increase in RAP in the DR stage, no change in RAP in the RR stage, and a decrease in RAP in the SS stage. The tutor did not notice the error and let it pass. The student realized the error and tried to correct it in his own curious fashion. Like human tutors

CIRCSIM-Tutor should encourage students to reflect upon and diagnose their own performances.

5.3.2.4 Inability to Answer. Sometimes the student does not know the answer and utters an explicit statement of her/his inability to give the answer (or refuses to answer, and just gives up). This initiative appears to be taken as a kind of giving up participating in the game, yet the student is obliged to utter something following the rules of the game. The tutor responds in the form of an explanation on the topic.

EX. 5.22.

K1-tu-56-3: What other neurally controlled structure is affected by the reflex and how?
K1-st-57-1: Cardiac muscle, CC i.
K1-tu-61-1: Think again sympathetic firing is being decreased.
K1-st-62-1: I don't know.
K1-tu-60-1: When MAP goes up it increases basroceptor nerve impulse input to the CV centers.
K1-tu-60-2: Sympathetic output TO ALL OF THE CV EFFECTORES is inversely related to the afferent input rate.
K1-tu-60-3: Parasympathetic output to the pacemaker is direclty related to the input afferent rate.
{PAUSE}
K1-tu-60-4: Still stuck?

5.3.2.5 Challenge. This kind of response reflects some sort of disagreement with what the tutor has said. The use of clue words like "but", especially at the start of the sentence, often indicates that the initiative is taken as a challenge to the tutor's preceding utterance. This act may happen as a result of not accepting the truth of the tutor's previous statement completely.

EX. 5.23.

K20-tu-46-2: But you forgot that the real pacemaker is dead and this guy's HR is determined by the broken artificial pacemaker.
K20-st-47-2: OOPS.
K20-st-47-2: BUT I WAS JUST READING EARLIER TODAY IN SMITH AND KAMPINE ABOUT HOW SANS CAN 'TURN ON' OTHER AREAS AND INFLUENCE HR WITHOUT ACTING FIRST ON THE SA NODE
K20-tu-48-1: It happens sometimes (extopic pacemaker) and sometimes it doesn't.
K20-tu-48-2: The description of this patient is asking you to assume that his HR is solely under the control of the artificial pacemaker.

5.3.2.6 Support: shows agreement with the tutor's claim. The student supports the tutor's point of view by accepting the knowledge the tutor is trying to give. The act of support is an indication of the student's alignment of thought with the tutor.

EX. 5.24.

K4-tu-59-1: Let me remind you of the vascular function curve.
K4-tu-59-2: It shows the relationship between central venous P (same as RAP) and CO when CO is the independent variable.
K4-tu-59-3: DO you remember that?
K4-st-61-1: Yes. I guess I do now.
K4-st-60-2: A decrease in CVP would be in response to an increased CO.

5.3.2.7 Time Delay/Extension: Sometimes all that the tutor sees is a student pause. The student is busy in working the problem out and needs time to come up with a correct answer. The tutor's offer of help is the typical response to student pauses.

EX. 5.25.

K16-tu-17-1: Make your next prediction please
K16-st-18-1: {Pause}
K16-tu-19-1: Do you need any help to make a prediction at this point
K16-st-20-1: I am thinking …

K16-st-20-2: I just need a second more
K16-tu-21-1: Ok

5.3.2.8 Compare and Contrast. It happens very often that the student confuses two parameters or state of affairs and asks the tutor to explain the difference between them. It is a subtype of request for information.

EX. 5.26.

K10-tu-61-1: Let's put in the correct order, RAP (the dependent variable) is inversely proportional to CO (the independent one).
K10-tu-61-2: OK?
K10-st-62-1: What's the difference?
K10-tu-63-1: If RAP is the independent variable and it goes up, you get increased filling and increased SV (i.e.> CO).
K10-tu-63-2: That's Starling's Law.

5.3.3 Focus of Attention or Content. Initiatives are not fully understood until their focus has been determined. We incorporate information about the focus of attention defining the discourse structure. Grosz and Sidner [1986] characterize focus as a discourse element on which the understanding system can concentrate. The list of focus/content options is shown in Figure 5.5.

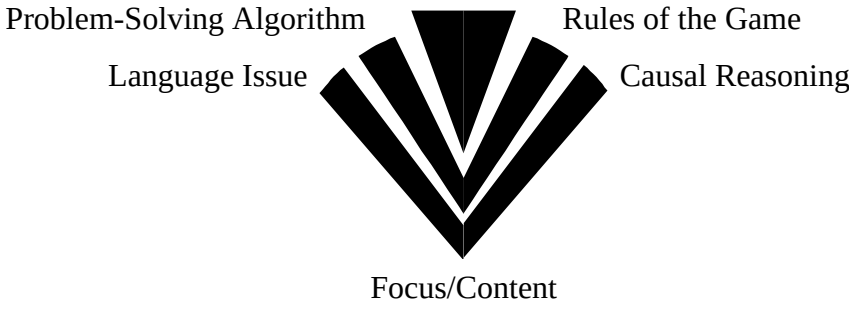


Figure 5.5 The Focus /Content Options for Student Initiatives

In order to save time and resources it is practical to focus the attention on the most useful and salient features. Sidner [1979] tells us that focusing explains how a hearer decides what the speaker is talking about, and therefore it must be the first criterion for speaking relevantly. Grosz [1986] also stresses the importance of focusing on the knowledge relevant to a particular situation rather than diverging on an extensive knowledge base most of which may be irrelevant to the current discourse. The dialog fragments later in 5.2.3 illustrate the role of focus in interpreting the initiatives in our tutorial dialogs.

5.3.3.1 Language Issues. The opportunity to teach the language of causal explanations along with the reasoning process is a major argument for devising a natural language interface. Our expert tutors are very concerned about language issues. The proper use of the sublanguage is a strong argument for a natural language interface. The knowledge of correct terminology and its appropriate usage is essential for meaning negotiation. This enables people not only to capture the true sense of a word but also to determine phrase meanings or sentence meanings and infer metonymical uses if any. That's why our tutors emphasize language matters as a bridge toward learning.

EX. 5.27.

K12-tu-45-3: Does venous return go up immediately?
K12-st-46-1: Does the rate of blood removal from the central veins mean that blood entering the right atrium, if so ithink venous return does go up immed.
K12-tu-47-1: We need to get our terminology straight.
K12-tu-47-2: Venous return means blood returning from the systemic circulation to the heart.

K12-tu-47-3: That does not go up immediately.

5.3.3.2 Causal Reasoning. The focus is on a parameter or a relation or a mechanism. The student is required to predict the changes regarding the parameters in the given prediction table as a part of the problem solving procedure. Patterns of errors in the predictions or in the dialogue or questions in the form of initiatives inform the tutor about the missing knowledge. Note the focused phenomena in the example given below:

EX. 5.28.

K16-tu-37-2: Does changing the length of the muscle change its CONTRACTILITY?
K16-st-38-1: I think I am getting contractility mixed up with stroke volume…
K16-st-38-2: Contractility is the force of contraction that I think goes up with increased heart rate, but I am not sure how

The focus of many of the student initiatives is on the relations: either causal relations or equations that imply causal relations. How a change in one parameter causes a change in another or causes some effect falls under the notion of causality. The understanding of the underlying causes and effects is important to recognizing the function and behavior of the parameters. These relations are essential to the causal reasoning that our tutors want the students to learn.

EX. 5.29a

K7-tu-102-4: Understand?
K7-st-103-1: But isn't CO×TPR = MAP?
K7-tu-104-1: Yes.

EX. 5.29b

K2-tu-38-1: You're on the right track but need some course correction.
K2-tu-38-2: The baroceptors respond to the change in MAP caused by the increase in HR.
K2-tu-38-3: Think again about the direction in which TPR would change.
K2-st-39-1: Ok, I had thought that an increase in HR would cause an increase in CO, therefore triggering sympathetic response.

EX. 5.29c

K1-tu-27-2: Why would there be an increased amount of blood coming into it?
K1-st-28-1: I guessed there would not be increased RAP, but would the TPR increase because of the increased CO?

The students need to understand which parameters are mediated by the nervous system and which involve haemodynamic forces.

EX. 5.30.

K7-tu-75-1: Remember, this is a neurally controlled variable.
K7-tu-75-2: The reflex is responding to increase in MAP in the DR.
K7-tu-75-3: Try again.
K7-st-76-1: I still don't understand.

5.3.3.3 Problem-Solving Algorithm. In problem-solving, the students are concerned with how the qualitative result is produced, and the tutor teaches about the sequence of computational steps that must be performed to get the desired value. The central issues are the primary variables and sequential changes in other variables in logical order. In the following example the focus is on understanding the orderly steps required in the steady state (SS) phase.

EX. 5.31.

K17-tu-56-1: I am a bit confused over your order of prediction.
K17-tu-56-2: Since CO is determined by SV, how could you predict CO first and SV later?

K17-st-57-1: I was just going down the list of seven variables and adding the magnitude of change (+ or -) from the DR and RR columns, as CIRCSIM demonstrated.
K17-st-57-2: I don't understand your question?

5.3.3.4 Rules of the Game. The student needs to be familiar with the phases and the order of the columns in the prediction table. S/he is expected to know what these phases mean.

EX. 5.32a

K16-tu-41-2: Does sympathetic stimulation change during the DR phase?
K16-st-42-1: Does dr mean diastolic relaxation?
K16-tu-43-1: NO!
K16-tu-43-2: The DR occurs during the period of time before any reflex response to the perturbation of the system take place.

EX. 5.32b

K27-st-19-1: Do you want me to predict the first thing that wil change?
K27-tu-20-1: Yes, in order to successfully predict how the system will respond you have to start with the first thing that changes.

5.3.4 Degree of Certainty - Hedging. Our transcripts of expert tutoring sessions contain many types of hedges in the student input. Almost any speech act can be hedged, although imperatives are not hedged as often as declarative or interrogative sentences in our data. We then decided to treat hedging as a separate dimension because it reflects different shades of meaning in the student input. George Lakoff [1973] undertook a study of hedges revealing that natural language concepts have vague boundaries and fuzzy edges, and concludes that:

> … and the sentences of natural language will be neither true, nor false, nor nonsensical, but rather true to a certain extent and false to a certain extent, true in certain respects and false in other respects. [Lakoff, p. 183]

Robin Lakoff [1971] addressed the pragmatics of modality and showed that must, can not, and other modals function as performatives. They can also function as hedges - may and might, in particular. We noted that almost any speech act can be hedged, although imperatives are not hedged as often as declaratives or interrogative sentences in our data. In our transcripts we see many types of hedges in the form of adverbs like maybe, perhaps; in the form of verbs like: I think, I guess; in the form of auxiliary verbs as may, might, can not; in the form of adverbial adjectives like: I am not sure, I am not comfortable; in the form of informal expressions like: sort of, and most often, question marks. The following examples are illustrative:

EX. 5.33. perhaps

K3-tu-53-1: The venous return may not change for a couple of minutes but what about the rate at which blood is being removed vfrom the central blood compartment?
K3-st-54-1: That rate would increase, perhaps increasing RAP???

EX. 5.34a I think

K2-tu-48-1: Sure.
K2-tu-48-2: And now we have a way to keep the MAP in line.
K2-tu-48-3: We have not got enough time to finish the exercise.
K2-tu-48-4: If you want to discuss it with me in class, I'd be happy to.
K2-tu-48-5: Thanks very much for your help.
K2-st-49-1: I think I would like to further discuss the idea of RAP.
K2-st-49-2: Unless compliance is involved, I still do not understand why the pressure in the right atrium decrease with an increase in right atrial filling.

The use of a disclaimer such as unless compliance is involved, further neutralizes the implied force of the sentence.

EX. 5.34b

K15-tu-67-1: Which do you want to change and to what?
K15-st-68-1: Im not sure; I think an increase in rap would increase preload and therefore increase co, but then would an increased co lower rap?

EX. 5.35. How about

K4-ti-47-1: Are you stuck?
K4-st-48-1: How about the RAP, which may have an effect on how much blood is reaching the ventricle.

EX. 5.36. sort of

K7-tu-39-1: Let me remind you then.
K7-tu-39-2: CO represents a process of taking blood from the central blood compartment and putting it into the arterial system.
K7-tu-39-3: That decreases central blood volume.
K7-tu-39-4: Now do you remember?
K7-st-40-1: sort of

Zadeh [1972] suggests that hedges like sort of, and very need algebraic functions to analyze their meaning. At this point we do not need to describe hedges in terms of a complete set of axioms for fuzzy predicate logic. We just need to note whether the student shows any uncertainty.

EX. 5.37. I am hesitant

K12-tu-61-1: Let me make sure that I understand.
K12-tu-61-2: You are saying that HR 0.
K12-tu-61-3: And that's correct.
K12-tu-61-4: And you're saying SV D.
K12-tu-61-5: I won't comment on the correctness of that yet.
K12-tu-61-6: What I want to know is how the reflex is going to get SV to D?
K12-st-62-1: Decrease filling time, decrease venousreturn.
K12-st-62-2: I'm just hesitant to say what comes first.

EX. 5.38. ???

K12-tu-93-1: no. I'm agreeing with you the vessels are dialated.
K12-tu-93-2: I was just giving you information that you could use to determine how the reflex accomplish that.
K12-st-94-1: Dilation results in increasing the vessel radius and thus tpr goes down (exponentially bya factor of4???)

EX. 5.39. maybe

K13-tu-23-1: Now what?
K13-st-24-1: Cc i maybe

EX. 5.40. I can not believe/must

K13-tu-43-1: And if rap d what will happen to sv?
K13-st-44-1: If the pulmonary circulation is all equilibrating rv and la then sv must drop but I can't believe it

EX. 5.41. I am not sure

K13-tu-55-2: One last question here...
K13-tu-55-3: Why did you predict that cc and tpr would be unchanged.
K13-st-56-1: TPR is largely a function of arteriol constriction.
K13-st-56-2: Cc changes in response to ans stimulation or ca build up durin tachecardia.
K13-st-56-3: Im not sure if 120bpm is fast enough to cause that

EX. 5.42. I am not comfortable

K20-tu-68-2: And notice in your argument that firs CO changes and that's what causes RAP t change, not the other way around.
K20-tu-68-3: See?
K20-st-69-1: SO CO. IS THE INDEPENDENT VARIABLE.
K20-st-69-2: BUT I AM STILL UNCOMFORTABLE BECAUSE I THOUGHT THAT RAP IS ANALOGOUS WITH THE AMOUNT THAT CAN BE POURED INTO THE RV SO I WANT SV TO GO UP WHEN RAP GOES UP.

EX. 5.43. I guess

K24-tu-48-1: Why did you say d?
K24-st-49-1: Because I thought that the pacemaker is stuck at 50, but I guess sympathetic come into play here, right?

The examples from (5.33) to (5.43) carry a certain degree of vagueness, hesitation, or doubt.

5.4 Specific Examples

In this section I present some examples with analyses that include all our categories.

EX. 5.44.

K3-tu-54-1: The venous return may not change for a couple of minutes but what about the rate at which blood is being removed vfrom the central blood compartment.
K3-st-55-1: That rate would increase, perhaps increasing RAP???

Surface Form: Other

Goal: Request for Confirmation

Focus: Causal Reasoning

Hedged: Yes

Here are some examples from a list of initiatives that Sanders left unclassified.

EX. 5.45.

K1-tu-83-1: Do you think that you really understand it?
K1-st-83-1: I am still unclear about RAP.

Surface Form: Declarative

Goal: Request for Information

Focus: Causal Reasoning

Hedged: No

EX. 5.46.

K4-st-84-1: I don’t think I understand the question.
K4-tu-85-1: What are the determinants of MAP?

Surface Form: Declarative

Goal: Repair

Focus: Causal Reasoning

Hedged: Yes

5.5 Further Analysis

Table 5.1 represents student initiatives I1 to I7, I8-I9, I10-I12, I13-I18 from sessions K10, K18, K14, and K22 respectively.

Table 5.1. Representation of Initiatives w. r. t. Surface Form, Communicative Goal, Focus, and Presence of a Hedge. (Transcripts: K10, K18, K14, K22)

	Focus					Communicative Goal						Focus				Hedge	
Initiative	Interrogative	Declarative	Imperative	Other	Pause or Silence	Information	Confirmation	Time Delay	Challenge	Support	Repair	Causal Reasoning	Language Issue	Problem Solving	Rules of Game	Hedged	Not Hedged
I1	√								√			√					√
I2				√			√					√				√	
I3		√				√						√					√
I4	√						√					√					√
I5	√					√						√					√
I6	√						√					√					√
I7	√					√						√					√
I8	√								√			√					√
I9					√			√					√			√	
I10					√			√						√		√	
I11	√					√									√		√
I12	√					√								√			√
I13	√								√					√			√
I14		√							√			√					√
I15		√					√					√				√	
I16	√						√					√					√
I17			√				√							√		√	
I18		√					√					√					√
Total	10	4	1	1	2	5	7	2	4	0	0	12	1	4	1	5	13

We see that most of the initiatives are in the form of a question, asking for confirmation. They are mostly centered around causal relations and are hedged. The approximate pattern of the highest occurring form, communicative goal, content, and degree of certainty of initiatives may easily be seen.

Let's take a look at some examples from the transcripts in which the student's communicative goal is a request for confirmation.

EX. 5.47.

K10-tu-47-1: An increase in contractility is caused by an increase in intracellular [Ca], and is independent of filling.
K10-tu-47-2: Filling increases contractile performance by changing the orientation of thick and thin filaments.
K10-tu-47-3: OK?
K10-st-48-1: Is increased IC [Ca] the only thing that can increase contractility?
K10-tu-49-1: Yes.

EX. 5.48.

K18-tu-38-1: That's pretty good except for HR.
K18-tu-38-2: Remember in this case this guy's HR is solelt determined by his broken artificial pacemaker.
K18-st-39-1: Wouldn't his other myocardial cells respond to sympathetic stimulation and couldn't they override his artificial pacemaker?
K18-tu-40-1: They might and then again they might not.
K18-tu-40-2: We`re assuming in this case that they don't.
K18-tu-40-3: So what do you say about R>?

In the following examples, we see the tutor emphasize the causal relation. The voyage of understanding winds up with a causal explanation. Cohen [1995, p.5] considers the general causal explanation as a target for a scientist, and counts three stages in explaining a phenomenon, i.e., description, prediction, and causal relation. He thinks description requires no special understanding, prediction requires at least an

understanding of the conditions under which behavior occurs, and causal explanation requires a thorough understanding of why certain behavior takes place. Our students seem to be going through the same process. In Examples 5.49 and 5.50 the student asks for information regarding the underlying algorithm and causal relation.

EX. 5.49.

K14-tu-75-1: It is true that if tpr i then map i.
K14-tu-75-2: However, rap is determined by co, not tpr or map.
K14-tu-75-3: So you still haven't predicted what will happen to rap.
K14-st-76-1: Khow can i determine rap by knowing the co if i can't determine the sv?
K14-tu-77-1: Well, you can start by thinking about the reflex that was activated and what it will seek to accomplish.
K14-tu-77-2: What is the stimulus here that activates the reflex?

EX. 5.50.

K22-tu-114-4: Do you have any further questions?
K22-st-115-1: Yes.
K22-st-115-2: In the equation map=co x trp if the tpr i, does the map i because more of the pressure or driving force is lost along the length of the vessels and therefore you need a higher pressure to move the blood the same distance?
K22-tu-116-1: If all you tell me is that tpr i I can not predict what will happen to map.
K22-tu-116-2: If co is o then map i.
K22-tu-116-3: If co goes down more than tpr increases then pressures falls.
K22-tu-116-4: If co d exactly as much as tpr i then map is 0.

Table 5.2 represents a difference of number and types of initiatives occurring during the tutoring sessions. The performance of two female students of the same age with the same tasks but different tutors is shown in the table.

Table 5.2. The Variability of Occurrence of Student Initiatives

Session Number	K10 (Pre-CIRCSIM)	K18 (Post-CIRCSIM)	K14 (Pre-CIRCSIM)	K22 (Post-CIRCSIM)
Initiatives Range	I1-I7 = 7	I8-I9 = 2	I10-I12 = 3	I13-I18 = 6
Procedure	HR I PACEMAKER	HR D PACEMAKER	HR I PACEMAKER	HR D PACEMAKER
Student Age	27	27	27	27
Student Gender	Female	Female	Female	Female
Tutor	Dr. Allen Rovick	Dr. Allen Rovick	Dr. Joel Michael	Dr. Joel Michael

5.6 Comparison between the Tutor and Student Goals

The occurrence of student initiatives can best be explained if it can be related to the communicative goals of the student, i.e., what the student is up to and wants to achieve. We find an asymmetry between tutor and student communicative goals (as summarized in Table 5.3) due to their different conversational roles and responsibilities.

The goals that appear to be the same are interpreted differently under the different functions. For example the function/role of the tutor's confirmation is to comply with a request from the student as compared to the function of the student's request for confirmation. The overall goal of the tutor is to assess the student's performance and help improve it, whereas the student's goal, we hope, is to learn as much as possible about problem solving in the domain. The tutor tries to elicit information from the student for

assessment purposes, whereas the student asks for information to gain more knowledge. In this give-and-take process a wealth of information circulates.

Table 5.3. Communicative Goals of Both Students and Tutors.

Student's Communicative Goals	vs.	Tutor's Communicative Goals
Request for Information		Acknowledgment
Request for Confirmation		Instruction in the "Rules of The Game"
Inability to Answer		Summary
Time Delay		Explanation
Conversational Repair (self, other, ask for, do)		Conversational Repair (self, other, ask for, do)
(Compare and Contrast)		Teaching the Problem Solving Algorithms
Challenge		Teaching the Sublanguage
Support		Brushing Off
Other		Probing the Student's Inference Process
		Help in Response to Pause

Let's highlight the difference through some of the fragments of discourse used by the tutor as well as the student in the course of tutoring session. Seemingly they are similar but in a real sense they are not.

EX. 5.51.

K5-st-45-1: Idon
K5-ti-46-1: Need help?

EX. 5.52.

K26-st-69-1: Need more help
K26-tu-70-1: Sorry about that!

K26-tu-70-2: The pressure in the right atrium is essentially the same as pressure in the central venous compartment.
K26-tu-70-4: What determines that volume?

In EX. 5.51 the fragment need help? is interpreted as an offer from the tutor in extending his help to get the student unstuck. In EX. 5.52 the fragment need more help conveys a request from the student for help. The student is requesting more information regarding the meaning of parameter RAP.

EX. 5.53.

K11-tu-65-2: How about the influence of a change in CO on RAP?

EX. 5.54.

K25-tu-52-2: But what determines the volume of blood in the central venous compartment?
K25-st-53-1: How about co?
K25-tu-54-1: Certainly, CO is the determinant i'm looking for here.

In EX. 5.53 the tutor is asking a question regarding the effect of CO on RAP, whereas in EX. 5.54 the student is using an almost similar expression for a hedged answer. Similarly, the asymmetry in the form of different intentions of the dialog between the tutor and the student may be noticed in the use of ok, right, good, and so forth.

5.7 Communicative Aspects of Repair in Tutorial Dialogue

An important ingredient of dialogues is the notion of repair when the plan construction is faced with something unexpected. Repair offers a tool to fix divergent interpretations. The gap due to miscommunication causes an obstacle in the process of building the structure. After pinpointing the error the system must be able to repair it in a cooperative fashion.

In the work of McRoy and Hirst [1995], misconception, misunderstanding, and nonunderstanding are defined in terms of their occurrence at different progressive turns. I tried to capture the notions in our domain and see if the theory works in the correctness of the dialogue acts (overall system). I am also interested in performing different kinds of clarification dialogue and selective verification in the development of the student plans.

5.7.1 Nonunderstanding. When a student comes across a situation where s/he finds it hard to get a message across that is consistent and coherent with the tutor's, it is taken as a display of nonunderstanding. Hirst et al. [1994] define nonunderstanding as one's failure to find any complete and unique explanation of an utterance. They recognize it by the feature that the participant knows that it has happened. It means that the utterance is either nonsensical or ambiguous. It cannot be interpreted completely or clearly. For example:

EX. 5.55.

K5-st-80-1: CO D.
K5-tu-81-1: Right.
K5-tu-81-2: Why?
K5-st-82-1: Because CC D.
K5-tu-83-1: So?
K5-st-84-1: I don't understand. (nonunderstanding)
K5-tu-85-1: How does CC D affect CO?

In K5-tu-83-1 the student can derive either more than one interpretation, or no interpretation at all, and so the obstacle is immediately known. In K5-tu-85-1 the tutor reconstructs the referring expression. We are exploring the possibility of modeling this

with the plan recognition and generation system also proposed by Heeman and Hirst [1995] which can recognize faulty plans and try to repair them.

5.7.2 Misconception. A misconception is due to an error in the prior knowledge of the student. Such errors can be recognized immediately in the case of misconception as compared to misunderstanding. The symptoms of misconceptions include references to entities that do not map to previously known objects or operations [Webber and Mays, 1983] or requests for clarification [Moore and Paris, 1989]. For example:

EX. 5.56.

K11-tu-53-2: So let me ask you, are there any other of these variables that are primarily under neural control?
K11-st-54-1: Cc, hr
K11-tu-55-1: Right again.
K11-tu-55-2: But we know in this problem, HR is solely under the control of the artificial pacemaker.
K11-tu-55-3: So let,s leave it out.
K11-tu-55-4: But if CC is under neural control, how would it be affected in the DR period?
K11-st-56-1: I edv
K11-tu-57-1: You can't have it both ways.
K11-tu-57-2: If CC is under neural control and we`re talking about the period before any change in neural activity then CC???
K11-st-58-1: But, it is ALSO under intrinsic control (misconception])
K11-tu-59-1: You are confusing Starling's Law with a change in contractility.
K11-tu-59-2: The length/tension relation of the heart is not a change in contractility.
K11-tu-59-3: A change in contractility moves the length/tension curve from one location to another.
K11-tu-59-4: Increased contractility means that at a given EDV you get more contractilt performance out of the ventricle.
K11-st-60-1: Ok
K11-tu-61-1: So what's your prediction about CC?
K11-st-62-1: O
K11-tu-63-1: Wright again. [sic]

5.7.3 Misunderstanding. Hirst et al. [1994] distinguish misunderstanding from nonunderstanding by the presence of the fact that the participant does not know, in the beginning, that it has happened. Misconception causes misunderstanding. In misunderstanding the student thinks s/he has a complete, and consistent knowledge, whereas the tutor does not think so. The participants continue with their dialogue based on their cross-purposes. A point is reached when the dialogue breaks down and one of the participants realizes that there has been misunderstanding. For example:

EX. 5.57.

K2-tu-44-5: What comes after that?
K2-st-45-1: MAP will be the next to decrease
K2-tu-46-1: Sure.
K2-tu-46-2: And now we have a way to keep the MAP in line.
K2-tu-46-3: We have not got enough time to finish the exercise.
K2-tu-46-4: If you want to discuss it with me in class, I'd be happy to.
K2-tu-46-5: Thanks very much for your help.
K2-st-47-1: I think I would like to further discuss the idea of RAP.
K2-st-47-2: Unless compliance is` involved, I still do not understand why the pressure in the right atrium decrease with an increase in right atrial filling.
K2-st-47-3: I will attempt to first find the answer in the monograph assigned.
K2-st-47-4: Thank you for this fulfilling session!
K2-tu-48-1: Wait.
K2-tu-48-2: I apparently left you with a seriously wrong impression.
K2-tu-48-3: RAP goes up with increased atrial filling and down with smaller central blood volumes.
K2-tu-48-4: The two do not go in opposite directions.
K2-tu-48-5: I think that we do need to talk about this some more.
K2-tu-48-6: Please call me or drop into my office.
K2-tu-48-7: Thanks again.
K2-st-49-1: Your welcome.
K2-st-49-2: I will make an appointment with you next week.
K2-st-49-3: See you then

The student's misunderstanding is revealed in turn K2-st-47-2. At this point the interpretation of the tutor and the student seems to diverge. Until this point the tutor

thought that the student had obtained a complete and correct interpretation. What the student types in (K2-st-47-2) indicates that she has not obtained the interpretation that the tutor intended. So he decided (in K2-tu-48-2) to announce that a misunderstanding has occurred and to try to resolve it (as in K2-tu-48-3). It was possible that the misunderstanding might have gone unnoticed if the student has not expressed herself in the end. That shows how important it is for the student to self-explain.

The beliefs of the participants are in conflict about that part of the relevant knowledge. This leads to the situation of misunderstanding. Again, according to Hirst et al. [1994] misunderstanding can be self-misunderstanding or other-misunderstanding. Self-misunderstanding is the one made and detected by the same person. Other-misunderstanding is made by one but detected by other. Both types of misunderstanding can be remedied either through self correction or other correction.

EX. 5.58.a

K22-st-115-2: In the equation map=co x trp if the tpr i, does the map i because more of the pressure or driving force is lost along the length of the vessels and therfore you need a higher pressure to move the blood the same distance?
K22-tu-116-1: If all you tell me is that tpr i I can not predict what will happen to map.
K22-tu-116-2: If co is o then map i.
K22-tu-116-3: If co goes down more than tpr increases then pressures falls.
K22-tu-116-4: If co d exactly as much as tpr i then map is 0.
K22-st-117-1: I should have stated that co is held constant
[Self Correction]
K22-tu-118-1: If tpr increases and co is constant then map will increase.
K22-tu-118-2: this just says that the same flow through a system will greater resistance will cause more of the pressure to be dissipated.
K22-tu-118-3: Remember, we're really talking about pressure gradients, not just the pressure a one end of the vessel.
K22-st-119-1: Ok

EX. 5.58.b

K28-tu-104-2: I guess that weve cover your errors.
K28-tu-104-3: Is there anything else that you want to go over?
CT= 47:52 ET= 0:46 IT= 0:4
K28-st-105-1: I said that RAP would be down, wouldn't it be up in SS as a result of Co being down in SS
[Self & Other Correction]
K28-tu-106-1: Yes, I had written it down wrong.
K28-tu-106-2: I'm glad that you caught it.
K28-tu-106-3: Should we cover anything else?

5.7.4 Refusal to Answer. Often what appears to be a new problem turns out to be a variation of one that has already been solved. An important skill in problem solving is the ability to recognize that a problem is similar to one solved earlier. As students progress through the physiology course, they start building up a library of plans and procedures. Sometimes the student feels stuck and unable to solve the problem. For example:

EX. 5.59.

K1-tu-56-3: What other neurally controlled structure is affected by the reflex and how?
K1-st-57-1: Cardiac muscle, CC i.
K1-tu-58-1: Think again sympathetic firing is being decreased.
K1-st-59-1: I don't know.
K1-tu-60-1: When MAP goes up it increases baroceptor nerve impulse input to the CV centers.
K1-tu-60-2: Sympathetic output TO ALL OF THE CV EFFECTORES is inversely related to the afferent input rate.
K1-tu-60-3: Parasympathetic output to the pacemaker is directly related to the input afferent rate.
K1-tu-60-4: {PAUSE} Still stuck?
K1-st-61-1: Yes
K1-tu-62-1: OK.
K1-tu-62-2: This reflex is designed to hold BP constant.
K1-tu-62-3: BP just went up because of the artificial pacemaker.

K1-tu-62-4: The reflex has to change thins in a direction to lower BP.
K1-tu-62-5: It has to lower TPR and lower CO to do that.
K1-st-63-1: SV d

Students derive good mental models of explanation by receiving good explanations from the tutor. The research presented here aims to provide an empirical foundation for such models, by examining how tutors and students carry out such necessary tasks as offering help, intervening when there is a need, fixing the bugs, and giving explanations, etc.

5.7.5 Conversational Repair. The communicative roles in the form of asking for repair or doing repair can be symmetrical or reflexive. There are different classes of repair depending on how soon after the comprehension problem it is initiated. Figure 5.6 displays different types of repair initiated at various turns.

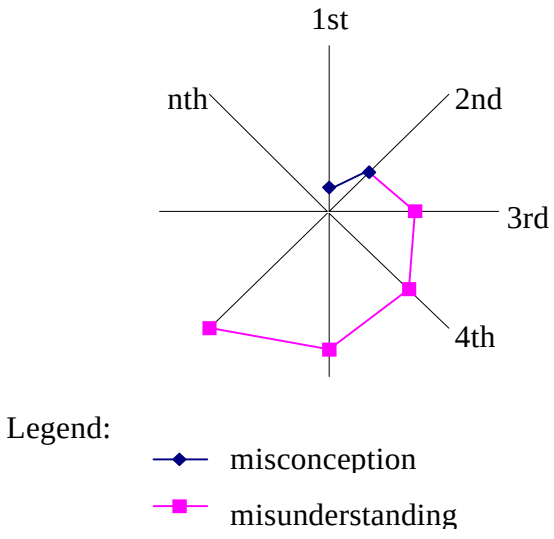


Figure 5.6 The “nth-turn” [Schegloff, 1992] Repair in Response to Misconception and Misunderstanding

When the student/tutor says something that is not consistent with the tutor's/student's expectations, then the tutor/student may ask for repair. Before the act of repair the student may arrive at a misconception, or misunderstanding, or not understanding or a dead end. This results in doing repair, or asking for repair as a contingency pair.

The recognition of non-understanding yields to the next turn repair.

EX. 5.61. Misconception, 2nd Turn Repair

K16-st-42-1: Does dr mean diastolic relaxation?
K16-tu-43-1: NO!
K16-tu-43-2: The DR occurs during the period of time before any reflex response to the perturbation of the system takes place.

A prolonged misunderstanding causes complex repair in the later turns. When students work through a problem with the tutor, they very often verbalize what they are doing, step-by-step. They do it to display to the tutor how they have understood the problem and how they understand what they are currently doing to solve the problem. So every student utterance of this sort is a display of understanding. Any such display of understanding calls for confirmation or disconfirmation from the tutor. A confirmation is an OK or agreement signal to the student understanding. A disconfirmation is a disagreement signal.

The next chapter takes the two phenomena of student initiative and tutor response in the frame of verbal behavior and analyzes the factors influencing them from the behaviorist perspective. Chapter VI is concerned with how a model of student plan and goals can contribute to interactive environment and appropriate response generation. It presents different research models of the student plan recognition.

CHAPTER VI

INITIATIVES AND RESPONSES: A BEHAVIORIST APPROACH

We call an initiative any action taken by the student to change the course of the dialogue. The response is the tutor's reaction to that initiative. The action or reaction of persons under specified circumstances is called behavior. Behavior is determined by one's beliefs or one's conditioning.

Our empirical study of recorded transcripts of human tutoring sessions helped us to some extent in identifying the actions of the tutor and the contexts that influence the student behavior. Hume [1995] pinpoints the effects of behavior in this manner:

> [Their] hinting behavior influences their modeling of the student; their model of the student influences their hinting behavior. [p.108]

Initiative-Response, as a subset of our tutoring process, can be viewed as one particular task in an information process. Students play roles that are connected to their goals. Behavior can be changed by its consequences. Skinner puts it this way:

> If we are to predict behavior, we must deal with the probability of response. We may define learning as a change in the probability of response [1972, pp. 77-78].

6.1 Tutoring Environments

As Cohen [1995, p.1] says "we are fundamentally empirical creatures, always asking, what is going on? Is it real or merely apparent? What causes it? Is there a better explanation?" We see the reflection of Cohen's outlook in the tutor's curious probing of student's behavior that performs a certain goal/role in a certain environment. Our study of

the transcripts shows that our tutors are interested in understanding the student's reasoning process. Sometimes they compare how students think with how they want them to think.

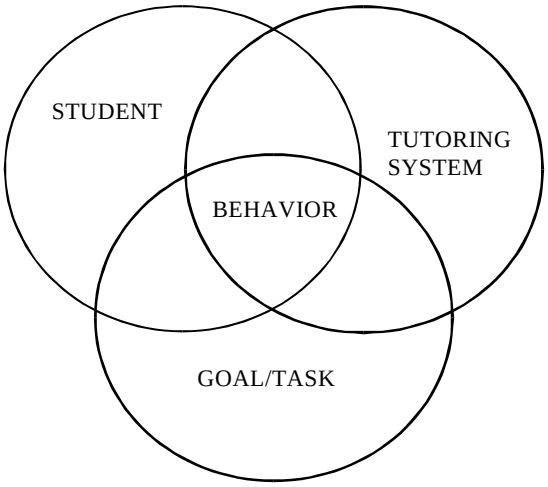


Figure 6.1 Factors that Influence the Behavior. Adapted from [Cohen, 1995, p. 3]

Engelmann and Carnine [1982, p.3] argue that a theory of instruction begins with the assumption that the environment is the primary variable in accounting for what the learner learns. The different skills learned by people under different circumstances justify the assumption. Learning is individualized and depends on the individual's background, age and experience. Of course, the complexity of the task or subject matter is also taken into account in learning and determining the behavior of the learner.

Computerized learning environments are characterized by the amount of control the student is allowed during the learning process. The proportion of the student's cognition, the tutor's forte, the choice of topic and its explanation can be viewed as a continuum ranging from a rote learning environment to a discovery environment. In

Schank's [1986] SWALE model, for instance, a new learning environment is produced when an exceptional event is observed and questions are generated to guide the building of an explanation for the event.

6.2 Operant and Respondent

An operant characterizes a response or behavior elicited by an environment rather than by a specific stimulus; it is identified by its consequences in the environment. The initiative expresses the student's goal. The student generates the initiative by choosing and executing courses of action that are likely to contribute to that goal. Such a course of action is a plan. Goals can be evaluated in terms of expected likelihoods [Pollock, 1995].

In order to understand the factors constituting student behavior it is necessary to understand the plans of the student, which are based on her/his goals. A plan is a partial solution to the problem of accomplishing a goal [Sacerdoti, 1975]. In the phenomenon of student initiatives the student constructs a communicative plan and executes it with the goal that the statement s/he inputs will have some intended effect on the tutor.

To understand the student plan it is necessary to understand the communicative act. To understand a communicative act it is necessary to recognize belief and intention (factors influencing the cognition). Perception is the initial point for belief formation. Perception like a causal process produces beliefs about an agent's surroundings. One can think of it as beginning with the activation of sensors, whose signals are processed in complex ways to produce a sensory image, and then beliefs are produced in response to that image [Pollock,1995]. Pollock sees a problem here, which is stated as:

> …more than one reflex can be triggered simultaneously, and it may be impossible to perform the actions dictated by them all. A reactive agent must have some mechanism for adjudicating disputes in such cases. The only obvious mechanism is to assign strengths to reflexes, and when two reflexes compete, the stronger wins. [p. 30]

We consider our dialogues as structured by Initiative-Response units (segments). Whenever an initiative occurs, a response follows.

6.3 Behavior Trace

A pattern of expectations about some of the communicative goals is found during the transcript analysis. For example, if the student asks for repair, then the tutor usually does repair in his turn. When a student requests confirmation, then the tutor's response must include the communicative goal of acknowledgment. Sometimes depending upon the constraints, it is followed by an explanation that ends with a follow up question. A request for information from the student normally elicits an explanation from the tutor. If the student is unable to answer then the tutor always offers his help. So far the initiative-response pattern in the conversational exchange seems to be regular. It has also been noticed that some of the tutor's goals are generated when the tutor senses the wrong usage of terminology, or lack of procedural know how or problem solving skills in the student initiative. This analysis gives us the sequence of adjacency pairs shown in Table 6.1.

Other types of tutor responses (summarized in Table 6.2) are apparently generated on the basis of analysis of the student model. If the last turn was not understood, or is believed to be deficient in some way this brings about an obligation to repair the utterance. A question establishes an obligation to answer the question.

Table 6.1. Contingency Pairs

(Parentheses indicate optional elements.)

Student Goal	Tutor Goal
Conversational Repair	Conversational Repair
Request for Information	Explanation
Request for Confirmation	Acknowledgment + (Explanation)
Time Delay	Help in Response to Pause

Table 6.2. Other Response Moves

Teaching the Sublanguage
Teaching the Problem Solving Algorithm
Probing the Student Inference Process
Instruction in the Rules of the Game
Brushing Off
Summary

Let me present the causal model of initiative and response obtained by exploring our tutoring sessions empirically.

6.4 Results

My exploratory study produced Table 6.3. Each row in the data table represents a single tutoring session. Each column represents an item of information or a measurement

of a different kind. Some information is categorical, not numerical such as whether an initiative contains a hedge or not. It measures the degree of certainty in terms of yes or no.

Table 6.3. Data for Twenty-Eight Sessions of the Keyboard-to-Keyboard Tutoring

Session Number	Tutor	Student Age	Student Sex	Proc.	# of Turns	# of Initiatives	Hedged Initiative	Hedged Initiative	Hedged Answer
							No	Yes	Yes
1	AR	22	F	HR I	80	8	2	6	0
2	AR	28	F	HR I	51	6	3	3	0
3	AR	23	F	HR I	82	1	0	1	7
4	AR	25	F	HR I	92	7	5	2	1
5	AR	22	M	HR I	113	7	1	6	1
6	AR	22	F	HR I	69	4	4	0	0
7	AR	23	F	HR I	115	9	3	6	1
8	AR	25	F	HR I	80	2	0	2	2
9	AR	22	M	HR I	39	7	5	2	0
10	AR	27	F	HR I	67	7	6	1	1
11	AR	26	F	HR I	88	8	8	0	1
12	JM	25	F	HR I	101	12	2	10	2
13	JM	27	F	HR I	83	7	4	3	0
14	JM	27	F	HR I	103	2	2	0	1
15	JM	34	M	HR I	96	2	1	1	0
16	JM	26	F	HR I	84	7	5	2	1
17	AR	22	M	HR D	69	4	3	1	0
18	AR	27	F	HR D	78	2	1	1	0
19	AR	26	F	HR D	92	0	0	0	0
20	JM	25	F	HR D	100	10	4	6	1
21	JM	27	F	HR D	82	0	0	0	0
22	JM	27	F	HR D	120	5	2	3	2
23	JM	34	M	HR D	83	0	0	0	0
24	JM	26	F	HR D	101	2	1	1	1
25	JM	32	M	HR I	165	11	9	2	0
26	JM	24	M	HR D	155	5	4	1	0
27	JM	23	M	HR D	167	8	7	1	3
28	AR	23	M	HR D	111	2	2	0	2
					2666	145	84	61	27

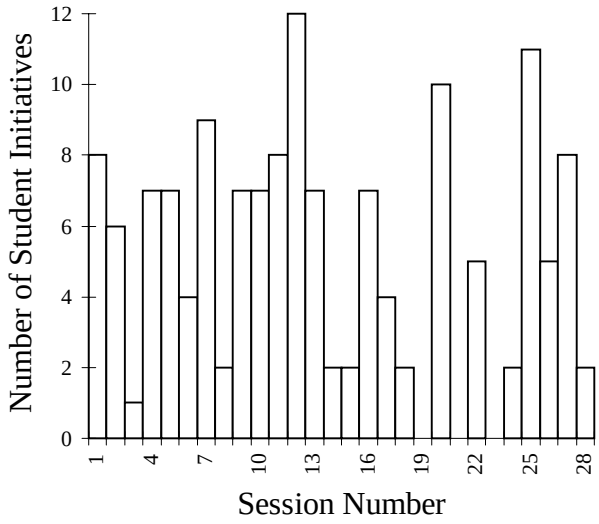


Figure 6.2 A Frequency Histogram for Student Initiatives in 28 Sessions

Visualizations such as the frequency histogram help us think about some aspects of distributions. The point is to analyze data in several ways to find regularities.

6.5 Initiatives and Responses

I have observed very interesting phenomena in student behavior as can be seen from Table 6.4. I did this study on twenty eight keyboard-to-keyboard transcripts. I also focused on sixteen tutoring sessions, where the eight sessions numbered from nine to sixteen were conducted before the students have gone through the CIRCSIM experience. The remaining eight sessions numbered from seventeen to twenty four were arranged after the students have had experience with CIRCSIM. I picked these sixteen sessions because the set of students in the pre and post sessions are the same and so are the tutors. In the pre-session the heart rate of a patient increases due to malfunction of the artificial

pacemaker. In the post-session the heart rate decreases due to the problem in the pacemaker.

Table 6.4. Types of Initiatives in Pre CIRCSIM vs. Post CIRCSIM

Types of Initiatives	PRE-CIRCSIM Hedging			POST-CIRCSIM Hedging		
	Y	N	Sum	Y	N	Sum
Request for Information	3	14	17	0	3	3
Request for Confirmation	13	7	20	10	1	11
Time Delay	1	0	1	1	0	1
Inability to Answer	1	0	1	1	0	1
Conversational Repair	0	8	8	0	1	1
Challenge	0	5	5	0	6	6
Support	0	0	0	0	0	0
Other	0	0	0	0	0	0
Total	18	34	52	12	11	23

We observed that the number of initiatives in the pre-CIRCSIM set are double the number in the post-CIRCSIM set. Also the kind of initiatives taken by the students differ. The proportion of pauses and conversational repair examples decreases in the post-sessions. However, the proportion of challenges increases. The proportion of requests of information and confirmation stays the same in both sessions. In the Pre-CIRCSIM sessions twenty out of fifty one (39%) are hedged. In the Post-CIRCSIM sessions twelve out of twenty six (46%) are hedged. In the Pre- CIRCSIM sessions there are twenty one

requests for confirmation, fourteen of them are hedged. In the Post-CIRCSIM sessions there are ten requests for confirmation and all ten of them (100%) are hedged.

6.5.1 Hedging. The occurrence of hedged and ordinary initiatives varies with respect to the students' communicative and cognitive needs. Hedging is predominantly found in requests for confirmation and pauses involving time delay or inability to answer. The students do not generally hedge when they ask for information.

Figures 6.3 and 6.4 show the counts of hedges in different types of student initiatives in twenty eight tutoring sessions. The most common type of hedged initiative (shown in Figure 6.3) is seen to be Request for Confirmation. On the other hand the most common type of unhedged initiative (shown in Figure 6.4) found is Request for Information. The student in K12 (K20) is showing consistent behavior.

Table 6.5. Initiatives and Turns per Session

Session #	# of Initiatives	%	# of Turns
K09	7	18	39
K10	7	10	67
K11	7	8	88
K12	12	12	101
K13	6	7	83
K14	3	3	103
K15	2	2	96
K16	7	8	84
K17	4	6	69
K18	3	4	78
K19	0	1	92
K20	12	12	100
K21	0	0	82
K22	5	4	120
K23	0	0	83
K24	2	2	101

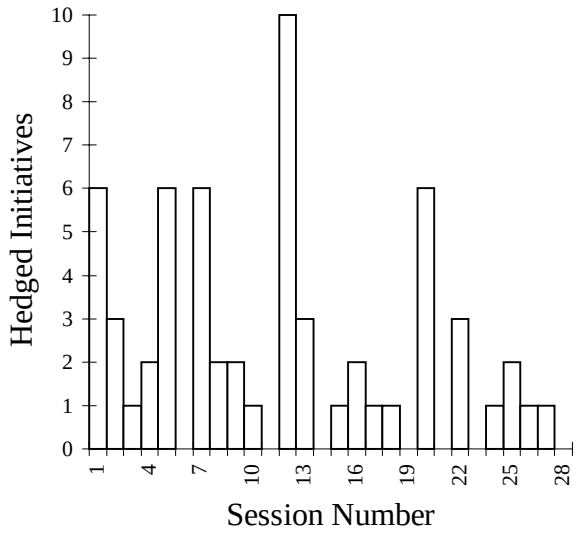


Figure 6.3 The Number of Hedged Student Initiatives in Sessions K1-K28

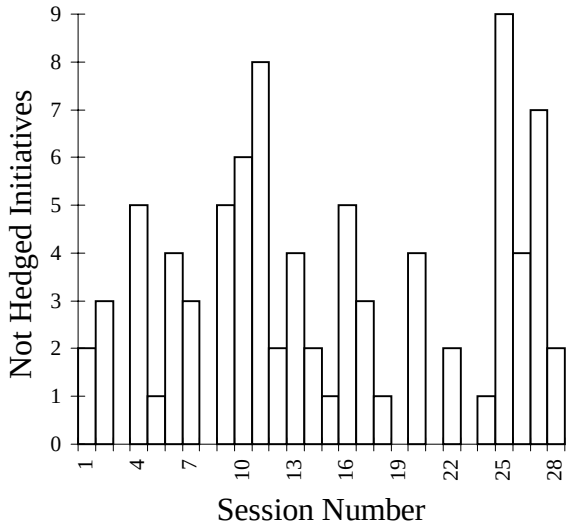


Figure 6.4 The Number of Student Initiatives Not Hedged in Sessions K1-K28

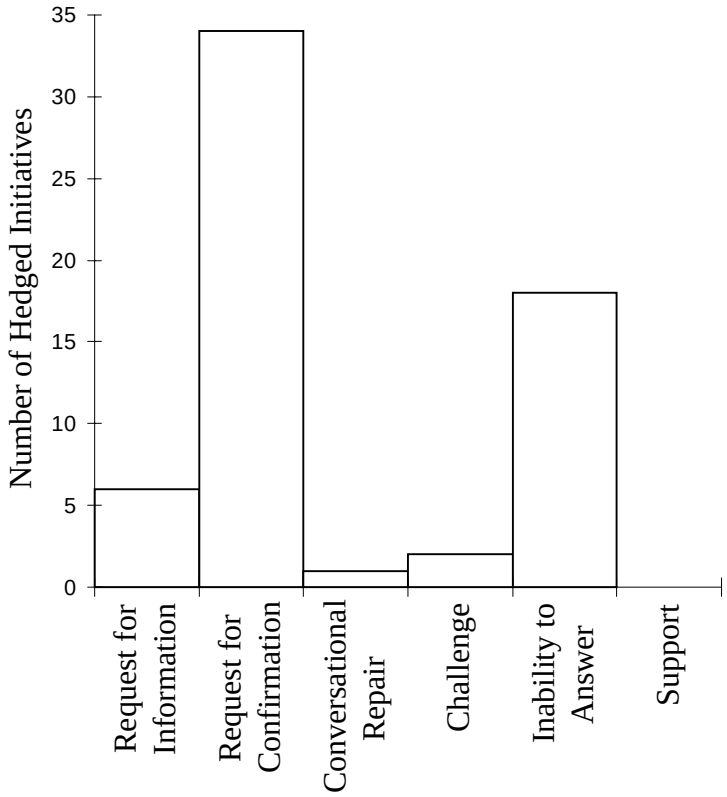


Figure 6.5 The Most Frequent Types of Hedged Initiatives are Request for Confirmation and Inability to Answer in Sessions K1-K28.

Table 6.6. 2 × 2 Table for Study on Student Initiatives versus Hedging in K1-K28 Sessions

Main Types of Student Initiative	Hedging Yes	Hedging No	Total
Request for Information	6	29	35
Request for Confirmation	34	26	60
Total	40	55	95

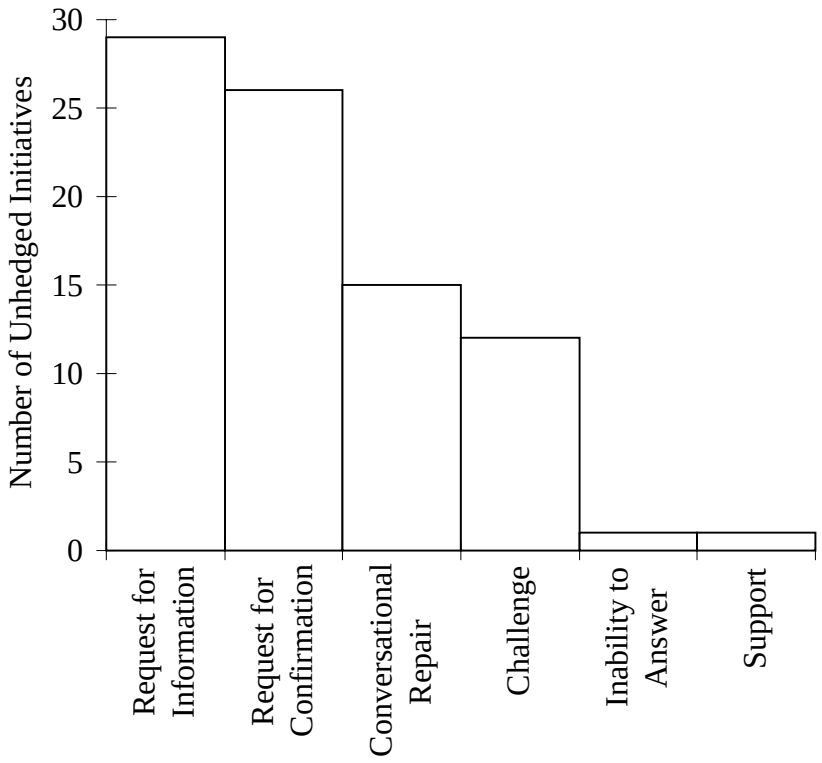


Figure 6.6 The Most Frequent Types of Unhedged Initiatives are Request for Information and Request for Conversational Repair.

Are the dependencies between request for confirmation, request for information, and hedging significant? We can confirm these hypotheses using the Chi Square test. The chi square distribution involves degrees of freedom. In the chi square test for independence, the number of degrees of freedom equals the number of rows minus one multiplied by the number of columns minus one, given as follows:

$$df = (r - 1)\,(c - 1)$$

where r denotes the number of rows and c stands for number of columns here. So in our case the degree of freedom is one. We test our hypothesis that the two most common types of initiative (request for information and request for confirmation) are related to the

hedging factor. The data is arranged as a two by two contingency table, with occurrence (yes or no) of the student initiatives.

$$\chi^2 = \frac{(6\times 26 - 29\times 34)^2 \times 95}{40\times 55\times 35\times 60} = \frac{(156-986)^2\times 95}{4620000} = 14.17$$

For the two-by-two contingency table labelled Table 6.6, the probability of obtaining χ^2 = 14.17 when the type of initiative and hedging are not related is less than .001; therefore we reject the null hypothesis of independence. We conclude that that there is a dependency between the degree of certainty (hedging) and occurrence of request for information and confirmation. The proportion of hedging in initiatives of the type that request information is significantly less than the proportion of hedging in initiatives that request for confirmation.

6.6 Post Action Transition

Table 6.6 represents ten classes of tutor responses to five main classes of student initiatives. In the execution of a fragment of a dialogue, if a student action is an initiative, then the tutor action is expected to be a tutor response. The fragments may vary in frequency of occurrence and length. Various units of initiative-response contribute specific values to the cells of the table. The column headed by Confirmation shows sixty transitions from an action, i.e., Request for Confirmation, to another action, i.e., acknowledgment, or acknowledgment and explanation, conversational repair, brush off, teaching the problem solving algorithm, teaching the rules of the game, probing the student inference process and help in response to pause with different probabilities. For

instance, the relative frequency of a transition to, say, the response acknowledgment given that the current action is request for confirmation is 7/60 = .12 = 12%.

Table 6.7. A Transition Table for Student Initiatives and Tutor Responses in Sessions K1-K28

Response \ Initiative	R for C A	R for I B	Repair C	Challenge D	Support M	I to A N	Total
Acknowledgment E	7 .12	5 .14	0	0	0	0	12
Acknowledgment+ Explanation F	34 .57	7 .2	0	5 .36	1 1	0	47
Explanation G	6 .1	14 .4	0	8 .57	0	1	29
Conversational Repair H	1	1	14 .88	0	0	1	17
Brush off I	1	2	1	1	0	0	5
Teaching the PSA J	4	2	1	0	0	1	8
IROG K	4	3	0	0	0	1	8
Probing the Student IP L	3	1	0	0	0	0	4
Help in Response to Pause P	0	0	0	0	0	15 .79	15
Total	60	35	16	14	1	19	145

Figure 6.7 shows a state-transition diagram that includes all the transition probabilities calculated in such a manner that the ones which exceed .1 are considered and the others are ignored for clarity.

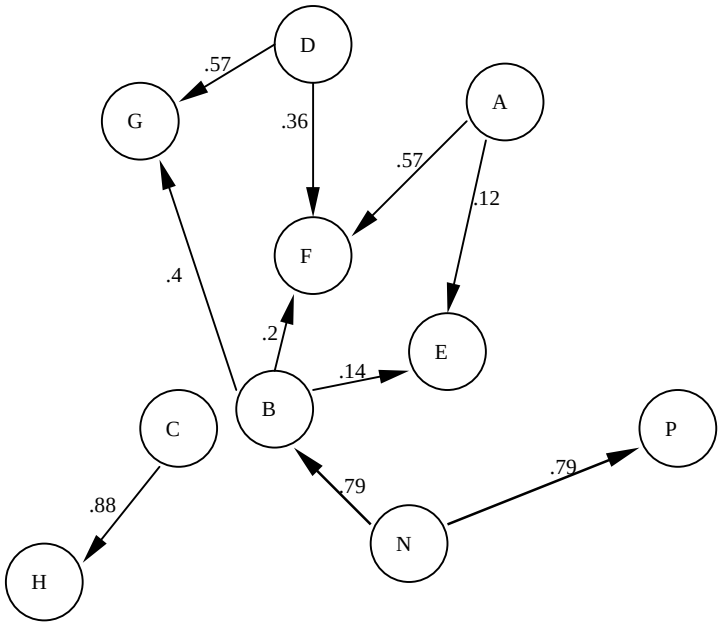


Figure 6.7 A State Transition Diagram

The chances of generating the response with the goal of acknowledgment and explanation or complex acknowledgment are high. Similarly for the action with the goal of request for information, we see that the probability of occurrence of the action with the goal explanation is the highest. Further conversational repair follows a request for conversational repair and an offer of help regularly follows a pause.

Let me now find the dependencies between events in emphasizing the initiative-response behavior. For that we consider the transition table and state-transition-diagram

as given above. We construct contingency tables to represent the number of times acknowledgment follows the request for confirmation, the number of times acknowledgment follows something other than request for confirmation, the number of times something other than acknowledgment follows request for confirmation, and the number of times something other than acknowledgment follows something other than request for confirmation. For convenience, if request for confirmation is denoted by A and acknowledgment is denoted by E, then the statements become AE, $\overline{A}$ E, A $\overline{E}$, $\overline{AE}$, respectively. I am using the chi-square test for a two-by-two table. The χ^2 statistic which is a function of the differences between observed and expected frequencies:

a	b
c	d

$$\chi^2 = \frac{(ad - bc)^2 N}{(a + b)(c + d)(a + c)(b + d)},$$

where N is the sum a + b + c+ d.

In our case:

Table 6.8. Contingency Table for Frequency of E (Acknowledgment) Following A (Request for Confirmation)

	A	$\overline{A}$	Total
E	7	5	12
$\overline{E}$	53	80	133
Total	60	85	145

$$\chi^2 = \frac{(560 - 265)^2 \times 145}{60 \times 85 \times 12 \times 133} = 1.55$$

The degree of freedom is (2-1) × (2-1) = 1. The value of chi-square distribution with one degree of freedom is 1.55. We see that the value of χ^2 is less than 3.841. From a table of critical values for the χ^2 distribution, we get the value that leads to acceptance of the null hypothesis of independence. Therefore, occurrence of acknowledgment does not necessarily follow request for confirmation.

Table 6.9. Contingency Table for Frequency of H (Conversational Repair) Following C (Request for Repair)

	C	$\overline{C}$	Total
H	14	3	17
$\overline{H}$	2	126	128
Total	16	129	145

C - Conversational Repair
H - Conversational Repair
$\chi^2 = 99.77$

The data in Table 6.9 give a $\chi^2 = 99.77$, which is quite a large number showing a strong relationship existing between request for conversation repair from the student and the conversational repair made by the tutor.

But sometimes it may not be appropriate to use a chi-square test here because of frequency of two (2) in the table. The use of the chi-square test is not suggested by many statisticians [Dawson-Saunder and Trapp, 1994, p. 152] when the expected frequencies are less than or equal to two (2), and many argue that the frequency number even less

than or equal to five (5) is too small to use the chi square test. There is no absolute rule. Let's use the alternative procedure called Fisher's exact test for any expected frequency less than two or if more than 20% of the expected frequencies are less than five. This test is used as an alternative to the chi-square test to examine association in the 2×2 tables when expected frequencies are small. Calculating the probability of the observed frequency for Table 6.9 gives:

$$P= \frac{(a+b)!(c+d)!(a+c)!(b+d)!}{a!b!c!d!n!} = \frac{(17)!(128)!(16)!(129)!}{14!3!2!126!145!} = 0$$

Fisher's exact test seems to be quite laborious to compute by hand. It is just to show that there is another alternative to chi-square test to examine association in 2×2 tables when expected frequencies are small.

Similarly,

Table 6.10. Contingency Table for Frequency of F (Acknowledgment + Explanation) Following A (Request for Confirmation)

	A	$\overline{A}$	Total
F	34	13	47
$\overline{F}$	26	72	98
Total	60	85	145

gives ,

$$\chi^2 = 27.48,$$

which is a significant number providing the evidence that the request for confirmation is mostly followed by the response of acknowledgment + explanation.

Table 6.11. Contingency Table for Frequency of G (Explanation) Following B (Request for Information)

	B	$\overline{B}$	Total
G	14	15	29
$\overline{G}$	21	95	116
Total	35	110	145

$$\chi^2 = 11.53$$

The critical value corresponding to 11.53 is less than 0.001; therefore we reject the null hypothesis of independence. We conclude that there is a dependency between the occurrence of move for request for information and the next move as a response of explanation.

Let us consider again the transition table 6.7 and state-transition diagram in Figure 6.7. We can see the relative frequency of G (Explanation) following D (Challenge) is .57. This shows that G follows D unusually often in a trace. Now we prove the validity using the chi-square test.

Table 6.12. Contingency Table for Frequency of G (Explanation) Following D (Challenge)

	D	$\overline{D}$	Total
G	8	21	29
$\overline{G}$	6	110	116
Total	14	131	145

$$\chi^2 = 13.36$$

The chi-square value confirms the hypothesis that the phenomenon of challenge is followed by the phenomenon of explanation.

The other combinations did not give significant results using the chi-square test.

6.7 Measures of Inter-Rater Reliability

I used the Kappa Statistic [Carletta, 1996] to assess agreement on our classification schemes. The kappa coefficient (*K*) measures a pairwise agreement among a set of coders making classification judgements. It was first introduced by Cohen [1960; 1968], and was used by Reggia [1985] as a method for measuring the performance of the Transient Ischemic Attack (TIA) expert system.

I adopted this measure to compare different results obtained from two colleagues, Stefan Brandle, Bruce Miller and myself when studying classification agreement. The raters' opinions serve as a valuable source of support to our theory. The interesting results in pairwise agreement are as follows:

Table 6.13. Relative Frequencies of the Classification of Student Initiatives and Tutor Responses with respect to Surface Form and Communicative Goal

Classification Tasks	FS	FB
Surface Form	97%	83%
Student Goal	80%	
Tutor Goal	86%	

Legend: FS Farhana and Stefan
FB Farhana and Bruce

The level of agreement between Stefan and me is pretty good; that shows our classification scheme is easy to learn. We further calculate the inter-rater reliability using the kappa coefficient as follows:

For the Surface Form, we get:

$$K = \frac{P(A) - P(E)}{1 - P(E)} = \frac{.97 - .2}{1 - .2} = .96$$

For the student's communicative goal, we get:

$$K = \frac{P(A) - P(E)}{1 - P(E)} = \frac{.80 - .125}{1 - .125} = .77$$

For the tutor's communicative goal, we get:

$$K = \frac{P(A) - P(E)}{1 - P(E)} = \frac{.86 - .1}{1 - .1} = .84$$

The Kappa Statistic has the following interpretation:

K < 0 “poor” agreement

0 – .2 “slight”

.21 –.40 “fair”

.41 –.60 “moderate”

.61 –.80 “substantial”

.81 –1 “near perfect”

Carletta et al. [1997] quote Landis and Koch [p. 25] describing these rating as “clearly arbitrary, but useful ‘benchmarks’.” In the kappa coefficient (*K*) of pairwise agreement:

K=0 means no agreement

K=1 means total agreement

Carletta [1996] quotes Kripppendorff [p.252] describing an acceptable level of agreement. He says that in content analysis:

K >.8 as good reliability

.67 < *K* <.8 allows indefinite conclusions to be drawn.

CHAPTER VII

DISTINGUISHING INITIATIVES FROM ANSWERS

A major problem for CIRCSIM-Tutor is to recognize when an initiative occurs. How can we tell whether the student is answering a question or expressing an initiative. We begin by illustrating some of the difficulties we find in distinguishing student initiatives from student answers to questions. Many researchers have found cue phrases to be a meaningful structuring constituent for discourse [Reichman, 1985; Grosz and Sidner, 1986; Litman and Allen, 1987, 1990].

7.1 Distinguishing Student Initiatives from Answers to Questions

Before CIRCSIM-Tutor can determine how to respond to student initiatives, we must distinguish initiatives from answers to questions. We must figure out whether the student is trying to answer a question, or ask one, or propose an explanation, or engage in conversational repair, or whatever. Some hedged answers look very much like questions. Students often use question marks as hedges, as well as adverbs like "maybe" or "sometimes." They also wrap both answers and explanations in "I think" or "I guess." We illustrate these phenomena through the following examples extracted from the transcripts.

EX. 7.1.

K10-tu-39-2: What other variable is under neural control-primarily?
K10-st-40-1: CC?
K10-tu-41-1: Yes.

In EX. 7.1 the tutor is definitely convinced that "CC?" is not an initiative but a hedged answer.

EX. 7.2.

K4-tu-45-3: What else affects the SV?
K4-st-46-1: Well, if SV is volume pumped per beat, and we already know that the number of beats is increased
K4-ti-47-1: Are you stuck?
K4-st-48-1: How about the RAP, which may have an effect on how much blood is reaching the ventricle.
K4-tu-49-1: Definitely, RAP affects ventricular filling.

In EX. 7.2 the tutor seems to be encouraging the student to recognize all possible determinants of Stroke Volume(SV).

7.2 Distinction between an Answer and an Initiative

We make a distinction between an answer and an initiative when the student uses some specific surface linguistic signals – clue words – that are associated with different types of initiatives (communicative goals) in a conversation. The lexical items such as the adverb *even*, the verb *remind*, and the conjunctions *and*, *or*, and *but* provide superb clues to the semantics. A list of observed clue words is given below:

(Interrogative form, Question, So, Pause, Still, Unclear, Hard, Understand, Unless, Sure, Sorry, Let, Lost, Think, Guess, Could, Unless, Well, Might, Perhaps, ?*, i.e., Hesitant, Fragment, Maybe, Sure, Or, Though, Trouble, Expect, Interrupt, Must, Can, I mean, And, Sort of, But, How about, If, Comfortable, Lost, Confused, Mix up)

Table 7.1 Clue Words and Phrases used for Initiative Recognition

Clue Words	Student Initiatives
Guess, perhaps, how about, also, so, bet, think, thinking, may be, ???, i.e., or	Request for Confirmation
Question, unclear, still, would, hard, hesitant, not sure, ask, discuss, explain, but with decl. though, trouble, let, confused, thought, but (if) with ?, just, see, sort of, I don't know, I don't understand	Request for Information
But, also, earlier	Challenge
Pause	Time Gain, Inability to Answer
Question, mean, familiar, previous, understand,	Conversational Repair

Some of these clue words are also found in hedged answers, which differ from the definite ones by containing a hedge. We distinguish the hedged answer from the initiative by finding a complete match of the rest of the statement with a definite answer to the question asked. For example:

Hedged Answers:

EX. 7.3.

K3-tu-23-3: What variable does TPR affect?
K3-st-24-1: MAP?
K3-tu-25-1: Not sure?

EX. 7.4.

K3-tu-35-3: What's the other main determinant of SV?
K3-st-36-1: After load?

EX. 7.5.

K3-tu-49-3: What else might affect filling?
K3-st-50-1: Perhaps RAP?
K3-tu-51-1: Absolutely correct.

Initiatives:

EX. 7.6.

K3-tu-53-1: The venous return may not change for a couple of minutes but what about the rate at which blood is being removed from the central blood compartment?
/st-init-begin Form: Other; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K3-st-54-1: That rate would increase, perhaps increasing RAP???
/st-init-end

Similarly the use of present and past tense in combination with an expected and unexpected answer makes a distinction between the type of initiative and answer. Also the scope of the clue word is counted toward the recognition of the student input. For example:

EX. 7.7.

K24-tu-48-1: Why did you say d?
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Rule of the Game; Certainty: Hedged
K24-st-49-1: Because i thought that the pacemaker is stuck at 50, but i guess sympathetics come into play here, right?
/st-init-end

Initiatives vs. Answers

EX. 7.8.

K20-tu-34-1: What are the determinants of SV?
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged

K20-st-35-1: I THOUGHT I GOT THIS ONE WRONG!!
/st-init-end
K20-st-35-2: DETERMINANTS ARE END-DIASTOLIC VOLUME, AFTERLOAD I. E. MAP, AND I THINK TO A SMALL DEGREE, HEART RATE.
K20-st-35-3: SO I THINK THAT SV GOES UP.
K20-tu-36-8: So what do you think happens to SV, given this info?
K20-st-37-1: SINCE CC IS NOT CHANGING THEN I WOULD THINK NO CHANGE IN SV.
K20-st-37-2: BUT SINCE C. O. D THEN RAPI I THINK SV I
K20-tu-38-1: Correct.
K20-st-61-2: THINKING FASTER THAN I TYPE.

EX. 7.9.

K11-tu-29-3: Do you see now?
/st-init-begin Form: Interrogative; Goal: Request for Information; PSA; Certainty: Not Hedged
K11-st-30-1: But sv also I, which would happen first?
/st-init-end

EX. 7.10.

K11-tu-57-2: If CC is under neural control and we`re talking about the period before any change in neural activity then CC???
/st-init-begin Form: Declarative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not Hedged
K11-st-58-1: But, it is ALSO under intrinsic control
/st-init-end

EX. 7.11.

/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Rules of the Game; Certainty: Not Hedged
K9-st-6-1: On the predictions table, what do DR RR SS mean
/st-init-end

EX. 7.12.

/st-init-begin Form: Interrogative; Goal: Conversational Repair; Focus: Language Issue; Certainty: Not Hedged
K2-st-9-1: What do you mean by "pass the effect"?
/st-init-end
/tu-resp-begin Form: Declarative; Goal: Conversational Repair; Mode: Monologue

K2-tu-10-1: I mean that the system behaves as though the left ventricle was filling from the right atrium

EX. 7.13.

K22-tu-110-2: Reflexes never fully compensate for the disturbance that initiates them.
K22-tu-110-3: But, now you have predicted tpr i, co i and map d.
K22-st-111-1: Tpr should remain i but co should d
K22-tu-112-1: Right.

EX. 7.14.

K16-tu-19-1: Do you need any help to make a prediction at this point?
K16-st-20-1: I am thinking ...
K16-st-20-2: I just need a second more
K16-tu-21-1: Ok

EX. 7.15.

K24-tu-92-1: Why did you predictr that co would be d in ss?
K24-st-93-1: Because i dont think that the reflex mech can ...
K24-st-93-2: Whoops, i think i was being hasty.
K24-st-93-3: I meant co i
K24-tu-94-1: No, you were right the first time.

EX. 7.16.

K18-tu-46-2: What comes after them?
K18-st-47-1: I meant I MAP.
K18-tu-48-1: And then?

EX. 7.17.

K24-tu-98-2: Then how much does co contribute relative to tpr?
K24-st-99-1: The same.
K24-st-99-2: What i meant was that changes in tpr may not be ...
K24-st-99-3: nevermind, i was thinking about something else.
K24-st-99-4: So co and tpr contribute the same
K28-tu-106-3: Should we cover anything else?
CT= 49:8 ET= 0:21 IT= 0:14
K28-st-107-1: I think that's it
K28-tu-108-1: OK.

The next section gives a sketchy analysis of the student input.

7.3 Input Analysis

Figure 7.1 gives an analysis of student input which may be disguised in several forms.

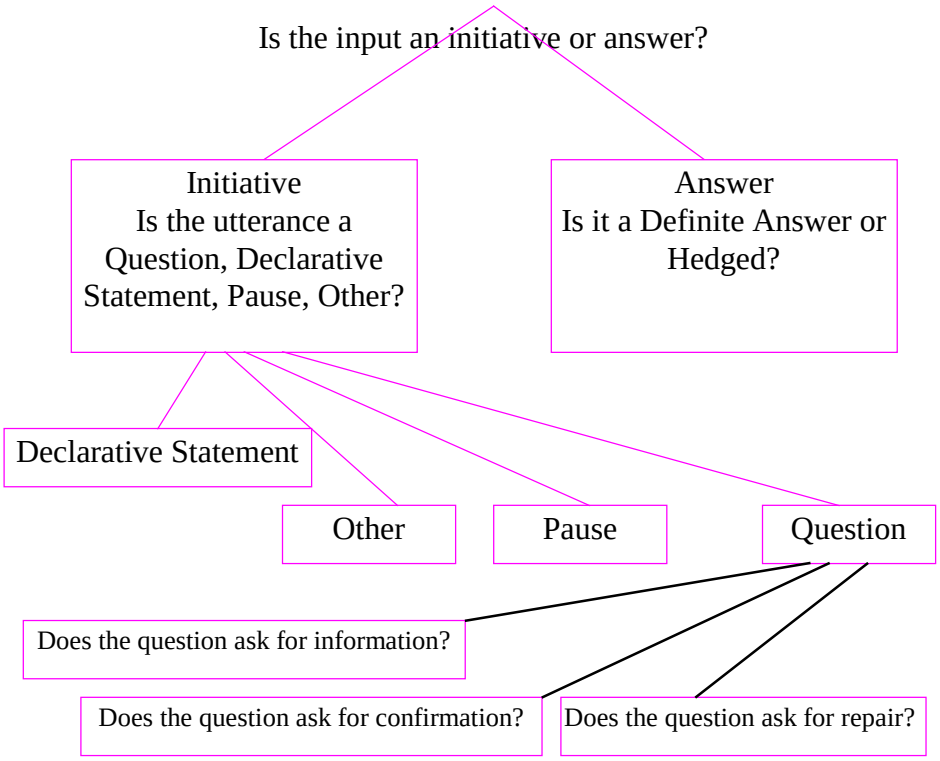


Figure 7.1 Input Filtering

When the student types input, it may be in different forms and content. It is classified either as an answer or an initiative. Again the answer may be a definite answer or a hedged answer. The initiative may also be a definite initiative or an indefinite one. The initiative may be in the form of a question or a statement or some expression that is not

expected as an answer to the question the tutor has asked. The most general form is interrogative which again may be a request for information or request for confirmation or request for repair. The clue words can be used as explicit signals of intentional move. For instance, the words mean, specific, restate, and rephrase suggest that the student asks for conversational repair or does conversational repair. Pause is an indication of some obstacle in the way of the student's thinking.

CHAPTER VIII

FUTURE RESEARCH

This chapter contains a brief outline of different models of student plan recognition that can be considered in future to handle some of our comprehension issues. It is beyond the scope of this thesis to investigate them at length. Nevertheless, they suggest ideas I hope to explore soon and they set the directions for further research.

8.1 Questionnaire for Student Users

I prepared a questionnaire in order to do another pilot study, by conducting a survey of the needs and desires of the students. What kind of responses do students want to receive? I could not do that because the precondition of having them work with CIRCSIM-Tutor (v.2) was unfulfilled. Hopefully, in future if the medical students at Rush get a chance to experience the system, the questionnaire can be used then. My questionnaire is given in the Appendix C.

8.2 Adaptive Networks

In view of the patterns in the dialogue described in Chapter VI, I thought that a model with a connectionist architecture would be appropriate for capturing the systematic aspects of these speech act sequences. The recurrent network saves an encoding of the preceding dialogue and uses this information to generate the plan underlying temporal sequences [Britton and Graesser, 1996].

We have explored the possibility of recognizing patterns of initiative-response pairs using neural networks. Connectionist models are amenable to simulating complex behavior by means of adaptive networks made up of processing units. The strength of interconnections among units, which determine the input output relations that the network can simulate, are often modified by some feedback mechanism. Rumelhart chose to explore a connectionist approach to the notion of text-oriented grammars [Rumelhart and McClelland, 1986]. The feedback mechanism that supervises learning chooses patterns of activation of the connections in the network. The similarity to the nervous system encourages us in the hope of a useful interdisciplinary attack on the problems of complex human behavior [Smolensky, 1988]. Some view adaptive-network models as more closely guided by neurophysiological and neuroanatomical data [Crick and Asanuma, 1986; Minsky and Papert, 1988].

Rumelhart et al. [1986] present their view in support of neural network technology as follows:

> Schemata are not things. There is no representational object which is a schema. Rather schemata emerge at the moment they are needed from the interaction of large numbers of much simpler elements all working in concert with one another….In the conventional story, schemata are stored in the memory…In our case, nothing stored corresponds very closely to a schema. What is stored is a set of connectionist weights which, when activated….generate states that correspond to instantiated schemata. [Rumelhart et al. 1986, pp. 20-21]

In order to recognize the communicative goals of the student we characterize the student-tutor behavior as input and output to the connectionist architecture. We depend on our taxonomy and consider the communicative goals of the student as the vectors: S(form(5), goal (8), focus(6), hedged(2)), where the alternative values are:

form: declarative, interrogative, imperative, other

goal: request for information, request for confirmation, repair, pause, refusal to answer,

focus: parameter, relation, problem-solving algorithm, language issue, mechanism, rules of the game

hedging: yes, no

The tutor's responses are coded as follows:

T(form, goal, mode); T(form(5), goal(10), mode(5))

form: exclamation, declarative, interrogative, imperative, other;

goal: acknowledgment, explanation, summary, instruction in the rules of the game, teaching the sublanguage, teaching the problem-solving algorithm, help in response to pause, probing the student's inference process, brushing off, conversational repair;

mode: hinting, directed line of reasoning, monologue, analogy, rephrasing.

8.2.1 Recurrent Networks. We looked into a special type of neural network called a recurrent network. This approach has been used to learn strings of characters [Servan-Schreiber et al., 1989]. In a recurrent network, there are some units called context units that receive input signals from the previous time step. The weights on the connections among the units are fixed. The architecture for the recurrent network is shown in Figure 8.1. It has four layers. The input layer specifies the category of student initiative. There are eight nodes in the input layer, one for each student goal category. The appropriate node is activated when the initiative is received. For example, if the student

asks for repair, then S_k, (request for repair node), will be activated in the input layer of the network. The output layer contains the predictions for the tutor response. There are ten output nodes, one for each tutor goal category. An output node has an activation value that reflects the degree to which the network predicts that output node. For example, if the input is a student goal, say $S_{k,}$ we expect the corresponding tutor goal, say T_j the jth output where j varies from one to ten, to receive a high activation value in the output layer. Thus we hope to capture some regularity in the tutor responses.

The hidden layer captures higher order constituents that are activated by the initiative. Hidden layers are frequently implemented in connectionist architectures to capture internal cognitive mechanisms [Rumelhart and McClelland, 1986]. The hidden layer is needed when direct input-output mappings fail to capture the systematicity in the data. There are five nodes in the hidden layer of our network.

The context layer allows the network to induce temporal sequences. The context layer stores the activation from the hidden layer of the previous step in the speech act sequence. The hidden layer receives information about present and past inputs. The context layer must have the same number of nodes as the hidden layer. The input student goals are denoted by S_1, S_2, S_3, S_4, S_5, S_6, S_7, and S_8. The corresponding output (target) tutor goals are denoted by T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, and T_{10}.

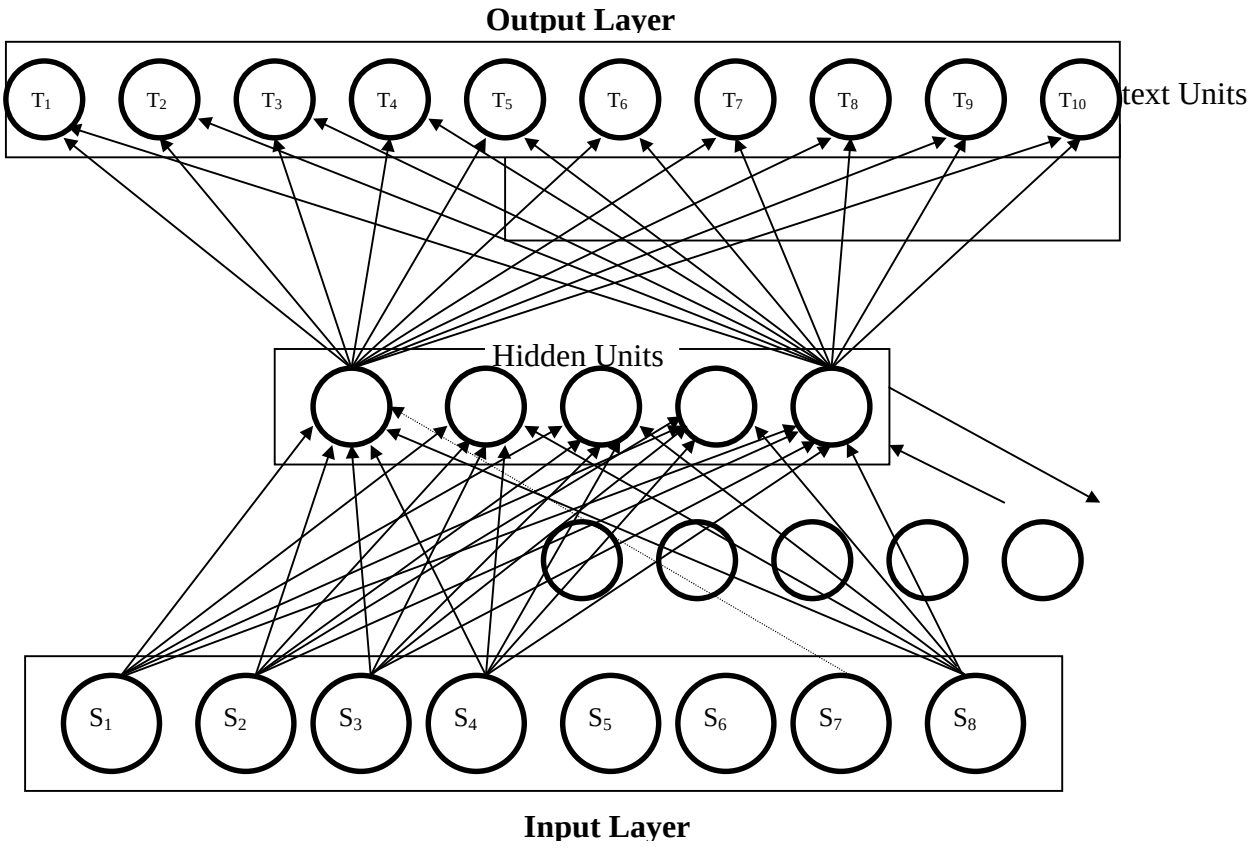


Figure 8.1 Recurrent Connectionist Network for Response Prediction

There are a total of 115 connections that are allowed to vary in the weight space of this model. There are 40 connections between the input layer and the hidden layer, 8 input nodes and 5 hidden layer nodes. Similarly there are 50 connections from the hidden layer to the output layer of ten tutor goal nodes. The other 25 nodes link the 5-node context layer to the 5-node hidden layer. The number of nodes in the hidden layer and context layer can be varied.

8.3 Patterns of Plan Recognition

Allen [1980] built his research on plan recognition on reasoning with nested beliefs. We have tried to utilize his strategy based on Searle's view of conversation as rule-governed behavior, and Grice's definition, equating understanding to recognition of the speaker's intent. If the student initiatives are defined as actions, then we can model them by using operators. The plan operators are put in a plan library. Let's see how an initiative can be represented by a plan. Assume that the student has a communicative goal of request for information.

The student's immediate goal is extracted from the semantic representation of her/his utterance. The semantic representation of a declarative utterance is as follows:

T.Inform[STUDENT, TUTOR, P]

where P is a proposition about an element in the domain knowledge base.

The semantic representation of an interrogative utterance is either of these two representations:

S.Request[STUDENT, TUTOR, Informif(TUTOR, STUDENT, P)]

S.Request [STUDENT, TUTOR, Informref(TUTOR, STUENT, ?x:XTYPE | P)]

Here ?x is a variable of type XTYPE, appearing in proposition P and whose rules satisfying P are requested. Informif and Informref are used for modeling requests for information. I got these notations from Carberry's [1990b, p. 43] description of Allen's

representation scheme. In the representations above *Informif(TUTOR, STUDENT, P)* means that the tutor knows if the proposition P is satisfied. *Informref(TUTOR, STUENT, ?x:XTYPE | P)* means that the tutor knows the referent of the variable. The student's immediate goal is then one of the following (which correspond to the above three semantic representations):

Want[STUDENT, Know(TUTOR, P)]

Want[STUDENT, Knowif(STUDENT, ?x:&XTYPE | P)]

For example, see the segment of a dialogue in Example 8.1. The tutor explains that increased filling (preload) does increase ventricular contractile performance; but this is the cardiac length/tension relationship (Starling's Law), not contractility. Contractility change shifts the position of the Starling curve. CC I (increase) would shift it upwards and to the left so that a constant filling would still cause an increase in contractile force.

EX. 8.1.

K10-tu-45-1: Well, first you have two phenomena confused.
K10-tu-45-2: Increased filling (preload) does increase ventricular contractile performance; but this is the cardiac length/tension relationship (Starling's Law), not contractility.
K10-tu-45-3: Contractility change shifts the position of the Starling curve.
K10-tu-45-4: CC I would shift it upwards and to the left so that a constant filling would still cause an increase in contractile force.
K10-tu-45-5: Do you see the difference?
K10-st-46-1: No -- this concept is hard for me to grasp.
K10-tu-47-1: An increase in contractility is caused by an increase in intracellular [Ca], and is independent of filling.
K10-tu-47-2: Filling increases contractile performance by changing the orientation of thick and thin filaments.
K10-tu-47-3: OK?
K10-st-48-1: Is increased IC [Ca] the only thing that can increase contractility?

K10-tu-49-1: Yes.
K10-st-50-1: Okay.

Here the student initiative No -- this concept is hard for me to grasp is taken as indirectly asking for information even though the surface form is declarative. It is a request that the tutor inform the student whether the tutor can carry out the specified request and is translated into the following surface speech act:

S.Request(STUDENT, TUTOR, Informif [TUTOR, STUDENT, cando

(STUDENT, Teach [Tutor, CONCEPT])

Although it is not an expected answer to the question asked by the tutor, yet the tutor has recognized what the student is up to. The tutor realizes that the student has confused the two phenomena.

A helpful response is generated in an attempt to overcome not only the stated goals but also the unstated obstacles in student plan. We need to develop the plan inference and obstacle detection processes.

8.4 Student Plan Understanding and Recognition

We use surface level linguistic actions as well as the occurrence of the referring expression and its content. The system must use the established conversational context in order to properly interpret the student utterance. For example:

EX. 8.2.

K4-tu-58-1: Let me remind you of the vascular function curve.
K4-tu-58-2: It shows the relationship between central venous P (same as RAP) and CO when CO is the independent variable.
K4-tu-58-3: Do you remember that?
K4-st-58-1: Yes, I guess I do now.

K4-st-58-2: A decrease in CVP would be in response to an increased CO.
K4-tu-59-1: Sure.

Without knowing the context, it is hard to interpret K4-st-58-2. The dialogue context is needed to know what "that" refers to, i.e., the relationship between central venous pressure (CVP) and cardiac output (CO). It helps to determine where the tutor response ends.

The expectation for the next outcome can be developed in the light of the current context. Proper use of expectation is a key aspect in constraining the search, in accomplishing meaningful interpretation (focus/content), organization of tutor activity, and effective processing of natural language input [Allen, 1995]. We include constraints, under which a feature can be used to refer to an object. These constraints help in both plan construction and plan inference. The derivation of the student plan is evaluated by finding an instantiation for the variables such that all of the constraints hold with respect to the tutor's belief about the student's beliefs. If the tutor is able to satisfy the conditions, then he will have understood the student plan. For example, in initiating repair if the initial referring expression is not understood, then the participants will collaborate [Hirst et al. 1994]. The top-level actions that make up collaboration may be: accept-plan(Plan), reject-plan(Plan), postpone-plan(Plan), replace-plan(Plan), and expand-plan(Plan).

EX. 8.3.

K5-tu-89-2: Now, where do you want to go?
K5-st-80-1: CO D.
K5-tu-81-1: Right.
K5-tu-81-2: Why?
K5-st-82-1: Because CC D.
K5-tu-83-1: So?
K5-st-84-1: I don't understand.

K5-tu-85-1: How does CC D affect CO?
K5-st-86-1: CC = HR X CO?
K5-tu-88-1: That's news to me.
K5-tu-88-2: Let's think about it differently.
K5-tu-88-3: Knowing what contractility means, what does CC affect?
K5-st-88-1: HR and SV.
K5-tu-89-1: HR?
K5-tu-89-2: That's under the control of the pacemaker.
K5-tu-89-3: Contractility refers to the myocardial (Muscle) properties.
K5-tu-89-4: What does CC affect?
K5-st-90-1: SV.
K5-tu-91-1: Sure.
K5-tu-91-2: So what happens to SV?
K5-st-92-1: If CC D, then SV d.
K5-tu-93-1: You got it.
K5-tu-93-2: Now I forgot where we were.
K5-tu-93-3: Please review your predictions for me .

Surface linguistic actions for the referring expressions:

s-refer (Ent): Expresses the speaker's intention to refer to the object corresponding to the discourse entity.

s-attrib(Ent, Pred): Used to describe the referent corresponding to the discourse entity Ent by means of the predicate Pred.

s-attrib-rel(Ent, ObEn, Rel): Used to describe the object corresponding to Object Entry (ObjEn).

s-accept(Plan): Communicates acceptance of a plan. Could be realized as Yes or an emphatic Ookay.

s-reject(Plan, acts): Communicates rejection of components of a plan, e.g., But..

s-postpone(Plan): Communicates postponement of judgment on a plan. Tentative OK

s-actions(Plan, Acts): Communicates an addition to components of a plan.

The actions taken with regard to entity, attribute and relation make use of plan repair techniques to refashion the expression, and use surface linguistic actions for collaborating to communicate the part of the referring plan that needs to be removed or added.

a. Communicate the source of error to the other participant

Once the plan is understood then the goal is adopted to communicate this to the speaker. This leads to the discourse action of acceptance of the plan [Allen and Perrault, 1980].

8.5 Discussion

According to Grosz [1981] and Reichman [1985], the discourse analysis is done better when the discourse is partitioned into related but distinct discourse units. Grosz called these partitions “focus spaces,” while Reichman called them “context spaces.” For the most part, the natural language interface may be able to treat each query as an isolated request for information, with little use of the utterance context within which the query occurs. In the absence of words indicating a topic shift, the tutor should believe that the speaker’s ill-formed utterance is relevant to the established dialogue context.

We see the use of intelligent computer systems, especially those which interact with students, as the most promising path of study.

Early detection of the student’s misconceptions can prevent the conversation going awry. If not detected in time, the error creeps in, causing serious misunderstanding later on. Students who have good mental models of explanations produce better

explanations or students derive good mental models by receiving good explanations from the tutors.

8.5.1 Social Interaction. Social interaction plays an important role in learning. Katz and Lesgold [1993, p. 295] referred to Bearison, Doise and Mugny who did research on social interaction and intellectual growth. Their studies indicate that cognitive conflicts (challenges) embedded in a social situation are more favorable to cognitive development than is an individual experience with conflicting viewpoints within her/his own mind. What we know, the meaning of the concepts we have, is associated with specific social problem-solving situations in which we have operated. When we encounter multiple situations that have some amount of commonality, we can learn by solving the issue of how to view those situations so that their commonalities stand out. Such viewpoints turn out to be powerful perspectives that facilitate generalization to new situations we may encounter in the future.

When the tutor and student work together the student starts to take over some of the specialized knowledge and skill. The conversational exchanges that occur during social interaction facilitate learning [Teasley and Roschelle, 1993]. The outcomes of our tutoring system can be affected positively by the use of social learning methods in a computerized learning environment. This computer-based activity is optimized by allowing the student to articulate her/his knowledge to understand a problem. Competent performance exhibits strong interactions between structures of knowledge and process of reasoning and problem solving [Glaser and Chi, 1988]. We are trying to help the students use a richer medical vocabulary and also get them to try out their ideas to see what works.

Besides the motivational and affect factors, the issues of cognition and information also need attention.

8.5.2 Issues. We classified our student initiatives according to surface form as interrogative, declarative, imperative, other and pause. The study of the structure of the forms of initiatives in keyboard-to-keyboard transcribed expert tutoring sessions uncovered some other hidden issues described below:

The surface form is not always a simple sentence, we also see compound, complex, and compound-complex kinds. For example:

EX. 8.4.

K12-tu-45-3: Does venous return go up immediately?
K12-st-46-1: Does the rate of blood removal from the central veins mean that blood entering the right atrium, if so ithink venous return does go up immed.
K12-tu-48-1: We need to get our terminology straight.
K12-tu-48-2: Venous return means blood returning from the systemic circulation to the heart.
K12-tu-48-3: That does not go up immediately.
K12-tu-48-4: It takes about a minute after CO I.
K12-tu-48-5: Does more blood enter the ventricale for CO to I, Yes.
K12-tu-48-6: But it's coming from the blood content of the ventricles (end systolic volume -- reserve), pulmonary blood volume, central venous volume.
K12-tu-48-8: Immediately after CO I, the entire central blood chamber decreases in volume.
K12-tu-48-8: That's because CO exceeds VR.
K12-tu-48-9: Understand?
K12-st-48-1: Yes thank you

It is evident in K12-st-46-1 that the surface form is a compound complex sentence. It is composed of two independent clauses and three subordinate clauses. The first independent clause (Does the rate of blood removal from the central veins mean that S_1 is

in interrogative form. The first subordinate clause S_1 (blood is entering the right atrium) .blood entering the right atrium) is in interrogative form. The second independent clause (ithink) is in declarative form with an attached adverbial clause (if so). The subordinate clause S_2 (venous return does go up immed.) is a sentential complement like S1. The study raises different questions like:

? which part of the initiative is more or less important.

? should it be treated as one initiative or two in one.

? in the case of two initiatives do we need to respond to both or only the more recent one.

? what is the criterion for prioritizing the initiatives.

We noticed that the tutor does not always answer the initiatives straight away. Sometimes instead, he tries to correct the misconception first and then comes back to handle the initiative. The tutor does not ordinarily abandon the topic until he is satisfied that the student knows the correct answer based on causal reasoning or his other instructional objectives are complete. For example:

EX. 8.5.

K12-tu-61-4: And you're saying SV D.
K12-tu-61-5: I won't comment on the correctness of that yet.
K12-tu-61-6: What I want to know is how the reflex is going to get SV to D?
K12-st-62-1: Decrease filling time, decrease venous return.
K12-st-62-2: I'm just hesitant to say what comes first.
K12-st-62-3: I'll go with tpr i to slow blood flow back to heart (I don't really like this idea)
K12-tu-63-1: Well let's see if we can get at the first question I asked and then we'll come back to TPR.
K12-tu-63-2: With regard to SV, what are it's determinants?

K12-st-64-1: Ventricular volume prior to onset of systole and cardiac contractility
K12-tu-65-1: Sure.
K12-tu-65-2: Now considering that we are in the RR period, i.e., the first things that are going to change are the things that are under neural control, which of these determinants would be the first affected?
K12-st-66-1: Cc
K12-tu-68-1: Of course!
K12-tu-68-2: And in what direction?
K12-st-68-1: Decrease
K12-tu-69-1: Right again.
K12-tu-69-2: And how would that affect SV?
K12-st-80-1: Decrease
K12-tu-81-1: Sure.
K12-tu-81-2: And what affect would that have?
K12-st-82-1: Decrease co
K12-tu-83-1: Yes again.
K12-tu-83-2: Then what?
K12-st-84-1: Map d
K12-tu-85-1: Yes, again.
K12-tu-85-2: And in this regard.
K12-tu-85-3: It is MAP that is regulated by the BAROceptor reflex.
K12-tu-85-4: That's why it's called that.
K12-tu-85-5: Now let's get back to TPR.
K12-tu-85-6: Do you have any new thoughts about it?

After this whole tutoring episode the tutor seems to be willing to consider a new topic. This raises more questions:

? how can we determine whether the initiatives contained in two separate sentences, for instance in K12-st-62-2 and K12-st-62-3 are two independent initiatives or just one.

Confusingly, the same clue words may involve different meanings. “But I am confused with the role of decreased tpr and rap,” uses the clarification sense of <u>but</u>, while in “But, it is ALSO under intrinsic control,” the introducer sense of <u>but</u> presents a challenge. Again the connotation is changed by the identity of the speaker - the tutor or the student.

From the classification perspective the situation is sometimes not clear cut. With a small number of communicative goals one faces the difficulty of fitting the intended message into the list of goals that is thought of as the best match (subsumed) to the goal. We need to clarify the details of the decision procedure.

With a large number of communicative goals one is faced with another difficulty, that of choosing the one that best expresses the student initiative.

Some other questions are:

- Can we label such a conversational move a student initiative? If yes, then can we apply Reichman's theory.
- How can we choose appropriate elements of a context to be included in the structural description?
- How can we deal with mixed-initiative interaction and transfer of control in our system?
- Would an adaptive network amenable to connectionist interpretation be useful?
- What diagnostic strategies can be used to pinpoint the causes of student misconceptions?
- What remedial techniques can be implemented to handle those misconceptions.

Representation continues to be matter of research. We face the same questions over and over but come up with different answers for designing a good representation. The use of proper technology in an appropriate manner can change hard situations to simple ones.

What we know, the meaning of the concepts we have, is tied to the specific social problem-solving situations that we observed. For an ambiguous situation, it seems

possible to find the information needed to resolve the ambiguity from the context of an utterance. Some pragmatic factors need to be taken into account. For example:

EX. 8.6.

> K4-tu-55-1: My question was just the opposite.
> K4-tu-55-2: Not how would an increase in SV affect CO, but how would an increase in CO (that's what you already said happened) would affect RAP.
> K4-st-56-1: An increase in CO would increase the RAP.
> K4-tu-58-1: Let me remind you of the vascular function curve.
> K4-tu-58-2: It shows the relationship between central venous P (same as RAP) and CO when CO is the independent variable.
> K4-tu-58-3: Do you remember that?
> K4-st-58-1: Yes, I guess I do now.

is followed by the student initiative:

K4-st-58-2: A decrease in CVP would be in response to an increased CO.

The K4-st-58-2 initiative must be the student's goal taken in context with whatever discussion has gone before. If it is considered in isolation, "that" in "Do you remember that?" can not be interpreted as referring to Starling's law. Until the context is known, we can not interpret it correctly. If the logical form of the production is to reflect the intended meaning, processes that are assigned to pragmatics must be used to reach the referent of that. As Moore puts it:

> …sentences per se do not have logical forms; only sentences in context do. [Moore, p. 118]

The problem confronting the system is "why would the student say that in this situation?" The appropriate context may reveal the essence.

When we encounter multiple situations that have some amount of commonality, we can learn by solving the issue of how to view those situations so that their

commonalties stand out. Such viewpoints turn out to be powerful perspectives that facilitate generalization to new situations we may encounter in the future.

CHAPTER IX

CONCLUSION

9.1 Summary

We are attempting to add more sophistication to our existing tutoring system CIRCSIM-Tutor. This system aims at teaching cardiovascular physiology to first year medical students with the goal that they learn problem solving using causal reasoning. The system starts with a problem followed by a question related to making predictions about qualitative changes in seven core cardiovascular variables, and engages the student in a remedial tutoring dialogue by keeping the control throughout. Sometimes, however, instead of answering the question from the tutor the student attempts to seize control by asking a question, or producing a self-explanation. The desire to make our system handle this kind of student behavior has led me to try to find techniques and strategies that can be implemented.

This thesis describes the salient features involved in understanding and responding to student plans in an intelligent tutoring system. If our CIRCSIM-Tutor is to generate appropriate responses, it must demonstrate an adequate level of comprehension. In order to determine what the tutor should do, we have studied the behavior of students and tutors in human tutoring sessions.

We came up with classification schemes for student initiatives and tutor responses.

1. We used four dimensions for classifying the student plan: Surface Form, Communicative Goal, Focus/Content, and the Degree of Certainty.
2. We used three dimensions in classifying the tutor responses: Surface Form, Communicative Goal, and Delivery Mode. The tutors normally set a goal and devise a strategy to accomplish it in an effective manner. In this process new subgoals may be set up and this process repeats itself.

In summary the stream of dyadic conversation is segmented into a sequence of initiative-response speech acts and each student goal is assigned to one of eight and tutor's goal is assigned to one of ten categories. I discussed the classification schemes for student initiatives and tutor responses with the expert tutor (Joel Michael) and he said that the tutor responses are perfectly fine. He expressed his views about the difficulty of considering the concepts of *parameter*, *causal relation*, and *mechanism* individually, and reasoned that he tends to take them at coarser grained level. We were convinced and we decided to put the three in one package calling it causal reasoning. He also suggested that we merge *compare and contrast* with *request for information.* We also decided on combining the two categories of inability to answer and time delay into one category.

Two colleagues Stefan Brandle and Bruce Mills have categorized both initiatives and responses. For the Surface Form, we get agreement of .97 with the Kappa Statistic (*K*) value =.96. For the Student's Communicative Goal we get agreement equal to .80 with K = .77. For the Tutor's Communicative Goal we get agreement .86 with K =.84. The raters' opinions serve as a valuable source of support to our theory.

We have also studied the relationship between frequent initiative-response pairs and we have shown several of these relationships to be significant using a χ^2 test.

9.2 Significance

The model of plan understanding accounts for many features of human behavior. The aim of this research is to construct an interactive dialogue system that will understand student plans and respond to the needs of the student. The education process can be made effective and interesting if the students are allowed to have control over the instruction they receive, especially in the case of computer-based learning environments. When the student feels that their learning needs are not being attended to, boredom, frustration, and loss of interest prevail. This research enables us to move in the direction of implementing mixed-initiative dialogue in our system.

In order to identify and interpret various student initiatives, the system must screen the input and retain the gist of the input to be handled accordingly. I present a computational model of problem solving and learning in which the reasoning system performs a diagnostic problem solving task. The structures represent the mental operators underlying the reasoning process. A fruitful tutoring session solidifies the student membership in the community of experts and provides opportunities for further conversational exchanges about more advanced topics, with other members of the community.

APPENDIX A

ANNOTATED TRANSCRIPTS

TRANSCRIPT ANNOTATION

The annotation procedure allows us to display information about any tag or set of tags. The markup of the transcripts can help us in providing the data to support or reject certain hypotheses. For example, novice tutors are more verbose than expert tutors, or monologues (explanations) are used as tutoring tactics more often than hints.

Transcript header that starts with the string Transcript: followed by the transcript number and other demographic information, for example, date, teacher, student and her/his experience of CIRCSIM. Each transcript corresponds to one tutoring session. The sentences in the transcript begin with its identifier in column 1. The identifier as K10-tu-1-1, introduces K10 as the tenth transcribed keyboard-to-keyboard tutoring session with an expert tutor, tu as the participant (tu or st) tutor, number one (1) as the participant's first legitimate move to type contiguously (turn) such as 1 indicates the first turn of the tutor, and about the number of sentences typed (in sequence) by during the turn.

The markups that I have done, has a slash in column 1 followed by the annotation type and class. The annotation types are st-init-begin, st-init-end, tu-resp-begin, tu-resp-end etc. The suffixes -begin and -end mark the boundaries of the segment or sections of tutorial dialogue. The classification of student initiative and tutor response follows with respect to four and three dimensions respectively. For example, in the following annotation:

/st-init-begin Surface Form; Communicative Goal; Focus/Content; Degree of Certainty
<text>
/st-init-end

st-init-begin indicates the beginning of student initiative followed by the values of the components of student initiative: surface form, communicative goal, focus, and degree of certainty.

The text of initiative follows except the pause form. /st-init-end indicates the end of the student initiative. Sometimes we notice nested initiatives as:

/st-init-begin (main)
<text>
/st-init-begin
<text>
:
/st-init-end
/st-init-end (main)

Somewhat similar idea of annotation is working behind tutor responses classified with respect to three dimensions: surface form, communicative goal, delivery mode. For example:

/tu-resp-begin Surface Form; Communicative Goal; Delivery Mode
<text>
/tu-resp-end

The nested response may occur as follows:

/tu-resp-begin (main)
<text>
/tu-resp-begin Class: Surface Form; Communicative Goal; Delivery Mode
<text>
/tu-resp-end
/tu-resp-end (main)

Most of the time multiple types of student initiatives occurring together are treated by selecting the dominant goal usually considering the latest one in order.

Transcript: K10 (PRE-CIRCSIM)
Date: 4/23/1990
Teacher: Rovick
Student: M.O.
Student Sex: F
Student Age: 27
Tutor: AR
Protocol: Two
Procedure: HR I Pacemaker
Initiative: 6 (7)
Hedged: 1
Not Hedged: 5 (6)
Hedged Answer: 4
Response: 6 (7)

K10-tu-1-1: Hi.
K10-tu-1-2: I'm glad you found it.
K10-tu-1-3: Please type your social security number.
K10-tu-1-4: If you make a mistake you can erase by backspacing.
K10-st-2-1: XXX-XX-XXXX
K10-tu-3-1: Have you used either CIRCSIM OR HEARTSIM?
K10-st-4-1: Nope
K10-tu-5-1: Good.
K10-tu-5-2: Then please read page 1.
K10-st-6-1: Ok
K10-tu-7-1: Please read page 2.
K10-st-8-1: Ok
K10-tu-9-1: Please read page 3.
K10-st-10-1: Ok
K10-tu-11-1: Please read page 4.
K10-st-12-1: Ok
K10-tu-13-1: Please read page 5.
K10-st-14-1: Ok
K10-tu-15-1: Begin by pre;dicting the direct change in the first variable that would be affected.
K10-st-16-1: Hr i
K10-tu-17-1: Correct.
K10-tu-17-2: And what's next?
K10-st-18-1: Co i
K10-tu-19-1: Swell.
K10-tu-19-2: Next?
K10-st-20-1: Map i
K10-tu-21-1: Super.
K10-tu-21-2: Then?
K10-st-22-1: Rap i

K10-tu-23-1: Next.
K10-st-24-1: Cc i
K10-tu-25-1: Next.
K10-st-26-1: Sv i
K10-tu-27-1: KNext and last, TPR?
K10-st-28-1: Tpr i
K10-tu-29-1: Ok.
K10-tu-29-2: Let's take a look at some of your predictions.
K10-tu-29-3: Take the last one first.
K10-tu-29-4: Can you tell me how TPR is controlled?
K10-st-30-1: Autonomic nervous system
K10-tu-31-1: Yes.
K10-tu-31-2: And the predictions that you are making are for the period before any neural changes take place.
K10-tu-31-3: So what about TPR?

/st-hedged-answer-begin
K10-st-32-1: I thought TPR would increase due to higher flow rate through vasculature.
/st-hedged-answer-end

K10-tu-33-1: You just said that the primary control over the TPR was via the autonomic NS.
K10-tu-33-2: The ANS activity would not have time to change yet in the DR period.
K10-st-34-1: OOkay.
K10-st-34-2: I was thinking about TPR intrinsically and extrinsically.

/st-init-begin Form: Interrogative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not hedged
K10-st-34-3: So ANS would affect the system extrinsically and control it <u>but wouldnt there be more friction on the fluid going through the tube?</u>
/st-init-end
/tu-resp-begin Form: Declarative, Declarative, Declarative,_, Other; Goal: Explanation; Mode: Monologue
K10-tu-35-1: TPR is a function of the extent of contraction of the vascular smooth muscle.
K10-tu-35-2: That determines the vascular radius, present in the resistance equation for each blood vessel as an inverse 4th power function.
K10-tu-35-3: Sure increaseing the flow by increasing the pressure gradient would occur but the calculated TPR wouldn't change.
K10-st-36-1: Ok
K10-tu-37-1: So TPR|?
/tu-resp-end

/st-hedged-answer-begin
K10-st-38-1: I'm trying to remember what else TPR is dependent on.

/st-hedged-answer-end

K10-st-38-2: Since reflex hasn't kicked in the radius should be the same.
K10-st-38-3: Viscosity is the same.
K10-st-38-4: I would like to change my response re TPR to zero change.
K10-tu-39-1: Good.
K10-tu-39-2: What other variable is under neural control-primarily?

/st-hedged-answer-begin Form: Other
K10-st-40-1: CC?
/st-hedged-answer end

K10-tu-41-1: Yes.
K10-tu-41-2: You predicted that it would go up.
K10-tu-41-3: Still feel that way?
K10-st-42-1: Yes.
K10-tu-43-1: But remember that we`re dealing with the period before there can be any neural changes.
K10-tu-43-2: How can CC go up if it's under neural control?
K10-st-44-1: If contractility increases with increased preloadin --I was thinking that volume o blood would be higher and that a stretch would cause increased or ce o contraction.

/st-hedged-answer-begin
K10-st-44-2: I don't know where the extra blood is coming from so I can't really deend this answer.
/st-hedged-answer-end

K10-tu-45-1: Well, first you have two phenomena confused.
K10-tu-45-2: Increased filling (preload) does increase ventricular contractile performance; but this is the cardiac length/tension relationship (Starling's Law), not contractility.
K10-tu-45-3: Contractil ity change shifts the position of the Stqarling curve.
K10-tu-45-4: CC I would shift it upwards and to the left so that a constant filling would still cause an increase in contractile force.
K10-tu-45-5: Do you see the difference?

/st-init-begin Form: Declarative; Goal: Request for information; Focus: Causal reasoning; Certainty: Not hedged
K10-st-46-1: No -- this concept is hard for me to grasp.
/st-init-end
/tu-resp-begin Form: Declarative, Declarative, Other; Goal: Explanation; Mode: Monologue
K10-tu-47-1: An increase in contractility is caused by an increase in intracellular [Ca], and is independent of filling.

K10-tu-47-2: Filling increases contractile performance by changing the orientation of thick and thin filaments.
K10-tu-47-3: OK?
/tu-resp-end

/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Causal Reasoning; Certainty: Not hedged

K10-st-48-1: Is increased IC [Ca] the only thing that can increase contractility?
/st-init-end

/tu-resp-begin Form: Other; Goal: Acknowledgment; Mode: Monologue
K10-tu-49-1: Yes.
/tu-resp-end
K10-st-50-1: Okay.

/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K10-st-50-2: So would it be accurate to say that contractility is defined as the number of bonds between thick and thin filaments due to presence of calcium -- ie allowed by the calcium present?
/st-init-end
/tu-resp-begin Form: Declarative, Declarative, Other,_, Interrogative; Goal: Acknowledgment + Explanation; Mode: Monologue
K10-tu-51-1: Yes and the units (functional) of contractility would be force/unit of filling.
K10-tu-51-2: Force/unit filling goes up iwhth increased IC [Ca}.
K10-tu-51-3: OK.
K10-st-52-1: Ok.
K10-tu-53-1: So what's your prediction of CC in the DR?
/tu-resp-end

K10-st-54-1: No change.
K10-tu-55-1: Good.
K10-tu-55-2: Now let's get back to a subject you raised earlier about central blood volume.
K10-tu-55-3: You predicted that CO I.
K10-tu-55-4: Then you went on to predict that RAP I.
K10-tu-55-5: Do you know the relationship between RAP and CO when CO is the independent vari.e. changes first).?
K10-st-56-1: We talked about it in resource today but I haven't sat down in really accepted it yet.

/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not hedged

K10-st-56-2: Does RAP increase initially with increasing CO and then taper off as CO continues to I?
/st-init-end
/tu-resp-begin Form: Other, Declarative, Interrogative,_, Other, Interrogative,_, Imperative, Other; -ve **Acknowledgment + Explanation; DLR**
K10-tu-57-1: No.
K10-tu-57-2: When CO increases it transfers increased quantities of blood from the venous system into the arterial system, decreasing the CBV (central blood volume) and increasing the arterial blood volume (and pressure).
K10-tu-57-3: What would happen to the central venous pressure when CBV goes down?
K10-st-58-1: It decreases
K10-tu-59-1: Yes.
K10-tu-59-2: And what's the relationship between central venous pressure and atrial pressure?
K10-st-60-1: They are directly proportional -- so CO should be inversely propotional to RAP.
K10-tu-61-1: Let's put in in the correct order, RAP (the dependent variable) is inversely proportional to CO (the independent one).
K10-tu-61-2: OK?
/tu-resp-end

/st-init-begin Form: Interrogative; Goal: Request for Information-Compare & Contrast**; Focus: Causal Reasoning; Certainty: Not Hedged**
10-st-62-1: What`s the difference?
/st-init-end
/tu-resp-begin Form: Declarative, Declarative,_, Declarative; Goal: Explanation; Mode: Monologue
K10-tu-63-1: If RAP is the independent variable and it goes up, you get i.e.> CO).
K10-tu-63-2: That's Starling's Law.
/tu-resp-end

K10-st-64-1: Okay.
K10-tu-65-1: Sorry, our tim is up.
K10-tu-65-2: Thanks for helping out.
K10-tu-65-3: Don't forget to do CIRCSIM before we do our next tutoring session.
K10-st-66-1: Okay.
K10-st-66-2: Once again, sorry I was late.
K10-st-66-3: By the way, this is fun.
K10-tu-67-1: Thanks again.
K10-tu-67-2: Glad you like it.
K10-tu-67-3: It get's better with practice.
K10-tu-67-4: Bye

Transcript: K14 (PRE-CIRCSIM)
Date: 4/25/1990
Teacher: Michael
Student: S.M.
Student Sex: F
Student Age: 27
Tutor: JM
Protocol: Two
Procedure: HR I Pacemaker
Initiative: 3
Hedged: 1
Not Hedged: 2
Response: 3

K14-tu-1-1: Please type your social security number.
K14-tu-1-2: If you make a mistake you can use the backspace key to erase.
K14-tu-1-3: When you are done press the return key.
K14-st-2-1: XXX-XX-XXXX
K14-tu-3-1: Have you used the teaching programs circsim or heartsim?
K14-st-4-1: No
K14-tu-5-1: Please start by reading page 1 of the instructions that you have been given.
K14-tu-5-2: When you are done type OK and press return or type a question if you have one.
K14-tu-5-3: Always end a message with return.
K14-st-6-1: Ok
K14-tu-7-1: Please read page 2
K14-st-8-1: Ok
K14-tu-9-1: Now page 3
K14-st-10-1: Ok
K14-tu-11-1: Page 4 please
K14-st-12-1: Ok
K14-tu-13-1: Finally, read page 5
K14-st-14-1: Ok
K14-tu-15-1: Let's begin then.
K14-tu-15-2: What is the first parameter in the DR column you want to predict?
K14-st-16-1: Hr i
K14-tu-17-1: What's next?
K14-st-18-1: Co i
K14-tu-19-1: Next?
K14-st-20-1: Map i
K14-tu-21-1: Good.
K14-tu-21-2: What's next?
K14-st-22-1: Rap 0
K14-tu-23-1: How can you predict a change in rap without having predicted what will happen to its determinant?

K14-tu-23-2: {STUDENT INTERRUPTED TEACHER INPUT}

/st-init-begin Form: Pause; Goal: Time Delay/Inability to Answer; Focus: Problem Solving Algorithm; Certainty: Hedged
K14-st-24-1: *student has initiative but does not take it..*
/st-init-end
/tu-resp-begin Form: Other, Declarative, Interrogative,
K14-tu-25-1: My apology...
K14-tu-25-2: I wasn't paying attention!
K14-tu-25-3: Why don't you predict the next parameter?
/tu-resp-end

K14-st-26-1: Cc 0
K14-tu-27-1: Next?
K14-st-28-1: Sv 0
K14-tu-29-1: And finally?
K14-st-30-1: Tpr 0
K14-tu-31-1: Ok.
K14-tu-31-2: There are some errors here.
K14-tu-31-3: Let's start with this issue.
K14-tu-31-4: What parameter DOES determine rap?
K14-st-32-1: Map
K14-tu-33-1: Can you explain the mechanism by which map determines rap?
K14-st-34-1: No
K14-tu-35-1: Rap is approximartely equivalent to central venous pressure.
K14-tu-35-2: does that help?
K14-st-36-1: Yes
K14-tu-37-1: Can you now tell me what determines rap?
K14-st-38-1: Central venous pressure
K14-tu-39-1: Let's try it this way.
K14-tu-39-2: The central venous compartment is a compliant structure that contains a certain volume of blood.
K14-tu-39-3: what two parameters will directly determine the pressure that is present in the central venous compartment?
K14-st-40-1: Systolic and diastolic pressure
K14-tu-41-1: For a compliant structure (like a balloon filled with air) the pressure inside is a function of the complaince of the structure (how "stretchy" it is) and the volume it contains.
K14-tu-41-2: what parameter in the predictions table relates to the volume that will be present in the central venous compartment?
K14-st-42-1: Co and sv
K14-tu-43-1: Well co certainly does (sv is a determinant of co).
K14-tu-43-2: Do you know how rap will change if something produces a change in co?
K14-st-44-1: If co increases then rap should also increase
K14-tu-45-1: No.

K14-tu-45-2: When a change in co is the independent variable (the thing changed) then rap changes as the dependent variable IN THE OPPOSITE DIRECTION (co and rap are inversely related under these conditions).
K14-tu-45-3: Since you predicted that co i what will rap do?
K14-st-46-1: D
K14-tu-47-1: Right.
K14-tu-47-2: Now, what two parameters in the predictions table together determine the value of the sv?
K14-st-48-1: Co and hr
K14-tu-49-1: No.
K14-tu-49-2: It is true that co=sv x hr.
K14-tu-49-3: What I was asking is what determines how much blood is ejected from the heart each time it beats (the sv)?
K14-st-50-1: Rap and cc
K14-tu-51-1: Good.
K14-tu-51-2: Well, you made predictions about how rap and cc would change as a result of the pacemaker malfunction.
K14-tu-51-3: What do you think will happen to sv?
K14-st-52-1: 0
K14-tu-53-1: Well, you predicted that rap would in fact go down (since co went up) and you predicted that cc would not change (and that's correct)0.
K14-tu-53-2: So, what happens to sv?
K14-st-54-1: D
K14-tu-55-1: Right, sv goes down.
K14-tu-55-2: That being the case, how is that co goes up?
K14-st-56-1: Hr i
K14-tu-57-1: Right, hr goes up more than sv goes down.
K14-tu-57-2: Let's go on now.
K14-tu-57-3: please read page 6 of the instructions.
K14-st-58-1: Ok
K14-tu-59-1: What do you want to predict first in the rr column?
K14-st-60-1: Hr d
K14-tu-61-1: Remember that the malfunctioning pacemaker is the SOLE determinant of the patient's hr.
K14-st-62-1: Cc i
K14-tu-63-1: Let's come back to the question of what happens to hr in rr.
K14-tu-63-2: if only the pacemaker is determining hr how can it change as a result of the reflex?
K14-st-64-1: It can't
K14-tu-65-1: Ok, let's go on to your next prediction.
K14-st-66-1: Cc i
K14-tu-67-1: Next?

/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Rules of the Game; Certainty: Not Hedged

K14-st-68-1: Can i change my last prediction?
/st-init-end
/tu-resp-begin Form: Interrogative; Goal: Acknowledgment + Instruction in the Rules of the Game; Mode: Monologue
K14-tu-69-1: Yes, what would you like to change it to?
/tu-resp-end

K14-st-70-1: D
K14-tu-71-1: Good!
K14-tu-71-2: Now what?
K14-st-72-1: Sv d
K14-tu-73-1: Now, we have already discussed the fact that sv is determined by TWO parameters and you have only predicted one of them.
K14-st-74-1: Well, if we increase tpr then map i and rap i and since rap is the other determinant of sv then sv also will i
K14-tu-75-1: It is true that if tpr i then map i.
K14-tu-75-2: However, rap is determined by co, not tpr or map.
K14-tu-75-3: So you still haven't predicted what will happen to rap.

/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: PSA; Certainty: Not Hedged
K14-st-76-1: Khow can i determine rap by knowing the co if i can't determine the sv?
/st-init-end
/tu-resp-begin Form: Declarative, Interrogative,_, Other, Declarative, Interrogative,_, Interrogative,_, Interrogative,_, Interrogative,_, Declarative, Interrogative,_, Declarative, Interrogative,_, Other, Interrogative,_, Other,_, Other, Other,_, Other,_, Other; Goal: Explanation; Mode: DLR

K14-tu-77-1: Well, you can start by thinking about the reflex that was activated and what it will seek to accomplish.
K14-tu-77-2: What is the stimulus here that activates the reflex?
K14-st-78-1: Hr i
K14-tu-79-1: NO!
K14-tu-79-2: The baroreceptor reflex is measuring map and responding to changes in map.
K14-tu-79-3: So, what was the stimulus?
K14-st-80-1: Map i
K14-tu-81-1: And what will the reflex attept to accomplish?
K14-st-82-1: D map
K14-tu-83-1: How can the system decrease map?
K14-st-84-1: D sv and/or d tpr
K14-tu-85-1: Is sv a direct determinant of co?
K14-tu-85-2: {STUDENT INTERRUPTED TEACHER INPUT}
K14-st-86-1: Y

K14-tu-87-1: Again, apologies, i typed to fast.
K14-tu-87-2: What i meant to ask is whether sv is a direct determinant of map?
K14-st-88-1: Indirect
K14-tu-89-1: Right, map = co x tpr.
K14-tu-89-2: So, how can the reflex reduce map?
K14-st-90-1: D tpr
K14-tu-91-1: Or decrease co or more likely, reduce both of these.
K14-tu-91-2: With this in mind, what do you wnat to predict next?
K14-st-92-1: Tpr d
K14-tu-93-1: Next?
K14-st-94-1: Co d
K14-tu-95-1: Good.
K14-tu-95-2: Next?
K14-st-96-1: Map d
K14-tu-97-1: And finally?
/tu-resp-end

K14-st-98-1: Rap i
K14-tu-99-1: Good.
K14-tu-99-2: We are essentially out of time.
K14-tu-99-3: Thanks for your participation.
K14-tu-99-4: Please be sure that you do CIRCSIM before the next session we have scheduled.
K14-tu-99-5: Either tommorrow afternoon as scheduled or whenever you want to.
K14-st-100-1: Where do i do CIRCSIM at?
K14-tu-101-1: The computer facility on 4 academic facility.
K14-tu-101-2: We're scheduled for 1:30-4:30 and i will be there to assist
K14-st-102-1: Ok
K14-tu-103-1: We're done then.
K14-tu-103-2: Thanks.

Transcript: K18 (POST-CIRCSIM) (K10 is the same student in PRE-CIRCSIM)

Date: 5/3/1990
Teacher: Rovick
Student: M.O.
Student Sex: F
Student Age: 27
Tutor: AR
Protocol: Two
Procedure: HR D Pacemaker
Initiative: 2
Hedged: 1
Not Hedged: 1
Response: 2

K18-st-1-1: M.O.
K18-tu-2-1: Please type your social security number
K18-st-3-1: XXX-XX-XXXX
K18-tu-4-1: Have you done any part of CIRCSIM?
K18-st-5-1: Yes
K18-tu-6-1: About how many procedures?
K18-st-7-1: All
K18-tu-8-1: Good.
K18-tu-8-2: Please read page 1.
K18-st-9-1: Ok
K18-tu-10-1: Please read page 2.
K18-st-11-1: Ok
K18-tu-12-1: Please read page 3.
K18-st-13-1: Ok
K18-tu-14-1: Please read page 4.
K18-st-15-1: Ok
K18-tu-16-1: Please read page 5.
K18-st-17-1: Ok
K18-tu-18-1: Please make your first prediction.
K18-tu-18-2: Remember to keep track using the paper predictions table.
K18-st-19-1: Ok
K18-tu-20-1: What's your first prediction
K18-st-21-1: Decreased HR
K18-tu-22-1: It'll be easier if you use abbreviations.
K18-tu-22-2: What's your next prediction?
K18-st-23-1: D CO
K18-tu-24-1: And next?
K18-st-25-1: D MAP
K18-tu-26-1: And then?
K18-st-27-1: Nothing else would change initially

K18-tu-28-1: Isn't there a relationship between CO and RAP?
K18-st-29-1: Oh yeah.
K18-st-29-2: I RAP
K18-tu-30-1: Any other changes follow from this?
K18-st-31-1: I SV
K18-tu-32-1: Good.
K18-tu-32-2: Please read page6.
K18-st-33-1: Ok
K18-tu-34-1: Please begin your predictions.
K18-st-35-1: Ok
K18-tu-36-1: What's your first prediction?
K18-st-37-1: TPR, HR, CC all increase simultaneously.
K18-tu-38-1: That's pretty good except for HR.
K18-tu-38-2: Remember in this case this guy's HR is solelt determined by his broken artificial pacemaker.

/st-init-begin Form: Interrogative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not Hedged
K18-st-39-1: Wouldn't his other myocardial cells respond to sympathetic stimulation and couldn't they override his artificial pacemaker?
/st-init-end
/tu-resp-begin Form: Declarative, Declarative; Goal: Explanation; Mode: Monologue
K18-tu-40-1: They might and then again they might not.
K18-tu-40-2: We`re assuming in this case that they don't.
/tu-resp-end

K18-tu-40-3: So what do you say about R>?
K18-tu-40-4: {STUDENT INTERRUPTED TEACHER INPUT}
/st-init-begin Form: Pause; Goal: Time Delay; Focus: Language Issue; Certainty: Hedged
K18-st-41-1:
/st-init-end
/tu-resp-begin Form: Declarative; Goal: Conversational Repair; Mode: Rephrasing
K18-tu-42-1: That last should have been HR.
/tu-resp-end

K18-st-43-1: No change in HR
K18-tu-44-1: Good.
K18-tu-44-2: What do you want to predict next?
K18-st-45-1: I TPR
K18-tu-46-1: I got the TPR & the CC predictions already.
K18-tu-46-2: What comes after them?
K18-st-47-1: I meant I MAP.
K18-tu-48-1: And then?

K18-st-49-1: I SV
K18-tu-50-1: Would you explain your thinking here?
K18-st-51-1: Storke Volume increase due to increased CC
K18-tu-52-1: Good.
K18-tu-52-2: What's next?
K18-st-53-1: I CO
K18-tu-54-1: And what about RAP, last?
K18-st-55-1: I
K18-tu-56-1: How did you get that?
K18-st-57-1: I don't know what is happening between my brain and my fingers this morning.
K18-st-57-2: RAP would decrease due to increased CO
K18-tu-58-1: Correct.
K18-tu-58-2: Please read page 7.
K18-st-59-1: Ok
K18-tu-60-1: Please give me your predictions.
K18-tu-60-2: What's first?
K18-st-61-1: D HR
K18-tu-62-1: Next?
K18-st-63-1: D TPR{TEACHER INTERRUPTED STUDENT INPUT}
K18-tu-64-1:
K18-st-65-1: YESI TPR
K18-tu-66-1: Next?
K18-st-67-1: I CC
K18-tu-68-1: And then?
K18-st-69-1: D MAP
K18-tu-70-1: And then?
K18-st-71-1: I SV
K18-tu-72-1: Next?
K18-st-73-1: D CO
K18-tu-74-1: Last?
K18-st-75-1: I RAP
K18-tu-76-1: Well you certainly nailed these predictions.
K18-tu-76-2: Do you have anything you want to discuss?
K18-st-77-1: No.
K18-st-77-2: It all seems pretty straightforward.
K18-tu-78-1: Well then, thanks for your help.
K18-tu-78-2: The check will appear in your mail box asap.

Transcript: K22 (POST-CIRCSIM) (K14 is the same student in PRE-CIRCSIM)
Date: 5/3/1990
Teacher: Michael
Student: S.M.
Student Sex: F
Student Age: 27
Tutor: JM
Protocol: Two
Procedure: HR D Pacemaker
Initiative: 6 (5)
Hedged: 2
Not Hedged: 4 (3)
Hedged Answers 2
Response: 6

K22-st-1-1: S.M.
K22-tu-2-1: Please type your social security number
K22-st-3-1: XXX-XX-XXXX
K22-tu-4-1: Did you use circsim
K22-st-5-1: Yes
K22-tu-6-1: Ok, then let's start by reading page 1 of the instructions
K22-st-7-1: Ok
K22-tu-8-1: Page 2
K22-st-9-1: Ok
K22-tu-10-1: Page 3
K22-st-11-1: Ok
K22-tu-12-1: Page 4
K22-st-13-1: Ok
K22-tu-14-1: Finally, page 5
K22-st-15-1: Ok
K22-tu-16-1: Good, let's begin.
K22-tu-16-2: What's the first prediction you want to make in dr?
K22-st-17-1: Hr d
K22-tu-18-1: Ok, what next?
K22-st-19-1: Cc 0
K22-tu-20-1: Next
K22-st-21-1: Tpr 0
K22-tu-22-1: Next
K22-st-23-1: Co d
K22-tu-24-1: Next
K22-st-25-1: Sv i
K22-tu-26-1: Sv has two determinants and you have only predicted one of them.
K22-tu-26-2: How can you make a prediction about sv then?
K22-st-27-1: I can't.
K22-tu-28-1: What do you want to predict then?

K22-st-29-1: Map d
K22-tu-30-1: Next?
K22-st-31-1: Rap d
K22-tu-32-1: Are you done with dr?
K22-st-33-1: No
K22-tu-34-1: What do you want to predict next then?
K22-st-35-1: Sv d
K22-tu-36-1: Ok, let's consider your predictions.
K22-tu-36-2: Why did you predict that rap would d?
K22-st-37-1: On second thought, maybe it should be 0
K22-tu-38-1: Why?

/st-hedged-answer-begin
K22-st-39-1: Because a change in map does not affect rap directly
/st-hedged-answer-end

K22-tu-40-1: You are correct, but what parameter DOES produce a change in rap?
K22-st-41-1: End diastolic volume
K22-tu-42-1: When you talk about edv what structure in the heart are you referring tio?
K22-st-43-1: Oops the ventricles
K22-tu-44-1: Right, so what does alter rap?
K22-st-45-1: Venous resistance and blood volume
K22-tu-46-1: You are correct, both of these would alter rap.
K22-tu-46-2: However, neither of these are in the predictions table.
K22-tu-46-3: Do you rememebr a relationship between co and rap?
K22-st-47-1: Inverse proportion
K22-tu-48-1: Right.
K22-tu-48-2: So, given what you predicted would happen to co, what would predict will happen to rap?
K22-st-49-1: I
K22-tu-50-1: Right.
K22-tu-50-2: Let's move on.
K22-tu-50-3: Please read page 6
K22-st-51-1: Ok
K22-tu-52-1: What do you want to predict first in rr?
K22-st-53-1: In the direct response , if rap i then sv should also i
K22-tu-54-1: Right.
K22-tu-54-2: Go on to rr then
K22-st-55-1: Hr 0
K22-tu-56-1: Next
K22-st-57-1: Cc i
K22-tu-58-1: Next
K22-st-59-1: Tpr i
K22-tu-60-1: Next
K22-st-61-1: Sv i

K22-tu-62-1: How can you predict sv when you have only predicted one of its determinants ?
K22-st-63-1: Rap i
K22-tu-64-1: But you haven't predicted co yet?

/st-init-begin Form: Interrogative; Goal: Challenge; Focus: PSA; Certainty: Not Hedged
K22-st-65-1: But if i can't predict sv then how can i predict co?
/st-init-end
/tu-resp-begin *main* **Form: Other,_, Interrogative,_, Interrogative,_, Other; Goal: Explanation; Mode: DLR**
K22-tu-66-1: Because you do know what map will do.
K22-st-67-1: But co is a determinant of map
K22-tu-68-1: What is the reflex trying to accomplish?
K22-st-69-1: To i map
K22-tu-70-1: How can map be i?
K22-st-71-1: Because the tpr i
K22-tu-72-1: And by increasing co.
/tu-resp-end
/st-init-begin Form: Declarative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not Hedged
K22-st-73-1: I still don't see how you can assume that
/st-init-end
/tu-resp-begin Form: Declarative, Declarative, Declarative,_, Declarative, Declarative; Goal: Explanation; Mode: Monologue
K22-tu-74-1: Well, it is certainly true that if both tpr and co are i then map will be i.
K22-tu-74-2: The reflex in fact will attempt to utilize changes in both tpr and co to accomplish its task.
K22-tu-74-3: Thus, we do know that co will i.
K22-tu-74-4: The question then is how this is accomplished.
K22-st-75-1: By i sv
K22-tu-76-1: You are correct.
K22-tu-76-2: Since hr is 0 the reflex must i sv.
/tu-resp-end
/tu-resp-end *main*

K22-tu-76-3: You still have to predict what rap will do though.
K22-st-77-1: D
K22-tu-78-1: Right.
K22-tu-78-2: So, hjave you made all the rr predictions?

/st-init-begin Form: Declarative, Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K22-st-79-1: Maybe i should clarify what i mean by hr o.
K22-st-79-2: I mean that the body has no contol since it's artificial so it will still be d

/st-init-end
/tu-resp-begin Form: Declarative; Goal: Acknowledgment; Mode: Monologue
K22-tu-80-1: You are correct about this.
/tu-resp-end

K22-tu-80-2: Do you want to review for me what predictions you made about rr?
K22-st-81-1: Do you mean all of the predictions?
K22-tu-82-1: Yes, just list them for me.
K22-st-83-1: Hr 0, map i, tpr i, co i, sv i, cc i, and rap d
K22-tu-84-1: Good, all of these are correct.
K22-tu-84-2: Now read page 7
K22-st-85-1: Ok
K22-tu-86-1: What do you want to predict first?
K22-st-87-1: Rap i
K22-tu-88-1: Are you sure?

/st-init-begin Form: Imperative; Goal: Request for Confirmation; Focus: PSA; Certainty: Hedged
K22-st-89-1: Let me start somewhere else?
/st-init-end
/tu-resp-begin Form: Other; Goal: Acknowledgment; Mode: Monologue
K22-tu-90-1: Ok
/tu-resp-end

K22-st-91-1: Hr d
K22-tu-92-1: Next
K22-st-93-1: Tpr i
K22-tu-94-1: Next
K22-st-95-1: Cc i
K22-tu-96-1: Next
K22-st-97-1: Co i
K22-tu-98-1: Next
K22-st-99-1: Sv i
K22-tu-100-1: Finally
K22-st-101-1: Rap d
K22-tu-102-1: There's still one more to go
K22-st-103-1: Map i
K22-tu-104-1: Do you mean to predict that the map in ss will be greater than it was before the pacemaker malfunctioned?
K22-st-105-1: It probably won't
K22-tu-106-1: Why not?
/st-hedged-answer-begin
K22-st-107-1: I think that the reflexs will try and bring the map up but it won't be higher than before the change
/st-hedged-answer-end

K22-tu-108-1: Then what is your ss prediction for map?
K22-st-109-1: D
K22-tu-110-1: You are right.
K22-tu-110-2: Reflexes never fully compensate for the disturbance that initiates them.
K22-tu-110-3: But, now you have predicted tpr i, co i and map d.
K22-st-111-1: Tpr should remain i but co should d
K22-tu-112-1: Right.
K22-tu-112-2: Then what do you want to predict for rap?
K22-st-113-1: I
K22-tu-114-1: Right.
K22-tu-114-2: The "moral" of this story is that the disturbances that appear in dr are always larger than the reflex compensations that can occur.
K22-tu-114-3: Therefore, ss follows dr.
K22-tu-114-4: Do you have any further questions?
K22-st-115-1: Yes.

/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not hedged
K22-st-115-2: In the equation map=co x trp if the tpr i, does the map i because more of the pressure or driving force is lost along the length of the vessels and therfore you need a higher pressure to move the blood the same distance?
/st-init-end
/tu-resp-begin Form: Declarative, Declarative, Declarative, Declarative,_, Declarative, Declarative, Imperative, _; Goal: Explanation; Mode: Monologue
K22-tu-116-1: If all you tell me is that tpr i I can not predict what will happen to map.
K22-tu-116-2: If co is o then map i.
K22-tu-116-3: If co goes down more than tpr increases then pressures falls.
K22-tu-116-4: If co d exactly as much as tpr i then map is 0.
/tu-resp-end
/st-init-begin Form: Declarative; Goal: Conversational Repair-*Self-Repair***; Focus: Language Issue; Certainty: Not hedged**
K22-st-117-1: I should have stated that co is held constant
/st-init-end
/tu-resp-begin Form: Declarative, Declarative, Imperative,_; Goal: Explanation; Mode: Monologue+Hinting
K22-tu-118-1: If tpr increases and co is constant then map will increase.
K22-tu-118-2: this just says that the same flow through a system will greater resistance will cause more of the pressure to be dissapated.
K22-tu-118-3: Remember, we're really talking about pressure gradients, not just the pressure a one end of the vessel.
K22-st-119-1: Ok
/tu-resp-end
K22-tu-120-1: Thanks for you cooperation, it helped us a great deal.

APPENDIX B

CLASSIFICATION OF PREVIOUS UNCLASSIFIED

INITIATIVES AND RESPONSES

INITIATIVES LEFT UNCLASSIFIED BY SANDERS

Almost 35% of the initiatives which were left unclassified using the final scheme of Sanders, I classified them using the four dimensional scheme of classification for student initiatives. The corresponding tutor responses are also classified using the three dimensional scheme developed for responses.

K1-tu-76-2: Do you think that you really understand it?
Student Initiative 1
/st-init-begin Form: Declarative; Goal: Request for Information; Focus: Parameter; Certainty: Not hedged
K1-st-77-1: I am still unclear about RAP.
/st-init-end
Tutor Response 1
/tu-resp-begin Form: Declarative, Imperative, Declarative,_; Goal: Brushing Off; Mode: Monologue
K1-tu-78-1: We better talk about it at some other time.
K1-tu-78-2: Either make an appointment X26567 or catch me in the PLATO room when we are doing CIRCSIM.
K1-tu-78-3: Thanks a lot for your help.
/tu-resp-end
K1-st-79-1: Thank you.

K2-tu-36-3: 2-Think again about the direction in which TPR would change.
Student Initiative 2
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K2-st-37-1: Ok, I had thought that an increase in HR would cause an increase in CO, therefore triggering sympathetic response.
/st-init-end
K2-st-37-2: The Right atrial baroceptor would detect an increase in volume and therefore reactto lower TPR (my mistake) there would be vasodilation (a decreasein tpr)

Tutor Response 2
/tu-resp-begin Form: Declarative, Declarative, Declarative; Goal: Acknowledgment + Explanation; Mode: Monologue
K2-tu-38-1: Sure, if you had an increase in tpr, you could not correct a risein MAP.
K2-tu-38-2: We are dealing here with moment-to moment BP control via the carotid baroceptors.
K2-tu-38-3: Ok, so TPR goes down, its neurally controlled.
/tu-resp-end
K2-tu-38-4: What other variable is neurally controlled?
K2-tu-38-5: And how will it change?

K3-tu-53-1: The venous return may not change for a couple of minutes but what about the rate at which blood is being removed from the central blood compartment?
Student Initiative 3
/st-init-begin Form: Other; Goal: Request for Confirmation; Focus: Causal reasoning; Certainty: Hedged
K3-st-54-1: That rate would increase, perhaps increasing RAP???
/st-init-end
Tutor Response 3
/tu-resp-begin Form: Declarative, Interrogative; Goal: Acknowledgment + Explanation; Mode: Hinting
K3-tu-55-1: You are correct the rate of removal of blood would increase because CO is going up.
K3-tu-55-2: But if you take blood out of the central venous compartmen faster than it is returning, what happens to the central venous (I.E. RAP) pressure?
/tu-resp-end

K4-tu-73-2: And yes a normal person's HR would have decreased as you had previously predicted.
Student Initiative 4
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K4-st-74-1: The CC also responds to neural stimulation, and would increase.
/st-init-end
Tutor Response 4
/tu-resp-begin Form: Declarative, Declarative; Goal: Acknowledgment + Explanation; Mode: Hinting
K4-tu-75-1: Think about that again.
K4-tu-75-2: The reflex is being triggered by an increase in MAP in the DR.
/tu-resp-end

K4-tu-79-6: How are the falls in TPR and in CC connected to the decrease in MAP?
Student Initiative 5
/st-init-begin Form: Declarative; Goal: Conversational Repair; Focus: Causal Reasoning; Certainty: Hedged

K4-st-80-1: I don't think I understand the question.
/st-init-end
Tutor Response 5
/tu-resp-begin Form: Interrogative; Conversational Repair; Rephrasing
K4-tu-81-1: What are the determinants of MAP?
/tu-resp-end

K5-tu-44-3: How about yet another variable.
Student Initiative 6
/st-init-begin Form: Pause, Other; Goal: Inability to answer; Focus: Causal Reasoning; Certainty: Hedged
K5-st-45-1: {PAUSE} I don
/st-init-end
Tutor Response 6
/tu-resp-begin Form: Interrogative; Goal: Help in Response to Pause; Mode: Monologue
K5-ti-46-1: Need `help?
/tu-resp-end
K5-st-47-1: Yes.

Student Initiative 7
/st-init-begin Form:Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K5-st-51-1: So, when CO I, the central venous pressure will D?
/st-init-end
Tutor Response 7
/tu-resp-begin Form: Other, Interrogative, _, Other; Goal: Acknowledgment + Explanation; Mode: DLR
K5-tu-52-1: Absolutely correct.
K5-tu-52-2: What variable is essentially the same as central venous pressure?
K5-st-53-1: RAP.
K5-tu-54-1: Right.
/tu-resp-end

K5-tu-97-1: Why do you say that?
K5-st-98-1: Since RAP affects SV and I know SV D, then RAP D.
Student Initiative 8
/st-init-begin Form: Declarative; Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K5-st-98-2: But I'll bet that's not right...
/st-init-end
Tutor Response 8
/tu-resp-begin Form: Declarative, Declarative, Declarative, Imperative, Interrogative,_, Interrogative, Declarative; Goal: Acknowledgment + Explanation; Mode: DLR
K5-tu-99-1: Well you're right in your bet.
K5-tu-99-2: SV D because CC D.

K5-tu-99-3: That doesn't mean that RAP h as to be D!
K5-tu-99-4: Let me remind you again of the vascular function curve.
K5-tu-99-5: Does that help?
K5-st-100-1: RAP I.
K5-tu-101-1: Would you explain.
K5-tu-101-2: You're right but I just want to hear what you'r thinking.
/tu-resp-end

K6-tu-29-4: Do you remember it?
Student Initiative 9
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K6-st-30-1: Does it relate co and mean arterial pressure inversely?
/st-init-end
Tutor Response 9
/tu-resp-begin Form: Other, Declarative, Declarative, Other; Goal: Acknowledgment + Explanation; Mode: Monologue
K6-tu-31-1: No.
K6-tu-31-2: CO and MAP are directly related.
K6-tu-31-3: The vascular function curve relates CO and central venous pressure.
K6-tu-31-4: Remember?
/tu-resp-end
K6-st-32-1: Yes

K7-tu-99-5: Understand?
Student Initiative 10
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K7-st-100-1: But isn't CO X TPR =MAP ?
/st-init-end
Tutor Response 10
/tu-resp-begin Form: Other, Declarative, Declarative, Declarative; Goal: Acknowledgment + Explanation; Mode: Monologue
K7-tu-101-1: Yes.
K7-tu-101-2: And in the RR the MAP gets changed so as to counteract the change that occurs in the DR.
K7-tu-101-3: The MAP went up in the DR.
K7-tu-101-4: The reflex need to change CO and TPR so as to lower The MAP.
K7-st-102-1: Ok
/tu-resp-end

Student Initiative 11
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged

K10-st-50-2: So would it be accurate to say that contractility is defined as the number of bonds between thick and thin filaments due to presence of calcium -- ie allowed by the calcium present?
/st-init-end
Tutor Response 11
/tu-resp-begin Form: Declarative, Declarative, Other,_, Interrogative; Goal: Acknowledgment + Explanation; Mode: Monologue
K10-tu-51-1: Yes and the units (functional) of contractility would be force/unit of filling.
K10-tu-51-2: Force/unit filling goes up iwhth increased IC [Ca].
K10-tu-51-3: OK.
K10-st-52-1: Ok.
K10-tu-53-1: So what is your prediction of CC in the DR?

Student Initiative 12
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K10-st-56-2: Does RAP increase initially with increasing CO and then taper off as CO continues to I?
/st-init-end
Tutor Response 12
/tu-resp-begin Form: Other, Declarative, Interrogative,_, Other, Interrogative,_, Imperative, Other; Goal: Acknowledgment + Explanation; Mode: DLR
K10-tu-57-1: No.
K10-tu-57-2: When CO increases it transfers increased quantities of blood from the venous system into the arterial system, decreasing the CBV (central blood volume) and increasing the arterial blood volume (and pressure).
K10-tu-57-3: What would happen to the central venous pressure when CBV goes down?
K10-st-58-1: It decreases
K10-tu-59-1: Yes.
K10-tu-59-2: And what's the relationship between central venous pressure and atrial pressure?
K10-st-60-1: They are directly proportional -- so CO should be inversely proportional to RAP.
K10-tu-61-1: Let's put in the correct order, RAP (the dependent variable) is inversely proportional to CO (the independent one).
K10-tu-61-2: OK?
/tu-resp-end

Student Initiative 13
/st-init-begin Form: Interrogative; Request for Information-Compare and Contrast; Focus: Causal Reasoning; Certainty: Not Hedged
K10-st-62-1: What`s the difference?
/st-init-end
Tutor Response 13
/tu-resp-begin Form: Declarative, Declarative,_, Declarative; Goal: Explanation; Mode: Monologue

K10-tu-63-1: If RAP is the independent variable and it goes up, you get increased filling and increased SV (i.e.> CO).
K10-tu-63-2: That's Starling's Law. [could be the end of response]
K10-st-64-1: Okay.
K10-tu-65-1: Sorry, our tim is up.
/tu-resp-end
K10-tu-65-2: Thanks for helping out.
K10-tu-65-3: Don't forget to do CIRCSIM before we do our next tutoring session.

K11-tu-41-2: What about it?
Student Initiative 14
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K11-st-42-1: P=co*r, so if rap I and co I, does r also have to I?
/st-init-end
Tutor Response 14
/tu-resp-begin Form: Declarative, Interrogative,_, Other, Declarative; Goal: Teaching the Sublanguage/Conversational Repair; Mode: DLR
K11-tu-43-1: Well, I'm not completely sure of the symbols in your equation.
K11-tu-43-2: Do you mean p to be pressure and r to be resistance?
K11-st-44-1: Y
K11-tu-45-1: OK.
K11-tu-45-2: I don't know where rap comes into that equation, however.

Student Initiative 15
/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Language Issue ; Certainty: Not Hedged
K11-st-46-1: What did i write?
/st-init-end
Tutor Response 15
/tu-resp-begin Class: Declarative, Declarative,_, Other, Imperative, Interrogative,_, Other, Declarative, Declarative, Interrogative,_, Other; Conversational Repair + Explanation; Mode: DLR
K11-tu-47-1: You wrote p=co*r and then said that if rap I and co I does that mean that r has to I.
K11-tu-47-2: That's where I'm confused.
K11-st-48-1: I meant map, not rap
K11-tu-49-1: Oh. [could be EOR]
K11-tu-49-2: OK let's get to your question about TPR, then.
[going back and popping the old topic]
K11-tu-49-3: How is TPR controlled?
K11-st-50-1: Sympathetic vasoconstricrion->
K11-tu-51-1: Right.
K11-tu-51-2: TPR is primarily under neural control.
K11-tu-51-3: We're talking about what happens before there are any neural changes.

K11-tu-51-4: Now what do you say about TPR?
K11-st-52-1: O
K11-tu-53-1: Right.
/tu-resp-end

K12-st-62-1: Decrease filling time, decrease venous return.
Student Initiative 16
/st-init-begin [main]
/st-init-begin Form: Declarative; Goal: Request for Information; Focus: Problem Solving Algorithm; Certainty: Hedged
K12-st-62-2: I'm just hesitant to say what comes first.
/st-init-end
Student Initiative 17
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Problem Solving Algorithm; Certainty: Hedged
K12-st-62-3: I'll go with tpr i to slow blood flow back to heart (i don't really like this idea)
/st-init-end
/tu-resp-begin [main]
/tu-resp-begin Form: Imperative, Interrogative,_, Other, Interrogative,_, Other,_, Other,_,Other, Interrogative,_, Other, Other,_, Other,Other, Declarative, Imperative, Interrogative; Goal: Brushing Off/Teaching PSA; Mode: DLR
K12-tu-63-1: Well let's see if we can get at the first question I asked and then we'll come back to TPR.
K12-tu-63-2: With regard to SV, what are it's determinants?
K12-st-64-1: Ventricular volume prior to onset of systole and cardiac contractility
K12-tu-65-1: Sure.
K12-tu-65-2: Now considering that we are in the RR period, i.e. the first things that are going to change are the things that are under neural control, which of these determinants would be the first affected?
K12-st-66-1: Cc
K12-tu-67-1: Of course!
K12-tu-67-2: And in what direction?
K12-st-68-1: Decrease
K12-tu-69-1: Rightr again.
K12-tu-69-2: And how would that affect SV?
K12-st-70-1: Decrease
K12-tu-71-1: Sure.
K12-tu-71-2: And what affect would that have?
K12-st-72-1: Decrease co
K12-tu-73-1: Yes again.
K12-tu-73-2: Then what?
K12-st-74-1: Map d
K12-tu-75-1: Yes, again.
K12-tu-75-2: And in this regard.

K12-tu-75-3: It is MAP that is regulated by the BAROceptor reflex.
K12-tu-75-4: That's why it's called that.

Tutor Response 17
K12-tu-75-5: Now let's get back to TPR.
K12-tu-75-6: Do you have any new thoughts about it?
/tu-resp-end
Student Initiative 18
/st-init-begin Form: Declarative, Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K12-st-76-1: I'm thinking that tpr is a measure of pre-load force to the right heart and that if you increase pre-load force you will increase sv, something we don't want for this patient.
K12-st-76-2: So i think that tpr goes down
/st-init-end
Tutor Response 18
/tu-resp-begin Form: Declarative, Imperative, Interrogative, Declarative, Interrogative, Other, Declarative,_, Interrogative,_, Interrogative, Other, Other, Interrogative, Other, Interrogative, Other, Other; Goal: Acknowledgment + Explanation; Mode: DLR
K12-tu-77-1: Your answer is right but for all the wrong reasons.
K12-tu-77-2: Let's get back to this reflex.
K12-tu-77-3: What is it trying to do in this patient?
K12-st-78-1: Adjust for an unadjustable hr
K12-tu-79-1: What do the receptors measure?
K12-st-80-1: Stretch and some measure chemical comp.
K12-tu-81-1: I mean the BAROCEPTORS.
K12-st-82-1: Pressure
K12-tu-83-1: WHAT ARE THEY TRYING TO ACCOMPLISH WITH REGARD TO PRESSURE IN THIS PATIENT?
K12-st-84-1: Decrease it
K12-tu-85-1: How will TPR have to be affected to lower MAP?
K12-st-86-1: Decrease
K12-tu-87-1: Correct.
K12-tu-87-2: How does the reflex manage to lower TPR?
K12-st-88-1: Dilation of blood vessels
K12-tu-89-1: And how does it accomplish that?
/tu-resp-end
K12-st-90-1: Either decreased symp. or increased para.
Student Initiative 19
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K12-st-90-2: (did i reverse it)
/st-init-end
Tutor Response 19

/tu-resp-begin Form: Declarative, Declarative, Interrogative; Goal: Explanation; Mode: Monologue
K12-tu-91-1: There's practically no parasympathetic innervation of blood vessels (erectile tisse and a few other fun places).
K12-tu-91-2: Most -- --almost all of the innervation to blood vessels is sympathetic and the primary effect is norepi acting on alpha receptors to cause vasoconstriction.
K12-tu-91-3: Now what do you say about what the reflex does vis-a-vis TPR?
/tu-resp-end
Student Initiative 20
/st-init-begin Form: Declarative; Goal: Conversational Repair; Focus: Language Issue; Certainty: Not Hedged
K12-st-92-1: I'm sorry i just got lost.
K12-st-92-2: Are you saying it is not vasodilation
/st-init-end
Tutor Response 20
/tu-resp-begin Form: Other, Declarative, Declarative; Goal: Conversational Repair; Mode: Monologue
K12-tu-93-1: No.
K12-tu-93-2: I'm agreeing with you the vessels are dilated.
K12-tu-93-3: I was just giving you information that you could use to determine how the reflex accomplished that .
/tu-resp-end
Student Initiative 21
/st-init-begin Declarative, Other; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K12-st-94-1: Dilation results in increasing the vessel radius and thus tpr goes down (exponentially bya factor of4???)
/st-init-end
Tutor Response 21
/tu-resp-begin Form: Declarative; Goal: Explanation; Mode: Monologue
K12-tu-95-1: That equation that you're referring to applies to single vessels only.
/tu-resp-end
/tu-resp-end [main]

K13-tu-47-5: do you have any question about this?
Student Initiative 22
/st-init-begin Form: Interrogative, Challenge; Focus: Causal Reasoning; Certainty: Not Hedged
K13-st-48-1: If sv d every time hr i how can co ever increase
/st-init-end
Tutor Response 22
/tu-resp-begin Form: Interrogative,_, Interrogative,_, Other, Interrogative,_, Declarative; Goal: Explanation; Mode: DLR
K13-tu-49-1: What are the two parameters that determine co?

K13-st-50-1: Sv and hr
K13-tu-51-1: Can you write the simple equation that relates co, sv and hr?
K13-st-52-1: Sv times hr =co
K13-tu-53-1: Good.
K13-tu-53-2: Then if co is up and sv down what must have happened?
K13-st-54-1: Hr i more than svd
K13-tu-55-1: Right, that's exactly what happens.
/tu-resp-end
Student Initiative 23
/st-init-begin Form: Declarative; Goal: Request for Confirmation, Focus: Causal Reasoning; Certainty: Hedged
K13-st-56-3: Im not sure if 120bpm is fast enough to cause that.
/st-init-end
Tutor Response 23
/tu-resp-begin Form: Other; Goal: -ve Acknowledgment; Mode: Monologue
K13-tu-57-1: Probably not.
/tu-resp-end
K13-tu-57-2: But more to the point, both tpr and cc change only when the reflex alters the activity in the ans.
K13-tu-57-3: And since dr is BEFORE the reflex can act, both must be o in dr.
K13-tu-57-4: let's go on to the next column.

K13-tu-65-1: How can you predict the change in rap before you predict what happens to its determinant?
Student Initiative 24
/st-init-begin Form: Declarative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not hedged
K13-st-66-1: I thought that tpr and map determined venous return to the heart and therefor rap
/st-init-end
Tutor Response 24
/tu-resp-begin Form: Declarative, Declarative, Interrogative,_,; Goal: Explanation; Mode: Monologue
K13-tu-67-1: Rap (which is essentially the same as central venous pressure) is most directly related to the volume of blood in the great veins and their compliance.
K13-tu-67-2: The volume is determined by the balance between the outflow (co) and the inflow (vr).
K13-tu-67-3: therefore, there is an important relationship between co (as an independent variable) and rap (as the dependent variable.
K13-tu-67-4: any question about this? [could be the end]
K13-st-68-1: Ok
/tu-resp-end

Student Initiative 25
K15-tu-67-1: Which do you want to change and to what?

/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K15-st-68-1: Im not sure; I think an increase in rap would increase preload and therefore increase co, but then would an increased co lower rap?
/st-init-end

Tutor Response 25
/tu-resp-begin Form: Declarative, Declarative; Goal: Acknowledgment + Explanation; Mode: Monologue
K15-tu-69-1: You are correct; co and rap are inversely realted to each other.
/tu-resp-end [could have gone till tu-75-5]
K15-tu-69-2: Let's think about this situation this way.
K15-tu-69-3: By what means would you expect the reflex to decrease map?
K15-st-70-1: Tpr d thus map d
K15-tu-71-1: What would you expect to happen to co under these conditions?
K15-st-72-1: Co 0
K15-tu-73-1: Well, if co 0 and hr 0 then sv would have to be 0 and you didn't predict that.
K15-st-74-1: True, i predicted co i because i thought venous return might increase .
K15-tu-75-1: I think you have reversed cause and effect.
K15-tu-75-2: Venous return and cardiac output are identical in the steady state.
K15-tu-75-3: In any event, it isn't venopus return perse that determines co but rap, the ventricular filling pressure.
K15-tu-75-4: What happens here is that the reduced contractility results in decreased sv (in spite of increased rap) and decreased co.
K15-tu-75-5: Let's go on.

Student Initiative 26
/st-init-begin Form: Declarative; Goal: Request for Information; Focus: Causal Reasoning; Certainty: Not Hedged
K15-st-84-1: Cc d, but i really still dont understand why
/st-init-end
Tutor Response 26
/tu-resp-begin Form: Declarative; Goal: Brush off; Mode: Monologue
K15-tu-85-1: You're right and we'll talk about it further if there is time.
/tu-resp-end
K16-st-46-1: None.
Student Initiative 27
/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Causal Reasoning; Mode: Not Hedged
K16-st-46-2: Is sympa stimulation the only factor influencing cc?
/st-init-end
Tutor Response 27
/tu-resp-begin Form: Declarative; Goal: Brush Off; Mode: Monologue
K16-tu-47-1: It is in the experiment we are discussing today.
/tu-resp-end

K16-tu-47-2: All of your other DR predictions were correct, so please read page 6 so we can go on.
K16-st-48-1: Ok

K16-st-72-1: Can i ask you something...

Student Initiative 28
/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Causal Reasoning; Certanty: Not Hedged

K16-st-72-2: How does sympathetic or ps i.e. what is the mechanism?
K16-st-72-3: Does it act on the contractile cells themselves
/st-init-end
Tutor Response 28
/tu-resp-begin Form: Other, Declarative, Declarative; Gaol: Acknowledgment + Explanation; Mode: Monologue
K16-tu-73-1: Yes.
K16-tu-73-2: Sympathetic input ultimately causes increased intracellular Ca and hence results in greater force production.
K16-tu-73-3: Although the ventricles are sparsely innervated by the ps, it is usually said that the ps has no significant effect on contractility. [could have ended here]
K16-st-74-1: Thanks.
/tu-resp-end

K17-st-45-1: CO=HR X SV.
Student Initiative 29
/st-init-begin Form: Declarative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not hedged
K17-st-45-2: I thought that an increase in HR would lead to a lower RAP, but that a change in SV (for example via increased ejection fraction) would not change RAP.
/st-init-end
Tutor Response 29
/tu-resp-begin Form: Declarative,_,_, Other; Goal: Explanation; Mode: Monologue
K17-tu-46-1: Actually, any change in either HR or SV which causes CO to change affects RAP.
K17-st-47-1: Thank you.
K17-st-47-2: Then RAP=D
K17-tu-48-1: Correct.
/tu-resp-end

K17-tu-66-1: Is there anything else you would like to discuss?
Student Initiative 30
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged

K17-st-67-1: Would you please explain how a change in CO manifested because of a change in SV causes a change in RAP.
K17-st-67-2: I picture an increasing in SV because of increased contractility as resulting in a greater ejection fraction, but not in changing RAP -- -well, I guess I do see your point, because if a higher fraction of the volume is ejected from the ventricle, then more volume will have to leave the atrium to refill the ventricle and this will cause a lower RAP.
K17-st-67-3: Is this right? [this could be an initiative too]
/st-init-end
Tutor Response 30
/tu-resp-begin Form: Other; Goal: Acknowledgment; Mode: Monologue
K17-tu-68-1: Yes.
/tu-resp-end

K18-tu-38-2: Remember in this case this guy's HR is solelt determined by his broken artificial pacemaker.
Student Initiative 31
/st-init-begin Form: Interrogative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Hedged

K18-st-39-1: Wouldn't his other myocardial cells respond to sympathetic stimulation and couldn't they override his artificial pacemaker?
/st-init-end
Tutor Response 31
/tu-resp-begin Form: Declarative, Declarative; Goal: - ve Acknowledgment; Mode: Monologue
K18-tu-40-1: They might and then again they might not.
K18-tu-40-2: We`re assuming in this case that they don't.
/tu-resp-end
K18-tu-40-3: So what do you say about R>?
K18-tu-40-4: {STUDENT INTERRUPTED TEACHER INPUT}

Student Initiative 32
/st-init-begin Form: Declarative; Goal: Challenge; Focus: Causal Reasoning; Certainty: Not Hedged
K20-st-39-1: YES BUT IT DEPENDS ON WHICH VARIABLE IS INDEPENDENT.
K20-st-39-2: I THOUGHT THAT WHEN C. O. WAS THE INDEPENDENT VARIABLE, RAP VARIES INVERSLEY.
K20-st-39-3: BUT WHEN RAP IS THE INDEPENDENT VARIABLE C. O. VARIES DIRECTLY
/st-init-end
Tutor Response 32
/tu-resp-begin Form: Other, Declarative, Declarative, Declarative, Other,_, Other; Goal: +ve Acknowledgment + Explanation; Mode: Monologue
K20-tu-40-1: Correct again.
K20-tu-40-2: And in this case, it is the change in CO that causes RAP to change.

K20-tu-40-3: CO is the independent variable and RAP is dependent.
K20-tu-40-4: CO D and RAPI.
K20-tu-40-5: OK?
K20-st-41-1: YES
K20-tu-42-1: Good.
/tu-resp-end
K20-tu-92-2: Is there anything that you want to discuss?
Student Initiative 33
/st-init-begin Form: Declarative; Goal: Request for Information; Focus: Rules of the Game; Certainty: Not Hedged
K20-st-93-1: YEAH, IT IS FROM ANOTHER CIRCSIM PROGRAM THOUGH.
/st-init-end
Tutor Response 33
/tu-resp-begin Form: Other; Goal: Acknowledgment; Mode: Monologue
K20-tu-94-1: OK shoot.
/tu-resp-end
Student Initiative 34
/st-init-begin 1&2 Form: Declarative; Goal: Request for Information; Focus: Causal Reasoning; Certainty: Not Hedged
K20-st-95-1: I AM HAVING TROUBLE CONCEPTUALIZING RAP..OBVIOUSLY.
K20-st-95-2: AND IN ONE OF THE CASES THE PATIENT HAD INCREASED INTRATHORACIC PRESSURE WHICH LEAD TO I RAP...
/st-init-end
Student Initiative 35
/st-init-begin 3 Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K20-st-95-3: AM I REMEMBERING THIS RIGHT
/st-int-end
Tutor Response 35
/tu-resp-begin Form: Other, Declarative, Declarative, Declarative, Declarative, Interrogative, Declarative, Declarative,_,; Goal: Acknowledgment + Explanation; Mode: Monologue
K20-tu-96-1: Yes.
Tutor Response 34
K20-tu-96-2: With increased P(IT), everything in the thoracic cavity is compressed, including the heart.
K20-tu-96-3: So the pressure goes up in all of the cardiac chambers, the atria as well as the ventricles.
K20-tu-96-4: Therefore, there's no increase in filling pressure.
K20-tu-96-5: All pressures are up.
K20-tu-96-6: What P(IT) increase also does is to compress the veins in the thorax, increasing venous resistance.
K20-tu-96-7: That decreases venous return and causes the RAP to increase LESS than it would have from the compression.
K20-tu-96-8: That's equivalent to a decrease in filling pressure, Hence a fall in SV.

K20-st-97-1: OK.
/tu-resp-end
Student Initiative 36
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Certainty: Hedged
K20-st-97-2: SO, CO. D IN THE LATTER CASE BUT IN THE EARLIER CASE IT REMAINS THE SAME?
/st-init-end
Tutor Response 36
/tu-resp-begin Form: Declarative, Declarative, Declarative, Declarative,_,; Goal: Explanation; Mode: Monologue
K20-tu-98-1: In this example, the first variable (in the predictions table) to change is RAP.
K20-tu-98-2: It's effective" change is D (relative to what happens in the ventricle) so SV falls and CO falls.
K20-tu-98-3: In this case RAP is primary.
K20-tu-98-4: That is to say Filling is primary.
K20-st-99-1: Ok
/tu-resp-end

Student Initiative 37
/st-init-begin Form: Interrogative; Goal: Challenge; Focus: PSA; Certainty: Not Hedged
K22-st-65-1: But if i can't predict sv then how can i predict co?
/st-init-end
Tutor Response 37
/tu-resp-begin Form: Other; Goal: PSA; Mode: Monologue
K22-tu-66-1: Because you do know what map will do.
/tu-resp-end

Student Initiative 38
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K22-st-115-1: Yes. [could be answer]
K22-st-115-2: In the equation map=co x trp if the tpr i, does the map I because more of the pressure or driving force is lost along the length of the vessels and therfore you need a higher pressure to move the blood the same distance?
/st-init-end
Tutor Response 38
/tu-resp-begin Form: Declarative, Declarative, Declarative, Declarative,_, Declarative, Declarative, Imperative,_,; Goal: Explanation; Mode: DLR/monologue
K22-tu-116-1: If all you tell me is that tpr i I can not predict what will happen to map.
K22-tu-116-2: If co is o then map i.
K22-tu-116-3: If co goes down more than tpr increases then pressures falls.
K22-tu-116-4: If co d exactly as much as tpr i then map is 0.
K22-st-117-1: I should have stated that co is held constant
K22-tu-118-1: If tpr increases and co is constant then map will increase.

K22-tu-118-2: this just says that the same flow through a system will greater resistance will cause more of the pressure to be dissapated.
K22-tu-118-3: Remember, we're really talking about pressure gradients, not just the pressure a one end of the vessel.
K22-st-119-1: Ok
/tu-resp-end

K25-tu-42-3: Do you want to rethink this?
CT= 14:4 ET= 0:46 IT= 0:34
Student Initiative 39
/st-init-begin Form: Interrogative; Goal: Request for Information; Focus: Rules of the Game; Certainty: Not Hedged
K25-st-43-1: Shall i explain my thinking?
/st-init-end
Tutor Response 39
/tu-resp-begin Form: Other, _,_,_, Declarative, Imperative, Imperative,_,_, Other; Acknowledgment + Instructions in the ROG; Mode: DLR
K25-tu-44-1: Yes [response could have ended here]

K25-tu-162-1: For any parameter that you look at across the three columns, ss almost always follows dr (when dr and rr are changing in different directions).
CT= 30:47 ET= 0:45 IT= 0:5
Student Initiative 40
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K25-st-163-1: Ok, and this stems from the fact that the reflexes can only reduce the mag. but not fully correct, for the changes.
/st-init-end
Tutor Response 40
/tu-resp-begin Form: Declarative, Declarative; Goal: Acknowledgment + Brush Off; Mode: Monologue
K25-tu-164-1: You are right.
K25-tu-164-2: We have to end now.
/tu-resp-end
K25-tu-164-3: Thanks for your assistance.
K25-tu-164-4: I will be in the computer lab on Thursday to assist with CIRCSIM, so if you have any questions we can deal with them at that time.
K25-tu-164-5: Your money will come as fast as I can make the bureaocracy work here.

K26-tu-52-2: How is the inotropic state of the heart altered physiologically?
CT= 34:13 ET= 0:27 IT= 0:15
Student Initiative 41
/st-init-begin Form: Other; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Hedged
K26-st-53-1: By the force lenth relationship?

/st-init-end
Tutor Response 41
/tu-resp-begin Form: Fragment, Declarative, Declarative, Interrogative,_, Other, Interrogative,_, Other, Declarative; Goal: -ve Acknowledgment + Explanation; Mode: Monologue
K26-tu-54-1: No!
K26-tu-54-2: You are confusing the Frank-Starling effect (increased filling gives greater output) and contractility.
K26-tu-54-3: Contractility is the force of contraction AT ANY GIVEN FILLING.
K26-tu-54-4: What input to the heart determines contractility (or inotropic state)?
CT= 35:59 ET= 0:17 IT= 0:7
K26-st-55-1: Sympathetic
K26-tu-56-1: Right.
K26-tu-56-2: So, why didn't contractility change in dr?
CT= 36:30 ET= 1:2 IT= 0:38
K26-st-57-1: Because the change in heart rate didn't involve the autonomic nervous system
K26-tu-58-1: That's true but...
K26-tu-58-2: DR is defined as the period of time before any reflex activity can occur and hence before the symp nervous system could change its firing.
/tu-resp-end
K26-tu-58-3: How is tpr determined?
CT= 42:11 ET= 1:26 IT= 0:52

Student Initiative 42
/st-init-begin Form: Interrogative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K26-st-67-1: Is right atrial pressure coxtpr-pa
/st-init-end
Tutor Response 42
/tu-resp-begin Form: Other; Goal: -ve Acknowledgment; Mode: Monologue
K26-tu-68-1: no. (coxtpr is map)
/tu-resp-end

Student Initiative 43
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Mode: Causal Reasoning; Certainty: Hedged
K26-st-151-1: No since heart rate is no lomger under the control of the body you would probably expect map to be a little lower itn the steady state
/st-init-end
Tutor Response 43
/tu-resp-begin Form: Other, Declarative, Interrogative,_,; Goal: Explanation; Mode: Monologue
K26-tu-152-1: Well, your new prediction is correct, but...
K26-tu-152-2: Reflexes NEVER completely correct, even when the entire physiological system is intact and functioning normally.

K26-tu-152-3: Do you have any questions about this exercise?
CT= 65:25 ET= 0:4 IT= 0:2
K26-st-153-1: No
/tu-resp-end
K27-tu-150-4: So, what will co be in the ss?
CT= 64:57 ET= 1:21 IT= 0:23
Student Initiative 44
/st-init-begin Form: Declarative; Goal: Request for Confirmation; Focus: Causal Reasoning; Certainty: Not Hedged
K27-st-151-1: In the event that the i in sv cant compensate for the d in hr it will be d.
K27-st-151-2: If sv can compensate then it will return to normal
/st-init-end
Tutor Response 44
/tu-resp-begin Form: Declarative, Declarative, Interrogative, Interrogative,_,Other, Declarative, Interrogative,_, Declarative; Goal: Acknowledgment + Explanation; Mode: Monologue
K27-tu-152-1: Co doesn't have a "normal" value in the sense that you seem to be using that term.
K27-tu-152-2: The increase in sv that occurred is in fact smaller than the fall in hr and hence co is decreased.
K27-tu-152-3: And if co is down, what happened to rap in ss?
K27-tu-152-3: And if co is down, what happened to rap inss?
CT= 67:22 ET= 0:9 IT= 0:7
K27-st-153-1: I
K27-tu-154-1: Right.
K27-tu-154-2: So, you may notice that when a parameter changes in one direction in dr and the reflex changes it in the other direction that the result in ss is the same as what happened in the dr.
K27-tu-154-3: Is this clear?
CT= 68:29 ET= 0:49 IT= 0:36
K27-st-155-1: Yes only the arrow gets smaller
K27-tu-156-1: You are perfectly correct!

APPENDIX C

QUESTIONNAIRE

My name is Farhana Shah. I am conducting this survey as a part of my research on understanding the student plans in an intelligent tutoring system. The findings gathered from this survey will be incorporated into the design of a module for understanding and recognizing student plans in CIRCSIM-Tutor (v.x). This survey is mainly for understanding:

- the students' communicative needs
- their expectations from the CIRCSIM-Tutor
- their beliefs about how much comfort they feel in using the computerized tutor
- the factors that satisfy their creative desires

We are trying to improve the interaction (relation) between CIRCIM-Tutor and the student by providing an environment in which the student learns through collaboration with the tutor. The elements drawn from this study will aid in extending the effectiveness and intelligence of the system. We hope that in the future CIRCSIM-Tutor will understand students better and provide them with an interesting source of learning. The learning, of course, centers around the baroreceptor reflex and problem solving skills in the domain of cardiovascular physiology.

The survey contains questions regarding the CIRCSIM-Tutor and your feelings towards it. The degree of intensity varies from 1 to 5, i.e., strong to mild. We would appreciate your honest and thoughtful answers to the questions. You are requested to include your social security number on the form. That will allow us to track trends in student cognition. I personally assure you that all your responses will be kept confidential.

Your responses will give us valuable feedback on research areas we must focus on in research on building the CIRCSIM-Tutor as a good learning aid that can respond intelligently to your interests and curiosity. We hope the system will ultimately satisfy your perceived needs in learning.

Thank you for your time!

General Subject Information

SS #:	
DATE:	

A) Is there any thing that CIRCSIM-Tutor can do to make you feel more comfortable working with the keyboard and computer?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
Give you freedom to use natural language	1	2	3	4	5	6
Be more friendly and understanding	1	2	3	4	5	6
Be ready to respond to your questions	1	2	3	4	5	6
Give you opportunity for self-expression	1	2	3	4	5	6
Give you ability to ask questions	1	2	3	4	5	6
Any other-Please explain						

B) What prior expectations did you have regarding a computer tutorial program?

C) In solving a problem, if you make a mistake when filling a prediction column, do you think the error should be corrected by the CIRCSIM-Tutor:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
Straight away						
After the whole column is done						
Any Other						

D) What kind of response do you want from CIRCSIM-Tutor when you type each of the following underlined statements?

D1)

Student: <u>I don't understand.</u>

	Most Desirable	Desirable	Neutral	Undesirable	Least Undesirable	Not Applicable
A long explanation	1	2	3	4	5	6
Hint	1	2	3	4	5	6
Change of topic	1	2	3	4	5	6
Another question on the same topic	1	2	3	4	5	6
Summary	1	2	3	4	5	6
Any other-Please explain						

D2)

Tutor: Right.
: That's why TPR goes down.
: What other neurally controlled structure is affected by the reflex and how?
Student: Cardiac muscle, CC i.
Tutor: Think again sympathetic firing is being decreased.
Student: <u>I don't know.</u>

	Most Desirable		Neutral			Not Applicable
A long explanation	1	2	3	4	5	6
Hint	1	2	3	4	5	6
Change of topic	1	2	3	4	5	6
Another question on the same topic	1	2	3	4	5	6
Summary	1	2	3	4	5	6
An example	1	2	3	4	5	6

D3)

Student: MAP I
Tutor: next
Student: <u>[no response or pause for …seconds]</u>

When you do not respond to the question, is it because:

	Strongly Agree		Neutral	Disagree	Strongly Disagree	Not Applicable
You do not know the answer	1	2	3	4	5	6
You do not understand the question	1	2	3	4	5	6
Need Help-*	1	2	3	4	5	6
Any other-Please explain						

	Strongly Agree			Disagree	Strongly Disagree	Not Applicable
***** In case you need help, what kind of help you mean:						
Explanation	1	2	3	4	5	6
Correction	1	2	3	4	5	6
More time to think over	1	2	3	4	5	6
Hint	1	2	3	4	5	6
Any other-Please explain						

D4)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
Tutor: why did you predict that tpr would be unchanged?						
Student: <u>I'm not sure.</u>						
: <u>it doesn't make much sense, does it?</u>						

A long explanation	1	2	3	4	5	6
Hint	1	2	3	4	5	6
Change of topic	1	2	3	4	5	6
Another question on the same topic	1	2	3	4	5	6
Summary	1	2	3	4	5	6
Any other-Please explain						

E) Of the responses below that CIRCSIM-Tutor can make which one is the least desirable, and most desirable and why?

Most Desirable | Desirable | Natural | Somewhat Undesirable | Least Desirable | Not Applicable

1. Ignoring the student's question for the time being, and continuing with its own plans. For example:

Student: Have you overlooked my prediction of CC?
Tutor: No. There's something else.

2. Teaching the "Rules of The Game"-telling the student how to proceed in the session. For example:

Tutor: What happens next?
Student: Is the RR with regards to the initial situation or to the DR?
Tutor: The predictions that you make for RR should be how things change from the DR.

3. Review or Summary-summarizing what has gone before. For example:

Tutor: Let me summarize here.
: The reflex tries to reduce map.
: Hr and cc are decreased (tpr is stuck and can't change).
: The decrease in hr means th at co will fall.
: Co down means that rap will increase and thus sv will inc rease.
: OK so far?

4. Teaching the Problem Solving Algorithms-how to attack the problem and heading toward its solution. For example:

Tutor: So, please make your first prediction.
Student: So, do I predict RAP first, since it is listed first in the table?
Tutor: Please make your predictions in the order they will occur in the patient.

	Most Desirable	Desirable	Neutral	Somewhat Undesirable	Least Desirable	Not Applicable
5. Teaching the Sublanguage of Physiology-how to use the medical terminology correctly. For example: Student: Does DR mean Diastolic Relaxation? **Tutor: Well no. DR means Direct Response: the time before the reflex occurs.**						
6. Acknowledging or confirming the degree of correctness of student's statement. For example: Student:So Iam not incorrect in my thought processes? **Tutor: No. Your answer and explanation were correct.**						
7. Conversational Repair-making or asking for correction of something not well understood. For example: Student: I don't think I understand the question. **Tutor: What are the determinants of MAP?**						
8. Probing the Student's Inference Process-trying to understand you better. For example: Student: But if I can't predict sv then how can I predict co? **Tutor: Because you do know what map will do.**						
9. Help in Response to Pause-*what kind of assistance would you find most helpful? Tutor: What do you want to predict next? Student: PAUSE [no response] **Tutor interrupts: Need help?** Student: Yes						

	Most Desirable	Desirable	Neutral	Somewhat Desirable	Least Desirable	Not Applicable
10. Hinting-giving a clue instead of releasing full information to reach the correct answer or to correct any error **Tutor: Think again. You noted that sympathetic firing is d.** Student: I am stuck. **Tutor: What could decrease afferent sympathetic firing produce CC I?** [No Response] for ….seconds Student: Yes **Tutor: How does the reflex drop MAP, in addition to TPR d?** Student: SV d **Tutor How does SV decrease** Student: CC d and SV d **Tutor: Right. You haven't predicted all the determinants of SV though.**						
11. Explanation-Explaining the parameters and their causal relations. For example: Student: I think i am getting contractility mixed up with stroke volume…Contractility is the force of contraction that i think goes up with increased heart rate, but i am not sure how **Tutor: Ok, let me explain.** **The length-tension relationship of muscle says that as length goes up (as the ventricle fills more) the force of contraction will increase.Changes in contractility result in changes in force at the same fiber length or same filling. What input to the heart causes contractility to change?**						

(1) Very Important (2) Important (3) Neutral (4) Somewhat Important (5) Least Important (6) Not Applicable

1. Request for Information_asking for more information **Student: Can we talk some more about what TPR did in this session?**	1	2	3	4	5	6
2. Request for Confirmation_verification **Student: SO I AM NOT INCORRECT IN MY THOUGHT PROCESS?**	1	2	3	4	5	6
3. Repair (self, other) _correction **Student: I do not understand the question.**	1	2	3	4	5	6
4. Inability to Answer-showing ignorance **Student: I don't know.**	1	2	3	4	5	6
5. Challenge to what the tutor is claiming **Student: How can I predict CO when I don't know SV?**	1	2	3	4	5	6
6. Time Delay-pause **Student: [PAUSE]**	1	2	3	4	5	6
7. Confusing two concepts, e.g., Starling law & CC **Student: I think I am getting contractility confused with SV.**	1	2	3	4	5	6
8. Showing support to what has been said by the tutor Tutor: The explanation here is that change in sympathetic input varies the amount of intracellular Ca, which alters contractility. **Student: Changes in sympathetic simulation are reflected in changes in the level of inracellular Ca?**	1	2	3	4	5	6

G) Assuming you are given the options of student goals in their statements and tutor goals in response as follows. How would you prefer to associate the tutor goals with the student's goals in the relationship.

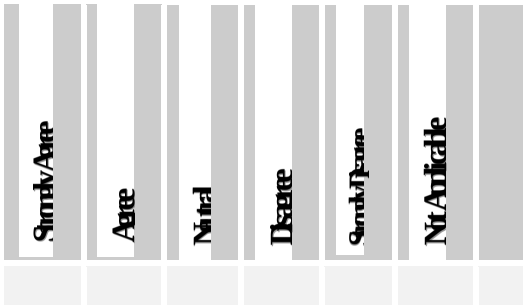
STUDENT GOALS	TUTOR GOALS
S1. Request for Information	**T1**. Acknowledgment
S2. Request for Confirmation	**T2**. Explanation
S3. Repair	**T3**. Summary
S4. Inability to Answer	**T4**. Instruction in the Rules of the Game
S5. Challenge	**T5**. Teaching the Sublanguage
S6. Support	**T6**. Teaching the Problem Solving Algorithm
S7. Time Delay/Extension	**T7**. Help in Response to Pause
S8. Compare and Contrast	**T8**. Probing the Student Inference Process
	T9. Brushing Off
	T10. Conversational Repair

S1	**T1**
S2	**T2**
S3	**T3**
S4	**T4**
S5	**T5**
S6	**T6**
S7	**T7**
S8	**T8**
	T9
	T10

G1) If there are more than one option to be associated to any student goal, how would you like to balance them in some portion of a percentage.

R	S1	S2	S3	S4	S5	S6	S7	S8
T1								
T2								
T3								
T4								
T5								
T6								
T7								
T8								
T9								
T10								
	100	100	100	100	100	100	100	100

H) Did you learn anything?



I) Any other comment(s)?

BIBLIOGRAPHY

Allen, James F. (1979). *A Plan-Based Approach to Speech Act Recognition.* Ph. D. Dissertation, University of Toronto.

Allen, James F. (1983). Recognizing Intentions from Natural Language Utterances. In Brady, Michael, Berwick, Robert C., and Allen, James eds. *Computational Models of Discourse*, pp. 107-166. Cambridge, MA: MIT Press.

Allen, James F. (1986). A Formal Logic of Plans in Temporally Rich Domains. *Proceedings of the IEEE,* vol. 74, pp.1364-82.

Allen, James F. (1987). *Natural Language Understanding*. First Edition. Menlo Park, CA: Benjamin/ Cummings.

Allen, James F. (1994). Mixed Initiative Planning: Position Paper. Paper presented at ARPA/Rome Labs Planning Initiative Workshop. URL: http://www.cs.rochester.edu/research/trains/mip/home.html.

Allen, James F. (1995). *Natural Language Understanding*. Second Edition. Menlo Park, CA: Benjamin/ Cummings.

Allen, James F. (1990). Two Views of Intention: Comments on Bratman and on Cohen and Levesque, In Cohen, Philip R., Morgan, Jerry, and Pollack, Martha E. eds., *Intentions in Communication*, pp. 72-75. Cambridge, MA: MIT Press/Bradford Books.

Allen, James F., and Perrault, C. Raymond (1980). Analyzing Intentions in Utterances. *Artificial Intelligence,* vol. 15, no. 3, pp. 143-178.

Allen, James F., and Litman, Diane J. (1986). Plans, Goals, and Language. *Proceedings of the IEEE,* vol. 74, pp. 939-47.

Alston, William (1964). *Philosophy of Language*. Englewood Cliffs, NJ: Prentice-Hall.

Anderson, James A. (1972). A Simple Neural Network Generating an Interactive Memory. *Mathematical Biosciences,* vol. 14, pp. 197-220. Reprinted in Anderson and Rosenfeld (1988), pp. 181-192.

Anderson, James A., and Rosenfeld, Edward eds. (1988). *Neurocomputing: Foundations of Research*. Cambridge, MA: MIT Press.

Anderson, John R. (1993). *Rules of the Mind*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Appelt, Douglas E. (1980). Problem Solving Applied to Language Generation. In *Proceedings of the 18th Annual Meeting of the Association for Computational Linguistics and Parasession on Topics in Interactive Discourse,* pp. 59-63. Philadelphia, Pennsylvania.

Appelt, Douglas E. (1982). Planning Natural Language Utterances. In *Proceedings of the National Conference on Artificial Intelligence,* pp. 59-62. Pittsburgh, Pennsylvania.

Austin, John (1962). *How to Do Things with Words.* Cambridge, MA: Harvard University Press.

Bates, Elizabeth (1976). *Language and Context*. New York, NY: Academic Press.

Bell, C. G., and Newell, Allen (1971). *Computer Structures: Reading and Examples*. New York, NY: McGraw-Hill.

Berne, R., and Levy, M. (1992). *Cardiovascular Physiology*. St. Louis. MO: Mosby-Year Book.

Bernsen, Niels Ole, Dybkjaer, Hans, and Dybkjaer, Laila (1996). Cooperativity in Human-Machine and Human-Human Spoken Dialogue. In *Discourse Processes*, vol. 21, no. 2, pp. 213-236.

Bloom, Benjamin S. (1984). The 2 Sigma Problem: the Search for Methods of Group Instruction as Effective as One-to-One Tutoring. *Educational Researcher*, vol. 13, pp. 4-16.

Bower, Gordon H., and Hilgard, Ernest R. (1981). *Theories of Learning.* Englewood Cliffs, NJ: Prentice-Hall.

Britton, Bruce K. and Black, John B. (1985). *Understanding Expository Text: A Theoretical and Practical Handbook for Analyzing Explanatory Text.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Britton, Bruce K., and Graesser, Arthur C. (1996). *Models of Understanding Text.* Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, John Seely, and Burton, Richard R. (1978). Diagnostic Models for Procedural Bugs in Basic Mathematical Skills. *Cognitive Science*, vol. 2, no. 2, pp. 155-192.

Brown, John Seely, Burton, Richard R., and Bell, Alan G. (1975). SOPHIE: A Step Toward Creating a Reactive Learning Environment. *International Journal of Man-Machine Studies*, vol. 7, no. 5, pp. 675-696.

Bruce, Bertram (1986). Generation as a Social Action. In Grosz, Barbara, Sparck, Jones, Karen, and Webber, Bonnie Lynn eds., *Reading in Natural Language Processing*, pp. 419-422. Los Altos, CA: Morgan Kaufmann.

Carberry, Sandra (1985). *Pragmatics Modeling in Information Systems Interfaces*. Doctoral Dissertation. University of Delaware, Newark, DE.

Carberry, Sandra (1987). Pragmatic Modeling: Towards a Robust Natural Language Interface. *Computational Intelligence*, vol. 3, no. 3, pp. 117-136.

Carberry, Sandra (1988). Modeling the User's Plans and Goals. *Computational Linguistics*, vol. 14, no. 3, pp. 23-37.

Carberry, Sandra (1989). A Pragmatic-Based Approach to Ellipsis Resolution. *Computational Linguistics*, vol. 15, no. 2, pp. 75-96.

Carberry, Sandra (1990a). Incorporating Default Inferences into Plan Recognition. In *Proceedings of the Eighth National Conference on Artificial Intelligence*, pp. 471-478. Cambridge. MA: MIT Press.

Carberry, Sandra (1990b). *Plan Recognition in Natural Language Dialog*. Cambridge. MA: MIT Press.

Carberry, Sandra, and Pope, Alan (1993). Plan Recognition Strategies for Language Understanding. *International Journal of Man-Machine Studies*, vol. 39, pp. 529-577.

Carbonell, Jaime R. (1970). *Mixed-Initiative Man-Computer Instructional Dialogues.* Ph. D. Dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Carbonell, Jaime R., and Collins, Allan (1973). Natural Semantics in Artificial Intelligence. In *Proceedings of the Third International Joint Conference on Artificial Intelligence,* pp. 344-351. Stanford, California.

Carletta, Jean (1996). Squibs and Discussions, Assessing Agreement on Classification Tasks: The Kappa Statistic. *Computational Linguistics,* vol. 22, no. 2, pp. 249-254. Cambridge, MA: MIT Press.

Carletta, Jean, Isard, Stephen, Gwyneth, Doherty-Sneddon, Isard, Amy, Kowtko, Jacqueline C., and Anderson, Anne H. (1997). The Reliability of a Dialogue Structure Coding Scheme. *Computational Linguistics*, vol. 23, no. 1, pp.13-31. Cambridge, MA: MIT Press.

Carr, B., and Goldstein, I. (1977). *Overlays: a Theory of Modeling for Computer Aided Instruction.* Cambridge, MA: AI Memo 406, MIT AI Laboratory.

Catania, Charles A. (1992). B. F. Skinner, Organism. *American Psychologist: Reflections on B. F. Skinner and Psychology*, vol. 47, no. 11, pp. 1521-1530. Hyattsville, MD: American Psychological Association

Cawsey, Alison J. (1991). A Belief Revision Model of Repair Sequences in Dialogue. In Ernesto Costa eds., *New Directions in Intelligent Tutoring Systems.* Springer Verlag:Berlin.

Chandrasekaran, B. (1993). Expert Interview: Allen Newell. *IEEE Expert*, vol. 8, no. 3, pp. 5-14. The SOAR Architecture.

Charniak, Eugene and McDermott, Drew (1985). *Introduction to Artificial Intelligence.* Reading, MA: Addison-Wesley.

Chi, Michelene, Glaser, Robert, and Farr, Marshall eds. (1988). *The Nature of Expertise.* Hillside, NJ: Lawrence Erlbaum Associates.

Chi, Michelene, and VanLehn, Kurt (1991). The Content of Physics Self-explanation. In *Journal of the Learning Sciences,* vol.1, no. 2, pp. 69-105.

Chi, Michelene, Leeuw, Nicholas, Chiu, Mei-Hung, and LaVancher, Christian (1994). Eliciting Self-Explanations Improves Understanding. *Cognitive Science,* vol. 18, no. 3, pp. 439-477.

Chiesa, Mecca (1992). Radical Behaviorism and Scientific Frameworks: From Mechanistic to Relational Accounts. In *American Psychologist: Reflections on B. F. Skinner and Psychology*, vol. 47, no. 11, pp.1287-1298. Hyattsville, MD: American Psychological Association.

Chipman, Susan F., Segal, Judith W., and Glaser, Robert eds. (1985). *Thinking and Learning Skills: Research and Open Questions,* vol. 2. Hillsdale, NJ: Lawrence Erlbaum Associates.

Chomsky, Noam (1965). *Aspects of the Theory of Syntax*. Cambridge, MA: MIT Press.

Chu-Carroll, Jennifer, and Carberry, Sandra (1994). A Plan-Based Model for Response Generation in Collaborative Task-Oriented Dialogues. *Proceedings of the Twelfth National Conference on Artificial Intelligence*, AAAI, pp. 799-805.

Chu-Carroll, Jennifer, and Carberry, Sandra (1995). Generating Information-Sharing Subdialogues in Expert-User Consultation. In *Proceedings of the Fourteenth International Joint Conference on Artificial Intelligence*, IJCAI, pp. 1243-1250.

Chu-Carroll, Jennifer, Lambert, Lynn, and Carberry, Sandra (1996). Modeling Intention: Issues for Spoken Language Dialogue Systems. *Proceedings of the International Symposium on Spoken Dialogue*, pp.13-24.

Clancey, William J. (1987). *Intelligent Tutoring Systems: A Tutorial Survey*, Report No. STAN-CS-87-1174. Palo Alto, CA: Stanford University.

Clancey, William J. (1992). Guidon-Manage Revisited: A Socio-Technical System Approach. In Frasson, C., Gauthier, G., and McCalla, G. eds., *Intelligent Tutoring Systems: 2nd International Conference*, pp. 21-36. Berlin, NY: Springer-Verlag.

Clark, Herbert H. (1996). *Using Language*. Cambridge, UK: Cambridge University Press.

Cohen, J. (1960). A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement*, vol. 20, pp. 37-46.

Cohen, J. (1968). Weighted Kappa: Nominal Scaled Agreement with Provision for Scaled Disagreement or Partial Credit. *Psychological Bulletin*, vol. 70, no. 4, pp. 213-220.

Cohen, Paul R.(1978). *On Knowing What to Say: Planning Speech Acts.* Ph. D. Dissertation, University of Toronto, Canada.

Cohen, Paul R. (1995). *Empirical Methods for Artificial Intelligence*. Cambridge, MA: The MIT Press.

Cohen, Philip R., and Perrault, C. Raymond (1979). Elements of a Plan-Based Theory of Speech Acts. *Cognitive Science*, vol. 3, pp.177-212. Reprinted in Webber, Bonnie, and Nilsson, Nils eds. (1981), *Readings in Artificial Intelligence.* Los Altos, CA: Morgan Kaufmann. Also in Grosz, B., Jones, K., and Webber, Bonnie eds. (1986), *Readings in Natural Language Processing*. Los Altos, CA: Morgan Kaufmann.

Cohen, Philip R., Morgan, Jerry, and Pollack, Martha E. eds. (1990). *Intentions in Communication*. Cambridge, MA: MIT Press/Bradford Books.

Cohen, Philip R., Perrault, C. Raymond, and Allen, James F. (1981). Beyond Question Answering. In Lehnert, Wendy, and Ringle, Martin eds., *Strategies for Natural Language Processing*, pp. 245-274. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, Philip R., and Levesque, Hector J. (1990). Persistence, Intention, and Commitment. In Cohen, Philip R., Morgan, Jerry and Pollack, Martha E. eds., *Intentions in Communication*, pp. 33-67. Cambridge, MA: MIT Press.

Cole, Peter, and Morgan, Jerry L. (1975). *Speech Acts: Syntax and Semantics*, vol. 3. New York, NY: Academic Press.

Collins, Alan, Warnock, Eleanor H., Aiello, Nelleke, and Miller, Mark L. (1975a). Reasoning from Incomplete Knowledge. In Bobrow, Daniel, and Collins, Alan eds., *Representation and Understanding: Studies in Cognitive Science*, pp. 383-415. New York, NY: Academic Press.

Collins, Alan, Warnock, Eleanor H., and Passafiume, Joseph J. (1975b). Analysis and Synthesis of Tutorial Dialogues. In Bower, Gorden ed., *The Psychology of Learning and Motivation*, vol. 9. Pp. 49-87. New York, NY: Academic Press.

Collins, Alan, and Stevens, Albert L. (1983). A Cognitive Theory of Interactive Teaching. In Reigeluth, Charles M. ed., *Instructional Design Theories and Models: An Overview*, pp. 247-278. Hillsdale, NJ: Lawrence Erlbaum Associates.

Crick, Francis, and Asanuma, C. (1986). Certain Aspects of the Anatomy and Physiology of the Cerebral Cortex. In Rumelhart, D., McClelland, and the PDP Research Group eds. *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, vol. 2, pp. 333-371. Cambridge, MA: MIT Press.

Dale, Robert, and Reiter, Ehud (1995). Computational Interpretations of the Gricean Maxims in the Generation of Referring Expressions. *Cognitive Science*, vol. 18, no. 2, pp. 233-263.

Dews, Shelly, Kaplan, Joan, and Winner, Ellen (1995). Why Not Say it Directly? The Social Functions of Irony. *Journal of Discourse Processes*, vol. 19, no. 3, pp. 347-367.

Dawson-Saunders, Beth and Trapp, Robert [1994]. *Basic and Clinical Biostatistics.* Norwalk, CT: Appleton and Lange.

Dickinson, C. J., Goldsmith, C. H., and Sackett, D. L. (1973). MACMAN: A Digital Computer Model for Teaching some Basic Principles of Hemodynamics. In *Journal of Clinical Computing*, vol. 2, no. 4, pp. 42-50.

Elhadad, Michael (1992). *Using Argumentation to Control Lexical Choice: A Functional Unification Implementation*. Ph. D. Dissertation, Columbia University, New York, NY.

Elmi, Mohammad Ali (1994). *A Natural Language Parser with Interleaved Spelling Correction Supporting Lexical Functional Grammar and Ill-Formed Input*. Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Engelmann, Siegfried, and Carnine, Douglas (1982). *Theory of Instruction: Principles and Applications.* New York, NY: Irvington.

Ericsson, K. Anders, and Simon, Herbert A. (1993). *Protocol Analysis: Verbal Reports as Data revised Edition.* Cmbridge, MA: The MIT Press.

Evens, Martha W., Woo, Chong W., Michael, Joel A., and Rovick, Allen A. (1996). Generating Natural Language Dialogue in an Intelligent Tutoring System for Cardiovascular Physiology. Unpublished paper, Computer Science, Chicago, IL: Illinois Institute of Technology.

Fausett, Laurene (1994). *Fundamentals of Neural Networks: Architectures, Algorithms, and Applications.* Englewood Cliffs, NJ: Prentice-Hall.

Fikes, Richard E. and Nilsson, Nils J. (1971). STRIPS: A New Approach to the Application of Theorem Proving to Problem Solving. *Artificial Intelligence*, vol. 2, pp. 189-208.

Fox, Barbara A. (1987). Interactional Reconstruction in Real-time Language Processing. *Cognitive Science*, vol. 11, pp. 365-387.

Fox, Barbara A. (1988a). Cognitive and Interactional Aspects of Correction in Tutoring, Technical Report #88-2, Institute of Cognitive Science, University of Colorado.

Fox, Barbara A. (1988b). Repair as Factor in Interface Design, Technical Report #88-4, Institute of Cognitive Science, University of Colorado.

Fox, Barbara A. (1993). *The Human Tutorial Dialogue Project: Issues in the Design of Instructional systems*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Fraser, Bruce (1971). An Analysis of "Even" in English. In Fillmore, Charles, and Langendoen, Terence eds., *Studies in Linguistic Semantics*, pp. 151-178. New York, NY: Holt, Reinhart and Winston, Inc.

Fraser, Bruce (1975). Hedged Performatives, In Cole, Peter, and Morgan, Jerry L. eds., *Speech Acts: Syntax and Semantics*, vol. 3, pp.187-210. New York, NY: Academic Press.

Frasson, C., Gauthier, G., and McCalla, G. eds. (1992). Intelligent Tutoring Systems. *Proceedings of Second International Conference, ITS' 92.* Montreal, Canada: Springer Verlag.

Ghemri, Lila (1992). A Cognitive Framework for Second Language Error Diagnosis. *Proceedings of Second International Conference on ITS*, pp. 260-268. Montreal, Canada.

Glaser, Robert, and Chi, Michelene T. H. (1988). Overview. In Chi, Michelene, Glaser, Robert, and Farr, Marshall eds., *The Nature of Expertise*, pp. xv-xxviii. Hillside, NJ: Lawrence Erlbaum Associates.

Graesser, Arthur C. (1981). *Prose Comprehension Beyond the Word*. New York, NY: Springer Verlag.

Green, Nancy, and Carberry, Sandra (1994). Generating Indirect Answers to Yes-No Questions. In *Proceedings of the Seventh International Workshop on Natural Language Generation*, pp. 189-198.

Grice, H. Paul (1957). Meaning. *Philosophical Review* 66, pp. 377-388.

Grice, H. Paul (1969). Utterer's Meaning and Intentions. *Philosophical Review* 78, pp. 147-177.

Grice, H. Paul (1975). Logic and Conversation. In Cole, P., and Morgan, J. eds., *Syntax and Semantics: Speech Acts*, vol. 3, pp. 41-58. New York, NY: Seminar Press.

Grosz, Barbara J. (1977). The Representation and Use of Focus in a System for Understanding Dialogues. In *Proceedings of the Fifth International Joint Conference on Artificial Intelligence*, pp. 67-76.(Cambridge MA, 1977) Los Altos, CA: Morgan Kaufmann.

Grosz, Barbara J. (1978). Focusing in Dialogue. In Waltz, David L. eds., *TINLAP-2*. NY: ACL. pp. 96-103.

Grosz, Barbara J. (1979). Utterance and Objective: Issues in Natural Language Processing. *Proceedings of the International Joint Conference on Artificial Intelligence*, pp. 1067-1076. Tokyo, Japan.

Grosz, Barbara J. (1980). Focusing and Description in Natural Language Dialogues. In: Joshi Aravind, Sag, Ivan, and Webber, Bonnie eds., *Elements of Discourse Understanding (1981)*: *Proceedings of a Workshop on Computational Aspects of Linguistic Structure and Discourse Setting*, pp. 84-105. Cambridge, UK: Cambridge University Press.

Grosz, Barbara J. (1986). The Representation and Use of Focus in a System for Understanding Dialogs. In Grosz, Barbara J., Jones, Karen Spark, and Webber, Bonnie Lynn eds., *Readings in Natural Language Processing*, pp. 353-362. Los Altos, CA: Morgan Kaufmann.

Grosz, Barbara J., and Sidner, Candace L. (1986). Attention, Intentions, and the Structure of Discourse. *Computational Linguistics*, vol. 3, no. 12, pp. 175-206.

Grosz, Barbara J., Joshi, Arvind K., and Weinstein, Scott (1983). Providing a Unified Account of Definite Noun Phrases in Discourse. In *Proceedings of the 21st Annual Meeting of the Association for Computational Linguistics*, pp. 44-50. Cambridge, MA: Association for Computational Linguistics.

Grosz, Barbara J., Jones, Karen Spark, and Webber, Bonnie Lynn (1986). *Reading in Natural Language Processing.* Los Altos, CA: Morgan Kaufmann.

Grosz, Barbara J., Appelt, Douglas, Martin, Paul, and Pereira, Fernando (1987). TEAM: An Experiment in the Design of Transportable Natural Language Interfaces. *Artificial Intelligence,* vol. 37, no. 2, pp. 173-244.

Grosz, Barbara J., Pollack, Martha E., and Sidner, Candace L. (1989). Discourse. In Posner, Michael eds., *Foundation of Cognitive Science*, pp. 437-468. Cambridge, MA: MIT Press.

Hayes, Phil (1980). Expanding the Horizons of Natural Language Interfaces. In *Proceedings of the 18th Annual Meeting of the Association for Computational Linguistics and Parasession on Topics in Interactive Discourse,* pp.71-74. Philadelphia, PA: University of Pennsylvania.

Heeman, Peter, and Hirst, Graeme (1995). Collaborating on Referring Expressions. *Computational Linguistics,* vol. 21, no. 3, pp. 351-382.

Hirst, Graeme, McRoy, Susan, Heeman, Peter, Edmonds, Philip, and Horton, Diane (1994). Repairing Conversational Misunderstandings and Nonunderstandings. *Speech Communication,* vol. 15, pp. 213-229.

Hobbs, Jerry R. (1990). Artificial Intelligence and Collective Intentionality: Comments on Searle and on Grosz and Sidner. In Cohen, Philip R., Morgan, Jerry, and Pollack, Martha E. eds., *Intentions in Communication*, pp. 446-459. Cambridge, MA: MIT Press/ Bradford Books.

Hobbs, Jerry R., and Evans, David (1980). Conversation as Planned Behavior. *Cognitive Science*, vol. 4, no. 4, pp. 349-377.

Hobbs, Jerry R., Stickel, Mark E., Appelt, Douglas E., and Martin, Paul (1993). Interpretation as Abduction. *Artificial Intelligence*, vol. 63, no. 1-2, pp. 69-142. Also in *Proceedings 26th Annual Meeting of the Association for Computational Linguistics* (1988), pp. 95-103. Buffalo, NY.

Hume, Gregory D. (1992). A Dynamic Student Model in a Cardiovascular Intelligent Tutoring System. *Proceedings of the Fifth Annual IEEE Symposium on Computer Based Medical Systems*, pp. 370-377. (Durham, NC) Los Alamitos, CA: IEEE Computer Society Press.

Hume, Gregory D. (1995). *Using Student Modeling to Determine When and How to Hint in an Intelligent Tutoring System.* Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Hume, Gregory D., Michael, Joel, Rovick, Allen, and Evens, Martha (1996). Hinting as a Tactic in One-on-one Tutoring. *Journal of the Learning Sciences*, vol. 5, no. 1, pp. 23-47.

Joshi, Aravind, Webber, Bonnie L., and Sag, Ivan (1981). *Elements of Discourse Understanding.* Cambridge, MA: MIT Press.

Joshi, Aravind, Webber, Bonnie, and Weischedel, Ralph. (1984). Living Up To Expectations: Computing Expert Responses. In *Proceedings of the Fourth National Conference on Artificial Intelligence*, pp. 169-175. Austin, Texas: AAAI.

Jurafsky, Dan (1989). Review of James Allen's Understanding Natural Language. *Artificial Intelligence,* vol. 38, no. 3, pp. 367-77.

Katz, Sandra, and Lesgold, Alan (1993). The Role of the Tutor in Computer-Based Collaborative Learning Situations. In Lajoie, Susanne P. and Derry, Sharon J. eds., *Computers as Cognitive Tools,* pp. 289-317. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Kay, Martin, Gawron, Jean Mark, and Norvig, Peter (1994). *Verbmobil: A Translation System for Face-to-Face Dialog.* Stanford, CA: Center for the Study of Language and Information (CSLI).

Khuwaja, Ramzan (1994). *A Model of Tutoring: Facilitating Knowledge Integration Using Multiple Models of the Domain*. Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Khuwaja, Ramzan, Evens, Martha W., Rovick, Allen A., and Michael, Joel A. (1992). Knowledge Representation for an Intelligent Tutoring System Based on a Multilevel Causal Model. In *Proceedings of Second International Conference, ITS*, pp. 217-224. Montreal, Canada: Springer-Verlag.

Khuwaja, Ramzan, Evens, Martha W., Rovick, Allen A., and Michael, Joel A. (1994a). Architecture of CIRCSIM-Tutor (v.3): A Smart Cardiovascular Physiology Tutor. In *Proceedings of IEEE Seventh Symposium on Computer-Based Medical Systems*, pp. 158-163. Winston-Salem, North Carolina.

Khuwaja, Ramzan, Evens, Martha W., Rovick, Allen A., and Michael, Joel A. (1994b). A Tale of Three Tutoring Protocols: The Implications for Intelligent Tutoring Systems. E. A. Yfantis ed., *Intelligent Systems, Third Golden West International Conference*, vol.1, pp.109-118. Dordrecht, Netherlands: Kluwer Academic Publishers.

Kim, Nakhoon (1989). *An Intelligent Tutoring System for Physiology*. Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Kim, Nakhoon, Evens, Martha, Michae, Joel, Rovick, Allen (1989). CIRCSIM-TUTOR: An Intelligent Tutoring System for Circulatory Physiology. In *Proceedings of the International Conference on Computer-Assisted Learning*, pp. 254-266. Dallas, TX.

Laird, J., Rosenbloom, P., and Newell, Allen (1986). *Universal Sublanguage and Chunking.* Kluwer Academic Publishers.

Lajoie, Susanne P., and Derry, Sharon J. (1993). *Computers as Cognitive Tools*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Lakoff, George (1973). Hedges: A Study in Measuring Criteria and the Logic of Fuzzy Concepts. *Papers from the Eighth Regional Meeting, Chicago Linguistic Society*, pp. 183-228. Chicago, IL: University of Chicago Linguistics Department.

Lakoff, Robin (1971). If's, And's, and But's About Conjunction. In Fillmore, Charles, and Langendoen, D. eds., *Studies in Linguistic Semantics*, pp. 114-178. Chicago, IL: Holt, Reinhart and Winston, Inc.

Lambert, Lynn, and Carberry, Sandra (1991). A Tripartite Plan-Based Model of Dialogue. In *Proceedings of the 29th Annual Meeting of the Association for Computational Linguistics*, pp. 47-54. Berkeley, CA.

Lambert, Lynn, and Carberry, Sandra (1992). Modeling Negotiation Subdialogues. *Proceedings of the 30th Annual Meeting of the Association for Computational Linguistics*, pp.193-200.

Lauer, Thomas W., Peacock, Eileen, and Graesser, Arthur C. (1992*). Questions and Information Systems*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Lee, Yoon Hee (1990). *Handling Ill-Formed Natural Language Input for an Intelligent Tutoring System*. Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Lehnert, Wendy G. (1978). *The Process of Question Answering: A Computer Simulation of Cognition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Levelt, William J. M. (1989). *Speaking: From Intention to Articulation.* Cambridge, MA: The MIT Press.

Li, Jun, Seu, Jai H., Evens, Martha W., Michael, Joel A., and Rovick, Allen A. (1992). Computer Dialogue System (CDS): A System for Capturing Computer-Mediated Dialogue. *Behavior Research Methods, Instruments, and Computers*, vol. 24, no. 4, pp. 535-540.

Light, Marc (1996). Morphological Cues for Lexical Semantics. In *Proceedings of 34th Annual ACL,* pp. 25-30. Santa Cruz, CA.

Litman, Diane J. (1986). Linguistic Coherence: A Plan Based Alternative. In *24th Annual Meeting of the Association for Computational Linguistics, Proceedings of the Conference,* pp. 215-223. New York.

Litman, Diane, and Allen, James (1987). A Plan Recognition Model for Subdialogs in Conversations. *Cognitive Science*, vol. 11, no. 2, pp. 163-200.

Litman, Diane, and Allen, James (1990). Discourse Processing and Commonsense Plans. In Cohen et al. (1990), pp. 365-388.

MacKay, D. G. (1966). To End Ambiguous Sentences. *Perception and Psychophysics*, vol. 1, pp. 426-436.

Marcus, Mitchell (1981). A Computational Account of Some Constraints on Language. In Joshi, Aravind, Webber, Bonnie L., and Sag, Ivan eds., *Elements of Discourse Understanding*, pp.177-200. Cambridge, MA: MIT Press.

McCarthy, John, and Hayes, Patrick J. (1969). Some Philosophical Problems from the Standpoint of Artificial Intelligence. In Meltzer, B., and Michie, D. eds., *Machine Intelligence*, pp. 463-502. New York: American Elsevier.

McClelland, James L., and Rumelhart, David E. (1988). *Exploration in Parallel Distributed Processing: A Handbook of Models, Programs, and Exercises.* Cambridge, MA: MIT Press.

McCoy, Kathleen F. (1985). The Role of Perspective in Responding to Property Misconceptions. In *Proceedings of the Ninth International Joint Conference on Artificial Intelligence*, vol. 2, pp. 791-793.

McKeown, Kathleen R. (1980). Generating Relevant Explanations: Natural Language Responses to Questions about Database Structure. In *Proceedings of the First Annual National Conference on Artificial Intelligence.*

McKeown, Kathleen R. (1985). *Text Generation*: *Using Discourse Strategies and Focus Constraints to Generate Natural Language Text.* Cambridge, UK: Cambridge University Press.

McRoy, Susan W (1993). *Abductive Interpretation and Reinterpretation of Natural Language Utterances.* Doctoral Dissertation, Dept. of Computer Science, University of Toronto, Canada: as CSRI Technical Report No. 288, University of Toronto, Dept. Of Computer Science.

McRoy, Susan W., and Hirst, Graeme (1995). The Repair of Speech Act Misunderstandings by Abductive Inference. *Computational Linguistics*, vol. 21, no. 4, pp. 435-478.

Mehrabian, Albert (1971). *Silent Messages*. Belmont, CA: Wadsworth.

Michael, Joel A., Rovick, Allen A., Evens, Martha W., Shim, Leemseop, Woo, Chong, and Kim, Nakhoon (1992). The Uses of Multiple Student Inputs in Modeling and Lesson Planning in CAI and ICAI Programs. In *Proceedings of the 4th ICCAL Conference*, pp. 441-452. Berlin:Springer-Verlag.

Michael, Joel, Rovick, Allen, and Evens, Martha (1994). Circsim-Tutor: A Smart Tutor Learning Environment Based on a Qualitative, Causal Model. In *Proceedings of the International Conference on Computer Assisted Education and Training in Developing Countries*, pp. 173-178. Midrand, Johannesburg, South Africa.

Minsky, Marvin, and Papert, Seymour (1988). *Perceptrons*. Cambridge, MA: MIT Press.

Moore, Johanna D. (1995). *Participating in Explanatory Dialogues.* Cambridge, MA: MIT Press. (ACL-MIT Press Series)

Moore, Johanna D., and Paris, Cecile L. (1989). Planning Text for Advisory Dialogues. In *Proceedings of the 27th Annual Meeting of the ACL*, pp. 203-211. Morristown, NJ: ACL.

Moore, Johanna D., and Paris, Cecile L. (1994). Planning Text for Advisory Dialogs: Capturing Intentional and Rhetorical Information. *Computational Linguistics*, vol.19, no. 4, pp. 645-694. Cambridge, MA: MIT Press.

Moore, Robert C. (1981). Problems in Logical Form. In *Proceedings of the 19th Annual Meeting of the ACL*, Stanford, CA, pp.117-124.

Newell, Allen (1975). A Tutorial on Speech Understanding Systems. *In Speech Recognition*, Reddy, D. Raj ed., pp. 3-54. New York, NY: Academic Press.

Newell, Allen (1990). *Unified Theories of Cognition*. Cambridge, MA: Harvard University Press.

Palmer, David C., and Donahoe, John W. (1992). Essentialism and Selectionism in Cognitive Science and Behavior Analysis. *American Psychologist: Reflections on B .F. Skinner and Psychology*, vol. 47, no. 11, pp. 1344-1358. Hyattsville, MD: American Psychological Association

Papert, Seymour (1980). *Mindstorms: Children, Computers and Powerful Ideas.* New York, NY: Basic Books.

Pereira, Fernando C. N., and Grosz, Barbara J. editors (1994). *Natural Language Processing*. Cambridge, MA: MIT Press.

Perrault, R., and Allen, James (1980). A Plan-Based Analysis of Indirect Speech Acts. In *American Journal of Computational Linguistics*, vol. 6, no. 3-4, pp. 167-182.

Piaget, J. (1932). *The Moral Judgement of the Child.* New York, NY: Harcourt Brace.

Polanyi, L. (1978). False Starts Can be True. In *Proceedings of the Berkeley Linguistics Society Fourth Annual Meeting*, pp. 628-639. Berkeley Linguistic Society.

Polanyi, L. (1985). Conversational Storytelling. In Dijk, T. ed., *Handbook of Discourse Analysis: Discourse and Dialogue*, vol. 3, pp. 183-202. New York, NY: Acdemic Press.

Pollack, Martha (1986a). *Inferring Domain Plans in Question-Answering*. Ph. D. Dissertation, University of Pennsylvania, Philadelphia, PA.

Pollack, Martha (1986b). A Model of Plan Inference that Distinguishes between the Beliefs of Actors and Observers. In *Proceedings of the Twenty Fourth Annual Meeting of the Association for Computation Linguistics*, pp. 207-214. New York.

Pollack, Martha (1987). Some Requirements for a Model of the Plan-Inference Processing Conversation. In Ronan Reilly ed., *Communication Failure in Dialogue*, pp. 245-256. North-Amsterdam: North-Holland.

Pollack, Martha E. (1990). Plans as Complex Mental Attitudes. In Cohen, Philip R., Morgan, Jerry and Pollack, Martha E. eds., *Intentions in Communication*, pp. 77-103. Cambridge, MA: MIT Press.

Pollock, John L. (1995). *Cognitive Carpentry: A Blueprint for How to Build a Person*. Cambridge, MA: MIT Press.

Preece, Jenny, Rogers,Yvonne, Sharp, Helen, Benyon, David, Holland, Simon and Carey, Tom (1994*). Human-Computer Interaction*. Reading, MA: Addison-Wesley.

Quilici, Alexander E. (1991). The Correction Machine: A Computer Model of Recognizing and Producing Belief Justifications in Argumentative Dialogs. *Dissertation Abstracts International*, vol. 52, no. 1-B, pp. 352.

Quilici, Alexander E. (1993). A Hybrid Approach to Recognizing Programming Plans. *Proceedings of IEEE Conference in Reverse Engineering*, pp.126-133. Baltimore, MD.

Quilici, Alexander E. (1994). Forming User Models by Understanding User Feedback. *User Modeling and User-Adapted Interaction*, vol. 3, no. 4, pp. 321-358.

Ram, Ashwin, and Leake, David B. (1995). Learning, Goals, and Learning Goals. In Ram, Ashwin, and Leake, David B. eds., *Goal-Driven Learning*, pp. 1-37. Cambridge, MA: The MIT Press.

Ramachandran, Kumar, and Evens, Martha (1995). Lexical Choice for an Intelligent Tutoring System. In *Proceedings of the Midwest Artificial Intelligence and Cognitive Science Conference*, MAICS, pp. 53-57. Carbondale, IL.

Ramshaw, Lance A. (1989). A Metaplan Model for Problem-Solving Discourse. In *Proceedings of the Fourth Conference of the European Chapter of the Association for Computational Linguistics*, pp. 35-42. Manchester, UK.

Redeker, G. (1986). *Language Use in Informal Narratives: Effects of Social Distance and Listener Involvement*. Ph. D. Dissertation, University of California, Berkeley, CA.

Redeker, G. (1990). Ideational and Pragmatic Markers of Discourse Structure. In *Journal of Pragmatics*, 14, pp. 369-381.

Reggia, J. A. (1985). Evaluation of Medical Expert Systems: A Case Study in Performance Analysis. In *Proceedings of the Ninth Annual Symposium on Computer Applications in Medical Care*, pp. 287-291. Baltimore, MD.

Reichman, Rachel (1978). Conversational Coherency. *Cognitive Science*, 3, pp. 283-327.

Reichman, Rachel (1985). *Getting Computers to Talk Like You and Me: Discourse Context, Focus, and Semantics (An ATN Model).* Cambridge, MA: MIT Press.

Riecken, Doug (1994). A Conversation with Marvin Minsky about Agents. *Communications of the ACM*, vol. 37, no. 7, pp. 23-29.

Robinson, Ann (1981). Determining Verb Phrase Referents in Dialogues. In *American Journal of Computational Linguistics,* vol. 7, no. 1, pp. 1-18.

Roch, Eleanor Heider (1973). Natural Categories. *Cognitive Psychology*, 4, pp. 324-350.

Rosch, Eleanor, Marvis, C. B., Gray, W. D., Johnson, D. M., and Boyes-Braem, P. (1976). Basic Objects in natural categories. *Cognitive Psychology,* vol. 8, pp. 382-439.

Rovick, Allen A., and Brenner, Lisa (1983). HEARTSIM: A Cardiovascular Simulation with Didactic Feedback. *The Physiologist*, vol. 26, no. 4,, pp. 236-239.

Rovick, Allen A., and Michael, Joel A. (1986). CIRCSIM: An IBM PC Computer Teaching Exercise on Blood Pressure Regulation. *In Proceedings of the 30th International Union of Physiological Sciences (IUPS) Congress, p. 318.* Vancouver, Canada. (Poster Abstract)

Rovick, Allen A., and Michael, Joel A. (1992). The Prediction Table: A Tool for Assessing Student's Knowledge. *American Journal of Physiology,* 263 (Advances in Physiology Education, 8), S33-S36.

Rumelhart, D. E., and McClelland, J. L. (1986). *Parallel Distributed Processing: Explorations in the Microstructure Cognition*, vol. 1. Cambridge, MA: MIT Press.

Rumelhart, D. E., Smolensky, P., McClelland, J., and Hinton, G. (1986). Schemata and Sequential Thought Processes in PDP models. In Rumelhart, D., McClelland, and the PDP Research Group, eds. *Parallel Distributed Processing*: *Exploration in the Microstructure of Cognition,* vol. 2, pp. 7-57. Cambridge, Ma: MIT Press.

Russell, Stuart J., and Norvig, Peter (1995). *Artificial Intelligence: A Modern Approach.* Upper Saddle River, NJ: Prentice Hall.

Sacerdoti, Earl D. (1974). Planning in a Hierarchy of Abstraction Spaces. *Artificial Intelligence* vol. 5, no. 2, pp. 115-135. Reprinted in Allen, Handler, and Tate 1990.

Sacerdoti, Earl D. (1975). The Non-Linear Nature of Plans. In *Proceedings of the Fourth International Joint Conference on Artificial Intelligence (IJCAI),* pp. 206-214. Georgia, USSR.

Sacerdoti, Earl D. (1977). *A Structure of Plans and Behavior*. Amsterdam: Elsevier-North Holland.

Sanders, Gregory A., Evens, Martha W., Hume, Gregory D., Rovick, Allen A., and Michael, Joel A. (1992). An Analysis of How Students Take the Initiative in Keyboard-to-keyboard Tutorial Dialogues in a Fixed Domain. In *Proceedings of the Fourteenth Annual Meeting of the Cognitive Science Society,* pp. 1086-1091. Bloomington, IN: Lawrence Erlbaum Associates.

Sanders, Gregory A. (1995). *Generation of Explanations and Multi-Turn Discourse Structures in Tutorial Dialogue, Based on Transcript Analysis.* Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Schank, Roger C. (1976). Research at Yale in Natural Language Processing. *Research Report #84*. New Haven, CN: Yale University.

Schank, Roger C., and Abelson, Robert P. (1977). *Scripts, Plans, Goals and Understanding: An Inquiry into Human Knowledge Structures.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Schank, Roger C. (1980). How Much Intelligence is There in Artificial Intelligence? *Intelligence*, vol. 4, no. 1, pp. 1-14.

Schank, Roger C. (1982). *Dynamic Memory: A Theory of Reminding and Learning in Computers and People*. Cambridge, UK: Cambridge University Press.

Schank, Roger C. (1988). *The Creative Attitude: Learning to Ask and Answer the Right Questions.* New York, NY: Macmillan**.**

Schank, Roger C. (1986). *Explanation Patterns: Understanding Mechanically and Creatively*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schank, Roger C., and Farrel, Robert (1988). Creativity in Education: A Standard for Computer-Based Teaching. *Machine-Mediated Learning*, vol. 2, no. 3, pp. 175-194.

Schank, R.C., and Jona, M. Y. (1991). Empowering the Student: New Perspectives on the Design of Teaching Systems. *The Journal of the Learning Sciences*, vol. 1, no. 1, pp. 7-35.

Schegloff, Emanuel A. (1992). Repair after Next Turn: The Last Structurally Provided Defense of Intersubjectivity in Conversation. *American Journal of Sociology*, vol. 97, no. 5, pp. 1295-1345.

Schegloff, Emanuel, Jefferson, G., and Sacks, H. (1977). The Preference for Self-Correction in the Organization of Repair in Conversation. *Language*, vol. 53, no. 2, pp. 361-382.

Schiffrin, Deborah (1994). *Approaches to Discourse.* Cambridge, MA: Blackwell.

Searle, John R. (1969). *Speech Acts*. Cambridge, UK. Cambridge University Press.

Searle, John R. (1970). *Speech Acts: An Essay in the Philosophy of Language*. Cambridge, UK: Cambridge University Press.

Searle, John R. (1975). Indirect Speech Acts. In Cole, Peter, and Morgan, Jerry L. eds., *Syntax and Semantics*, vol. 3, *Speech Acts*, pp. 59-82. New York, NY: Academic Press.

Searle, John R. (1992). *The Rediscovery of the Mind.* Cambridge, MA: MIT Press.

Searle, John R., and Vanderveken, Daniel (1985). *Foundations of Illocutionary Logic*. New York, NY: Cambridge University Press.

Servan-Schreiber, D., Cleermans, A., and McClelland, J. (1989). Learning Sequential Structure in Simple Recurrent Networks. In Touretzky, D. ed., *Advances in Neural Information Processing Systems 1*, pp. 435-443. San Mateo, CA: Morgan Kaufmann.

Seu, Jai Hyun (1992). *The Development of an Input Understander for an Intelligent Tutoring System Based on a Sublanguage Study*. Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Shah, Farhana., and Evens, Martha W. (1996). How to Respond to Student Initiatives in Tutoring Systems. In *Proceedings of the 1996 Midwest Artificial Intelligence and Cognitive Science Conference.* Bloomington, IN.
URL=http://www.cs.indiana.edu/event/maics96/proceedings/Shah/shah.html

Shah, Farhana, and Evens, Martha W. (1997). Student Initiatives and Tutor Responses in a Medical Tutoring System. In *Technical Report of AAAI Spring Symposium on Computational Models for Mixed Initiative Interaction.* Stanford, CA, np. .

Shim, Leemseop, Evens, Martha W., Michael, Joel A., and Rovick, Allen A. (1991). Effective Cognitive Modeling in an Intelligent Tutoring System for Cardiovascular Physiology. In *Proceedings of the 4th Annual IEEE Symposium on Computer-Based Medical Systems*, pp. 338-345. Baltimore, MD: IEEE Computer Society.

Sidman, M. (1960). *Tactics of Scientific Research*. New York: Basic Books.

Sidner, Candace Lee (1979). *Towards a Computational Theory of Definite Anaphora Comprehension in English Discourse*. Revised version of Ph. D. Dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Sidner, Candace Lee (1986). Focusing in the Comprehension of Definite Anaphora, In Grosz, Barbara J., Jones, Karen Sparck and Webber, Bonnie Lynn eds., *Readings in Natural Language Processing*, pp.363-394. Los Altos, CA: Morgan Kaufmann Publishers, Inc.

Skinner, Burrhus F. (1953). *Science and Human Behavior*. New York, NY: Free Press.

Skinner, Burrhus F. (1957). *Verbal Behavior*. Englewood Cliffs, NJ: Prentice Hall.

Skinner, Burrhus F. (1968). *The Technology of Teaching*. New York, NY: Appleton-Century-Crofts.

Skinner, Burrhus F. (1972). *Cumulative Record: A Selection of Papers* (3rd ed.). New York, NY: Meredith.

Skinner, Burrhus F. (1981). Selection by Consequences. *Science*, 213, pp. 501-504.

Sleeman, Derek H., and Brown, John Seely (1982). *Intelligent Tutoring Systems*. London, UK: Academic Press.

Smith, Ronnie (1992). *A Computational Model of Expectation-Driven Mixed-Initiative Dialogue Processing*. Ph.D. Dissertation, Dept. of Computer Science, Duke University, Durham, NC.

Smolensky, P. (1988). On the Proper Treatment of Connectionism. *Behavioral and Brain Sciences*, vol. 11, pp. 1-23.

Stampe, Dennis W. (1975). Meaning and Truth in the Theory of Speech Acts. In Cole, Peter, and Morgan, Jerry L. eds., *Speech Acts: Syntax and Semantics*, vol. 3, pp. 1-40. New York, NY: Academic Press.

Stevens, Albert L., and Collins, Allan (1977). The Goal Structure of a Socratic Tutor. In *Proceedings of the National ACM Conference*, pp. 256-263. Seattle, Washington: ACM.

Stevens, Albert, Collins, Allan, and Goldin, Sarah E. (1982). Misconceptions in Students' Understanding. In Sleeman, D. and Brown, J. S. eds., *Intelligent Tutoring Systems*, pp. 13-24. New York, NY: Academic Press.

Swamer, S., Graesser, A., Franklin, S., Sell, M., Cohen, R., and Bagget, W. (1993). A Connectionist Model of Speech Act Prediction. In *Proceedings of the 15th Annual Cognitive Science Society*, pp. 994-999. Hillsdale, NJ: Lawrence Erlbaum Associates.

Tannen, Deborah (1979). What is in a Frame? Surface Evidence for Underlying Expectations. In Freedle, Roy O. ed., *New Directions in Discourse Processing*, pp.137-181.

Teasley, Stephanie D., and Roschelle, Jeremy (1993). Constructing a Joint Problem Space: The Computer as a Tool for Sharing Knowledge. In Lajoie, Susanne P. and Derry, Sharon J. eds., *Computers as Cognitive Tools*, pp. 229-258. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Thomason, Richmond H. (1990). Accommodation, Meaning, and Implicature: Interdisciplinary Foundations for Pragmatics. In Cohen, Philip R., Morgan, Jerry, and Pollack, Martha E. eds., *Intentions in Communication,* pp. 325-363. Cambridge, MA: MIT.

Traum, D. R., and Allen, J. F. (1994). Discourse Obligations in Dialogue Processing. In *Proceedings of the Conference of 32nd Annual Meeting of the association for Computational Linguistics*, pp. 1-8. San Francisco, CA: Morgan Kaufmann.

Ur, Sigalit, and VanLehn, Kurt (1994). Steps: A Preliminary Model of Learning from a Tutor. In *Proceedings of the Sixteenth Annual Conference of the Cognitive Science Society,* pp. 893-898. Atlanta, GA.

VanLehn Kurt (1996). Conceptual and Meta Learning During Coached Problem Solving. In Frasson, Claude, Gauthier, Gilles, and Lesgold, Alan eds., *Intelligent Tutoring Systems: Third International Conference,* pp. 29-47. Montreal, Canada: Springer.

VanLehn, Kurt, and Jones, Randolph (1993). What Mediates the Self-Explanation Effect? Knowledge Gaps, Schemas or Analogies? In *Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society,* pp.1034-1039 . Boulder, Colorado.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Walker, M., and Whittaker, S. (1990). Mixed Initiative in Dialogue: An Investigation into Discourse Segmentation. In *Proceedings of the 28th Meeting of the Association for Computational Linguistics,* pp. 70-78. Pittsburgh, PA: Morgan Kaufmann.

Webber, Bonnie L. (1986). Questions, Answers, and Responses: Interacting with Knowledge Base Systems. In Brodie, Michael, and Mylopoulos, John eds., *On Knowledge Base Management Systems,* pp. 365-402. NewYork, NY: Springer Verlag.

Webber, Bonnie L., and Mays, Eric (1983). Varieties of User Misconceptions: Detection and Correction. In *Proceedings of the Eighth International Joint Conference on Artificial Intelligence,* Karlsruhe, pp. 650-652.

Wenger, Etienne (1987). *Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approach to the Communication of Knowledge,* Los Altos, CA: Morgan Kaufmann.

Wilensky, Robert (1983). *Planning and Understanding: A Computational Approach to Human Reasoning*. Reading, MA: Addison-Wesley.

Winograd, Terry. (1983). *Language as a Cognitive Process.* Reading, MA: Addison-Wesley.

Winston, Patrick H. (1984). *Artificial Intelligence*. Reading, MA: Addison Wesley.

Woo, Chong (1992). *A Multi-Level Dynamic Instructional Planner for an Intelligent Physiology Tutoring System*. Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.

Woo, Chong W., Evens, Martha W., Michael, Joel, and Rovick, Allen (1991). Dynamic Instructional Planner for an Intelligent Physiology Tutoring System. In *Proceedings of the 4th Annual IEEE Symposium on Computer-Based Medical System,* pp. 226-233. Baltimore, MD: IEEE Computer Society.

Young, R. Michael (1994). *A Developer's Guide to the LONGBOW Discourse Planning System*. Technical Report 94–4, Intelligent Systems Program, University of Pittsburgh.

Young, R. Michael, and Moore, D. Johanna (1994). Does Discourse Planning Require a Special-Purpose Planner? In *Proceedings of the AAAI Workshop on Planning for Inter-Agent Communication.* Seattle, Washington.

Zadeh, Lotfi. (1972). *Fuzzy Set-Theoretic Interpretation of Hedges*. Department of Electrical Engineering, University of California, Berkley.

Zhang, Yuemei. (1991). *Knowledge-Based Discourse Generation for an Intelligent Tutoring System.* Ph. D. Dissertation, Illinois Institute of Technology, Chicago, IL.