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AUTHOR Bell, Benjamin; And Others
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ABSTRACT

A hypermedia simulation, Sickle Cell Counselor, has been developed to anchor instruction for museum visitors using the task of advising couples about the decision to have children when there is a substantial genetic risk of sickle cell disease. A visitor can perform simulated laboratory tests and ask questions via interactive video. The anchored instruction model is closely related to cognitive apprenticeship theory. Patterns of interaction between the user, simulating the role of a genetic counselor, and the program are illustrated through an annotated example. The genetic counseling role makes the Sickle Cell Counselor a compelling program, but the human interest facet is really just a motivational device. The program supports the acquisition of the target knowledge well. The user is supported with knowledge from an experts screen, from learner-initiated coaching, and from implicit task guidance. An evaluation with adults at a community church (21 pretests and 10 posttests) suggests substantial gains in knowledge about sickle cell disease, as well as confidence in the material learned. Ten figures present evaluation findings. (Contains 10 references.) (SLD)

THE ROLE OF ANCHORED INSTRUCTION IN THE DESIGN OF A HYPERMEDIA SCIENCE MUSEUM EXHIBIT

Benjamin Bell, Ray Bareiss, & Richard Beckwith
The Institute for the Learning Sciences, Northwestern University

The Institute for the Learning Sciences has begun developing a framework, *Goal-Based Scenarios* (Schank, Fano, Jona, & Bell, 1993), for computer-based implementation of anchored instruction.[1] In the remainder of this paper we describe Sickle Cell Counselor, present an example interaction, evaluate our implementation of the Anchored Instruction model, and present findings from a preliminary study.

2. Sickle Cell Counselor Description

Anchoring Task

The user of this program plays the role of a genetic counselor, assisting clients who, for various reasons, have expressed an urgent desire to learn more about Sickle Cell. Situating the interaction within this context is important primarily because it makes the purpose of learning about Sickle Cell immediately obvious to the user. The task also provides a framework for integrating pieces of knowledge into a meaningful whole. The interaction is organized around four activities: Asking Experts, Doing Lab Tests, Calculating Risks, and Advising the Clients. Each activity is available to be visited and re-visited, in whatever sequence the user desires.

Experts Screen

When asked to counsel couples about Sickle Cell Disease, the average museum visitor will have, at best, limited knowledge of the disease and only a vague idea of how to go about the process. Asking questions of experts provides relevant knowledge and guidance as to how to apply it.

The experts screen provides access to four video agents via a graphical interface: a physician, a geneticist, a lab technician, and a guide. Agents are implemented using an hour of video on laser disc, which contains the answers to anticipated questions. Choosing an expert will display three questions from which the user can select one to ask the chosen expert; the questions available for each expert change in response to the current context in the counseling process.

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[1] Our implementation of anchored instruction differs significantly from those of Vanderbilt University's Learning Technology Center. See (Williams, in press) for recent analyses of anchored instruction and (Schank et al., 1993) for a description of GBSs.

The Role of Anchored Instruction in the Design of a Hypermedia Science Museum Exhibit*

Benjamin Bell, Ray Bareiss, and Richard Beckwith
The Institute for the Learning Sciences, Northwestern University

1. Introduction

Visitors to science museums are often overwhelmed by a barrage of information. Technologically-oriented exhibits, however, are unlikely to demonstrate the everyday relevance or commonsense nature of much of the scientific knowledge they embody. As a result, visitors typically interact with exhibits for one to three minutes and come away with decontextualized bits of knowledge, if anything.

We have designed a hypermedia simulation, Sickle Cell Counselor, which seeks to address these problems in the context of increasing museum visitors' understanding of Sickle Cell Disease. The system anchors instruction about Sickle Cell in the task of advising couples about the difficult decision of whether of not to have children when there is a substantial genetic risk of the disease. To carry out this task, a visitor can perform simulated laboratory tests and ask questions of several experts via interactive video.

The challenge of creating a situation within which people with varying levels of expertise and motivation could learn something, in a noisy, distracting space, was met by providing the user with a compelling reason for exploring the program, and complete control over where to go and what to do. Designing an activity to address these motivational issues is a necessary though not sufficient condition for learning; the activity must also be designed to support the pedagogical goals of the program.

Anchored Instruction (Bransford et al., 1991) proposes a model for the design of such instruction. This approach calls for creating an authentic task environment in which learners can appreciate the utility of the skills and knowledge they're acquiring, and can further recognize conditions under which these skills are applicable. This model is closely related to another effort to situate instruction in meaningful contexts, a theory articulated by Collins et al. (1989) called Cognitive Apprenticeship, which adapts characteristics of traditional apprenticeship instruction to cognitive processes.

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* Paper presented at the Conference of the American Education Research Association, April, 1993, Atlanta, GA.

The geneticist and the doctor have similar roles - offering expert knowledge to the user at appropriate times. The lab technician also provides some expertise, but in addition helps the user with the mechanics of the blood lab. The guide serves as the voice of the tutor, offering help and suggestions regarding not only how to navigate through the program, but also what to look for and what to try next.

Bloodlab

The most important step in determining clients' risk factors is identifying their hemoglobin gene types. The blood lab gives the user a chance to draw blood samples from each client, view them under the microscope, and perform a conclusive lab test. This activity is the most hands-on part of the program, and also gives users the opportunity to acquire and use knowledge in an authentic setting.

In the course of using the blood lab, users will see what red cells look like and how sickling affects their shape. Users will also observe how the differing electrical properties among hemoglobin types permit their differentiation within an electrical field (*i.e.*, via electrophoresis). The user's goal, though, isn't to "learn about red cells and hemoglobin", but to identify the clients' gene types. In pursuing this goal, a user acquires a working level of understanding of these concepts.

Computing Risks

Determining the clients' risk factors involves two steps: finding out their gene types and then seeing in what ways those types combine. This latter activity is presented by way of a Punnett Square, a simple visualization tool most secondary school students see in biology class. This Punnett Square acts as a graphical spreadsheet, allowing the user to select the gene types for each parent (AA, AS, or SS) and then watch the resulting possibilities fill the square via computer animation.

Advising the Clients

When the user feels that enough information has been collected, he or she can elect to advise the clients, selecting one of three types of advice from a menu. How the clients react depends on the what information the user has explored, but can be generalized for each advice type as follows:

User's Advice	General Client Response
You don't need to worry about Sickle Cell	become more specific about what it is that's worrying them
Let's get more answers	imply what they'd like to find out
It's too risky for you to have kids	angrily insist on a more detailed justification

Once the user determines the clients' risk factors, choice 1 becomes:

You've learned enough. Do what you think is best

Choosing this leads to an epilog (as does selecting a "quit" option) in which the clients return a year later to report their decision and its outcome. If the user determined the clients' risk factors, then the clients, in the end, express their gratitude, even though in some cases the outcomes are worst-case (*i.e.* having a child with Sickle Cell Disease). In contrast, when the user ends the session before determining the clients' risks, their reaction ultimately is frustration and anger that their decision had to be made without sufficient information.

3. An example interaction with Sickle Cell Counselor

The patterns of interaction between the user and program can best be illustrated by annotated example. In the text which follows, a button pressed by the user is indicated by a labeled button icon, the questions available to the user appear in a box, and video clips are paraphrased. Figure references appear in parentheses. The example begins immediately after the user has selected a client couple.

> **Zeke:** Help me out here. Our first child is healthy - real healthy. And then out of nowhere, my niece is born with Sickle Cell.
> **Denise:** I think we should stop having more children - I think we should be happy with the one healthy child we've got.
> **Zeke:** -But that's the point - William's healthy. That means we don't have Sickle Cell, right?

Client introduction sets the scenario - the couple isn't sure whether or not having a healthy child the first time means a second will be born healthy as well, and their uncertainty serves as the focus of the user's inquiry.

> **Guide:** Hi. I'm here to help you with your activities as Sickle Cell counselor. At this point, you can advise the clients, talk to experts, or do lab tests.

Do Lab Tests
Talk to Experts
Advise the Clients

The first time the user sees a new screen, the guide introduces it.

Guide: On this screen you can choose an expert and select a question to ask that expert. Dr. Cynthia Boyd is a physician, and can answer questions related to the medical aspects of Sickle Cell. Dr. Eugene Pergamont, a geneticist, can answer questions about genes and how people inherit Sickle Cell. And Dan, our lab technician, can help you learn how people are tested for Sickle Cell characteristics.

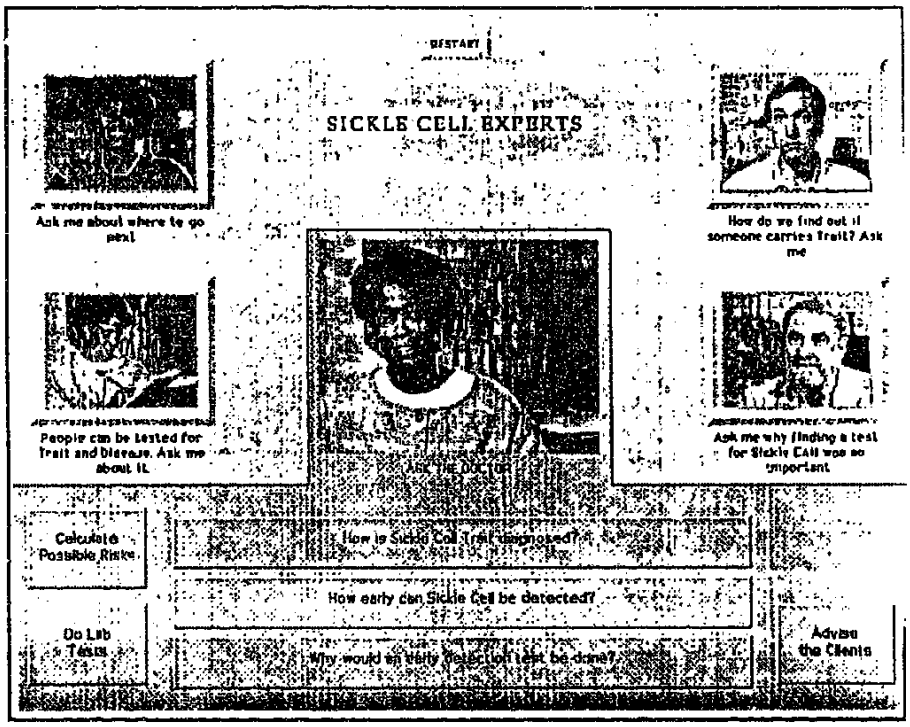


figure 1. Experts screen: asking the doctor

Doctor

How is Sickle Cell Trait diagnosed?
How early can Sickle Cell be detected?
Why would an early detection be done?

(figure 1) **Doctor**: Sickle Cell Disease and Sickle Cell Trait are both diagnosed using a laboratory test called hemoglobin electrophoresis. This gives us a breakdown of the kinds of hemoglobin a patient is carrying in the blood.

Do Lab Tests

Guide: This is the blood lab. Here you can perform tests normally done by a lab technician; you can take samples of your clients' blood, view them under a microscope, and perform electrophoresis testing.

(figure 2) User manipulates the tools provided in the interface to draw the clients' blood and view one of the samples under the microscope.

hat am I looking at?
What do sickled blood cells look like?
What should I do now?

Lab Tech: The red blood cells you're seeing look healthy. But since Sickle Cell Trait doesn't normally cause red cells to sickle, you can't tell by looking at the sample whether or not the client carries Trait. To do that, you'll need to run the electrophoresis test.

(figure 3) User performs electrophoresis testing and determines that both clients have AS hemoglobin, meaning they each carry Sickle Cell Trait.

Talk To Experts

User leaves the blood lab and the experts screen is displayed

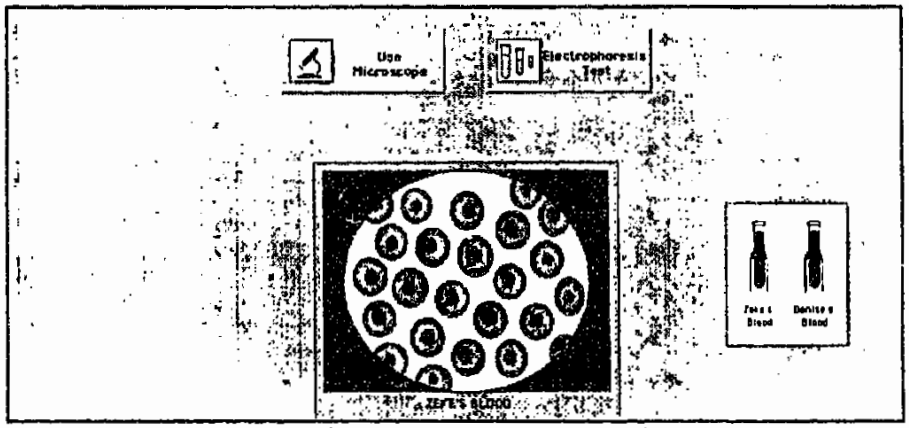


figure 2. Viewing clients' samples in the blood lab (detail)

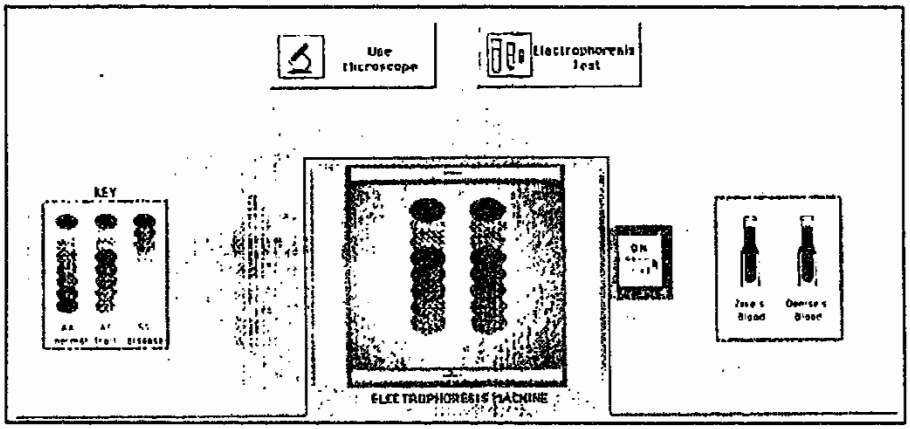


figure 3. Testing samples with electrophoresis apparatus (detail)

Geneticist

Is there a way to calculate the possible risks?
Is the Sickle Cell gene a recessive gene?
Can parents have more than one child with Sickle Cell?

(figure 4) Geneticist: Using the Punnett Square, recognizing what the genotypes of the parents are, one can easily figure out what the gene makeup of their offspring will be.

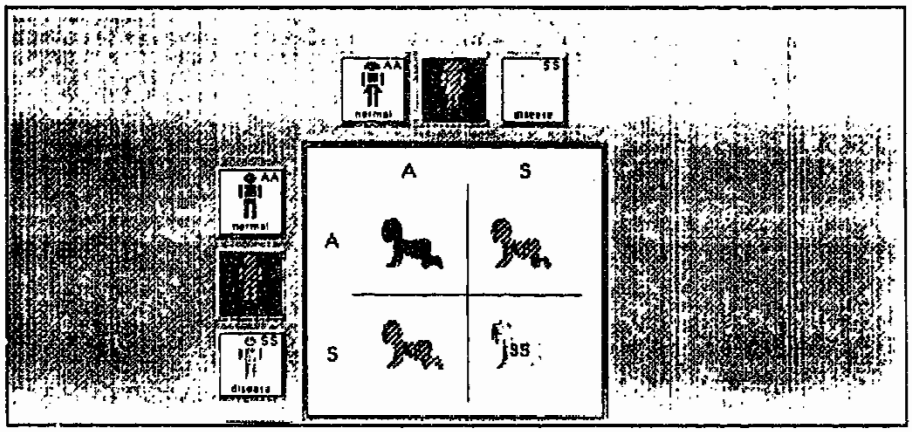
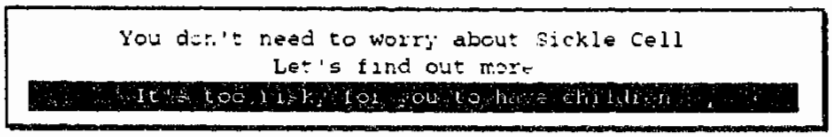
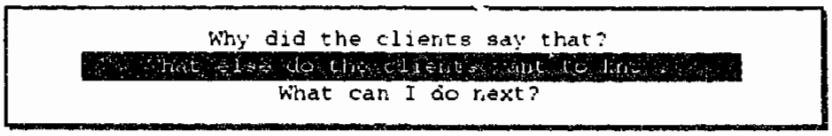


figure 4. A possible outcome shown by the Punnett Square (detail)

Advise the Clients



(figure 5) **Zeke**: What are you talking about? How did you decide that?
Denise: Yeah! what are *our* risks?

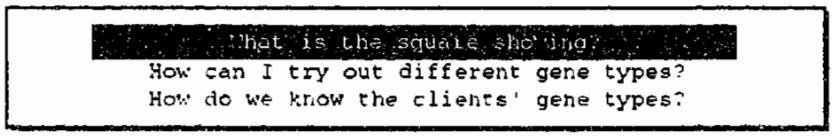


Guide: Finding out your clients' hemoglobin types was an important step. But they don't know their own risks of having a child with Sickle Cell.

☐ Calculate Possible Risks

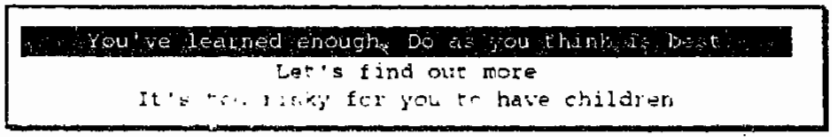
Guide: Here is a Punnett square. This shows you what the odds of each possible outcome are for two parents with the Hemoglobin types you specify. Since you've found out your clients' gene types, the square is already filled in to show your clients' possible outcomes.

The Punnett Square animates to show the clients' possible outcomes (if known)



Geneticist: The Punnett Square shows that 3 different types of offspring are possible. There is a 25% chance that the child will have SS-type hemoglobin and will have Sickle Cell Disease. There is a 25% chance that of AA, or normal hemoglobin. And there is a 50% chance that the child will have AS hemoglobin, meaning the child will carry the Sickle Cell Trait.

☐ Advise the clients



The first question on the advise-the-clients screen replaces "You don't need to worry about Sickle Cell" , because the user discovered that the clients do in fact face a Sickle Cell risk.

> **Guide**: About a year has passed, and your clients have come back to tell you what choice they made, based on the information you gave them.
>
> **Denise**: Well, after our counseling session with you, we talked everything out and decided to have another child, and, -
> **Zeke**: -we had a girl - Elizabeth- a beautiful girl.
> **Denise**: - and we found out she has Sickle Cell Disease...
> **Zeke**: ...but we knew the risks.
> **Denise**: It's hard sometimes...but when I look at her I know we made the right choice. Thanks for helping us.

Because this user gave the clients the essential information, their reaction expresses gratitude; in contrast, couples react with anger or frustration when the user ends the session before answering the clients' principal concerns.

4. Criteria for evaluating the anchoring task

The genetic counseling role helps make the Sickle Cell Counselor a compelling program, but the human-interest facet is really just a motivational device. The program's instructional potential relies more on how well the task context supports the acquisition of the target knowledge. We established three criteria for examining our implementation of the Anchored Instruction model.

1. Is the relationship between exploring the domain and achieving the anchoring task clear to the user?

Convincing a user to pursue some goal within the program depends, of course, on the anchoring task being sufficiently motivating.[2] More importantly, the task must organize the target knowledge so that users recognize the relevance of the information they're acquiring to the task. The genetic counseling cover story provides a transparent link between content material and task, since the user's mission is to seek out and provide the clients with the information they need. In other words, the knowledge users gather as counselors is the same as the knowledge we want them to acquire as learners.[3]

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[2]Extensive user evaluations do strongly suggest that the goal is motivating.

[3]This relates to studies of learning by teaching (Harel, 1986; Palthepu, Greer, & McCalla, 1991).

2. How central is the user's role in the task context?

In considering how a user's decisions affect a simulation, we should look beyond simply reacting to the user selections, which all interactive programs do by definition. Rather, the goal is to create a role in which the user actively directs the state of the program or the behaviors of simulated agents. This is why, for example, the Sickle Cell Counselor user is the *counselor* rather than a client, the thinking being that a patient in contemporary health care systems plays a passive role, and that the result would be a program better described as learning-by-being-done-to than as learning-by-doing.

3. Does the user control where to go and what to do?

It is our expectation that the feeling of being in control helps engage the interest of the user (Schank & Jona, 1991). We further suspect that the *process* of navigating around the interface can itself be helpful in encouraging the learner to reflect on the relational structure of the domain, analogous to the way a learner reflects on a problem-solving episode (Collins & Brown, 1988; Brown, 1985). In Sickle Cell Counselor, the user decides which activities are to be performed (*i.e.* what kind of information to gather) and in what sequence. The domain can be explored, in detail, by engaging the experts in a "conversation" about Sickle Cell Disease via the question-based interface. Besides keeping the user in control, the experts screen supports instruction as discussed below.

5. Supporting the user with multiple knowledge sources

Our discussion above focused on the anchoring task and its evaluative criteria. Satisfying these criteria might suggest that the task is appropriate, but does not entirely answer the question of how we expect the learner to learn. In Sickle Cell Counselor the user is supported with information from three sources: expert knowledge, learner-initiated coaching, and implicit task guidance.

Expert knowledge

The experts screen enables users to explore the domain in a pseudo-conversational way. Information is gathered incrementally as the user follows paths by selecting an expert, posing a question, viewing the expert's answer, and then similarly posing follow-up questions, a

dialog structure based on the ASK System architecture (Ferguson et al., 1992).

In Sickle Cell Counselor the links among the stories are implicit in the questions available for selection. A user would, for example, ask "can the genetic risks be predicted?" rather than select a link labeled "patterns of inheritance". This required that we anticipate the questions which would naturally arise in different contexts, and that we index the experts' video material to supply answers to those questions. This process is explained in more detail elsewhere (Bell & Bareiss, 1993). Browsing links, displayed as questions, make the interface more consistent with the "consulting-with-experts" task artifice. In other words, getting expert advice in order to help the clients is part of the anchoring task, and we therefore designed the interface to appear more conversational than encyclopedic.

Learner-initiated Coaching

During a conversational interaction with the experts, users may lose sight of what they're doing and where they are, an effect which can be described as "getting lost in hyperspace". Since browsing is a means for gathering information to help the clients, the issue is how to help users progress in the anchoring task without compromising the feeling that they're in control.

The Sickle Cell Counselor program answers this issue with learner-initiated coaching, provided in the form of questions the user may ask the Guide (who is always available), such as "what can I do now?" or "how do I fill the syringe?". In formulating answers to questions like these, we adopted a pedagogical stance which we think of as pseudo-Socratic: the Guide makes suggestions and refers to past actions the user has taken rather than telling the user what to do (although explicit instruction is eventually given to a stuck user). This form of coaching supplies needed help but keeps the user in control and avoids having the program guess when and why the user needs help.

Implicit Task Guidance

Task guidance is embedded within the model which directs how the clients behave. When the user decides to advise the clients, their response contains clues to help the user infer what plan might best satisfy the counseling objectives. For example, an angry client who

demands "What's so risky about carrying the Sickle Cell Trait?" is reacting to a user's advice that the risks are too great, but is also providing implicit guidance for the user to explore the medical implications of Trait. Seen in this way, the clients not only behave as agents in the anchoring task, they also embody a representation of that task, which, in practice, can suggest to the user promising areas to explore.

6. Results from user testing

This is a preliminary report on an evaluation of Sickle Cell Counselor, performed at the Second Baptist Church in Evanston, IL. The program was installed on two Macintosh computers arranged next to each other on a table in a mid-sized auditorium. The auditorium was filled with people attending an African clothing and handicraft sale. People using the program wore headphones to hear the audio portion and sat facing their monitor. If people indicated an interest in using the program they were asked (but not required) to fill out a pre- and posttest. Of those asked, 21 users filled out a pretest and 10 filled out a posttest. The pre- and post- tests were identical. The tests included nine questions about various aspects of Sickle Cell Disease. Seven of the questions required a short answer; two required the subject to determine the pattern of genetic transmission. The seven short answer questions were:

1) What is Sickle Cell Disease?

2) What is Sickle Cell Trait?

3) How is Sickle Cell detected?

4) Who is at risk for Sickle Cell?

5) You are a doctor and you discover that a particular couple under your care runs a considerable risk of having children with Sickle Cell Disease. What would be your advice to them?

6) What are the symptoms of Sickle Cell Disease?

7) What gene types must be present for a couple to be at risk for having children with Sickle Cell Disease?

The two questions addressing the pattern of transmission were:

8) Indicate {Y or N} for each couple below whether it is possible for them to have a child with Sickle Cell Disease {an AS indicates Sickle Cell Trait}

9) Rank the couples in order based on the likelihood they would have children with Sickle Cell Disease. {1=highest risk}

For questions eight and nine, the test forms included the figure at right, and noted that the columns of A's and S's referred to genes, that everyone has genes, and that S refers to a Sickle Cell gene and A refers to a normal gene.

	M	F	
1.	AA	AA	_____
2.	AS	AA	_____
3.	SS	AA	_____
4.	AS	AS	_____
5.	SS	AS	_____
6.	SS	SS	_____

The posttest was given immediately after using the program. The conditions under which this was collected are somewhat unusual so bear in mind that the users were pretested immediately before use. This means that subjects were aware of what they did not know when they were using the program and were probably more sensitive to the content than would be otherwise expected. The test was not multiple choice so respondents would still need to learn the correct answer from a wide array of possibilities (i.e., it was not narrowed down by the pretest). We expect to use the pretest scores in subsequent reports, but in the near future we will be collecting posttest data from respondents who have not taken a pretest.

The subjects were members of the church and ranged in age from mid teens to late adulthood. Twenty-one users filled out a pretest and eleven filled out a posttest. The pretest results for the subjects who took the posttest were virtually identical to the pretest results of those who didn't. Only ten posttests will be considered. We did not use the posttest results of one subject who returned to the computer and filled out the posttest as he reviewed the material.

Results for short-answer questions

For the short-answer questions (1—7), we looked across all the responses and counted each element within the answer. For example, in response to the question "What is Sickle Cell Disease?", a respondent may have said that it was a hereditary blood-disease in which the blood cells take on a sickled shape. In this case, we would have counted the response under three categories: blood disease,

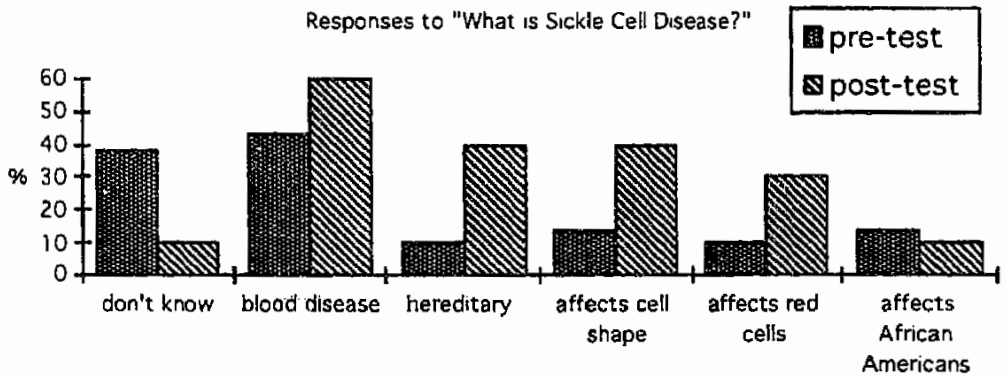
hereditary, and shape. Below we compare the pre- and posttest responses for each question.

1. What is Sickle Cell Disease?

Pretest: Thirty eight percent of our subjects said that they didn't know what Sickle Cell Disease was, forty three percent said it was a blood disease, ten percent said it was hereditary, fourteen percent thought it affected white blood cells, ten percent thought it affected red blood cells, fourteen percent said it affected African-Americans, fourteen percent reported that it affected the shape of blood cells, and five percent said it affected the blood's ability to carry oxygen.

Posttest: Ten percent said they did not know. Sixty percent said it was a blood disease. Forty percent said it was hereditary. Forty percent said the shape of cells was significant. Thirty percent said that it affected red blood cells. Twenty percent said it affected mobility. Ten percent said that African-Americans were at risk.[4] Ten percent said that two Sickle Cell genes must be present. Several answers now included the word *hemoglobin* which was not seen in any of the pretests.

The table below summarizes response results for this question.



[4]Some respondents were told that they did not have to repeat what they had gotten correct on the pre-test. This means that for any given question, a lower number of correct answers may be present than would be expected on the basis of change due to using the program. For example, in the case of question 1, one subject did not mention that sickle cell is a blood disease in the posttest (although this subject mentioned it in the pretest) and another mentioned on the pretest but did not mention on the postest that it was hereditary.

2. What is Sickle Cell Trait?

Pretest: Sixty two percent said that they did not know, ten percent said that it was not having the disease but still being able to pass it on to children, fourteen percent said the gene was present but not the disease, five percent attempted to draw a Punnett Square, and twenty four percent had mistaken perceptions of Sickle Cell Trait.

Posttest: Twenty percent said that they did not know. Fifty percent said that it was one Sickle Cell gene and one normal gene. Twenty percent said the gene was present but not the disease. Ten percent said something irrelevant.

3. How is Sickle Cell detected?

Pretest: Forty three percent of our respondents did not know, fifty two percent said that a blood test was required, five percent said a special test was required, and five percent said that the person would develop symptoms

Posttest: Sixty percent said a blood test, thirty percent said electrophoresis, ten percent said a hemoglobin test.

4. Who is at risk from SC?

Pretest: Fourteen percent said they did not know, forty eight percent said African-Americans, twenty four percent said children of people with Sickle Cell, ten percent said anyone, ten percent said Africans, five percent said Mediterraneans, and five percent said it depended on the climate.

Posttest: Seventy percent said African-Americans, fifty percent said children of people with Sickle Cell genes, ten percent said anyone, ten percent said Africans, and ten percent said Mediterraneans.

5. You are a doctor and you discover that a particular couple under your care run a considerable risk of having children with Sickle Cell Disease. What would be your advice to them?

Pretest: Twenty nine percent of our respondents said they did not know, twenty nine percent said that they would advise the clients not to have children, twenty four percent said they would advise the clients to make an informed decision, ten percent said they would

advise the clients to adopt, and ten percent said they would advise the clients to treat the children medically.

Posttest: Fifty percent said to give them information so that they could make an informed decision, twenty percent said it would depend on the risks, ten percent said to tell them to have no children, ten percent said to test the children and ten percent said to treat the children.

6. What are the symptoms of Sickle Cell Disease?

Pretest: Seventy six percent said that they did not know, ten percent said poor circulation, five percent said fatigue, five percent said shortness of breath, five percent said weak bones, and five percent said sickness.

Posttest: Thirty percent said that they did not know, thirty percent said pain, twenty percent said sickled cells, ten percent said fatigue, ten percent said clogged arteries, and ten percent said none.

7. What gene types must be present for a couple to be at risk of having children with Sickle Cell Disease?

Pretest: Eighty one percent said that they did not know, nineteen percent said the parents must have one Sickle Cell gene.

Posttest: Ten percent said that they did not know, sixty percent said each parent must have a Sickle Cell gene, ten percent simply said a Sickle Cell gene, ten percent said a parent with Sickle Cell Disease, and ten percent said two parents with Sickle Cell Disease.

Transmission pattern questions

8. We asked our respondents to identify which of the six possible hemoglobin gene combinations could lead to Sickle Cell Disease. Of these six combinations, three run a risk of Sickle Cell Disease.

Pretest: Thirty eight percent said they did not know. The percentage of subjects with the correct response for each gene combination is presented in the table below.

Posttest: None of our subjects said they did not know.

Gene types	Disease risk?	% correct (pre)	% correct (post)
AA/AA	no	57	100
AS/AA	no	38	60
SS/AA	no	24	50
AS/AS	yes	43	90
SS/AS	yes	48	100
SS/SS	yes	53	100

Identifying combinations with risk of Disease

9. Given these same six combinations of genes, we asked our subjects to rate the relative likelihood that the couple would have offspring with Sickle Cell Disease. Of the six combinations, for three there is no chance of having a child with Sickle Cell Disease. The remaining combinations have a chance of 25%, 50%, or 100% for AS/AS, AS/SS, and SS/SS, respectively. The relative likelihood for these should be rated successively higher by a knowledgeable subject.

Pretest: Thirty eight percent of our subjects said that they could not rate the likelihoods. The percentage of subjects with the correct response for each gene combination is presented in the table below.

Posttest: None of our subjects said that they did not know.

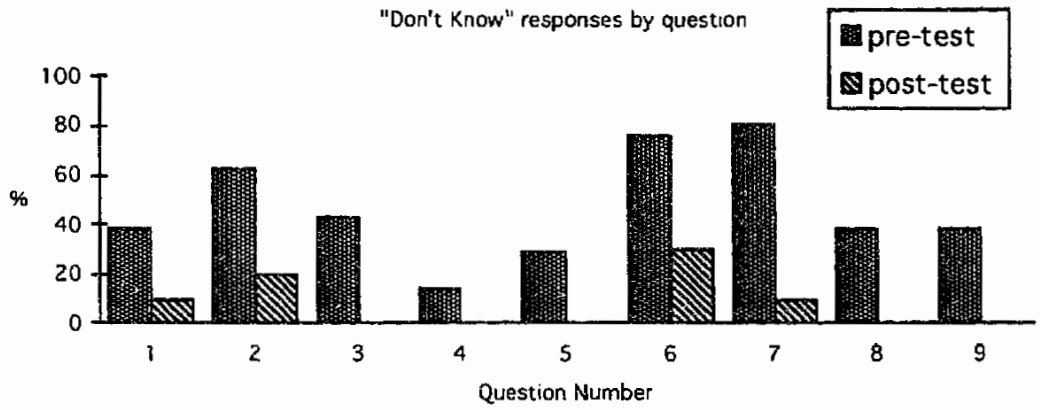
Gene types	Disease risk	% correct (pre)	% correct (post)
AA/AA	0%	57	100
AS/AA	0%	57	80
SS/AA	0%	38	50
AS/AS	25%	29	40
SS/AS	50%	43	100
SS/SS	100%	57	90

Rating the likelihoods of Sickle Cell Disease

We asked respondents on the posttest in what ways the program changed the way they felt about Sickle Cell Disease or the families affected by this disease. Forty percent did not answer. Of those who answered, fifty percent said they learned about varying probabilities of having children with Sickle Cell Disease, seventeen percent said they learned people with Sickle Cell could have children, seventeen percent said they learned it was genetic, and seventeen percent said they learned that the disease existed.

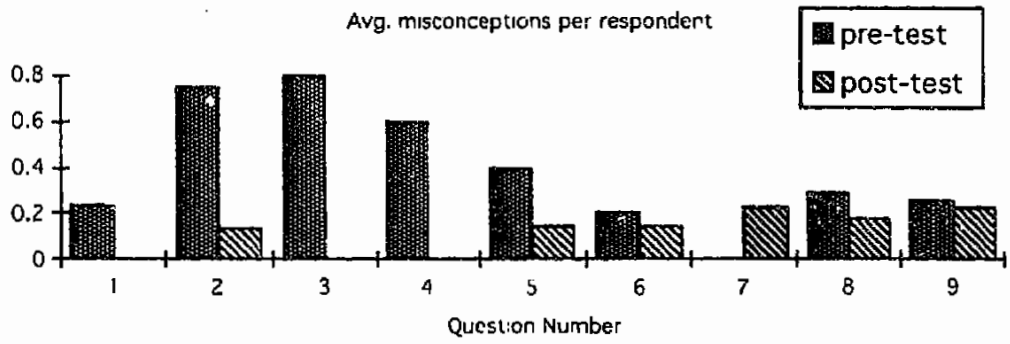
Summary

Clearly the most obvious difference between the pre- and post- test is in the number of "don't know" answers. In the posttest, subjects felt that they knew how to answer most questions, as illustrated below.



When we look at the answers our subjects gave on the pre- and post-tests, we can see that not only did they *feel* they could answer most questions, they were able to answer most questions. The two tables below show evidence of this. Note that these results include only those respondents who felt they could answer the question.

First, the average number of misconceptions among those subjects who chose to answer a question is lower on the posttests.



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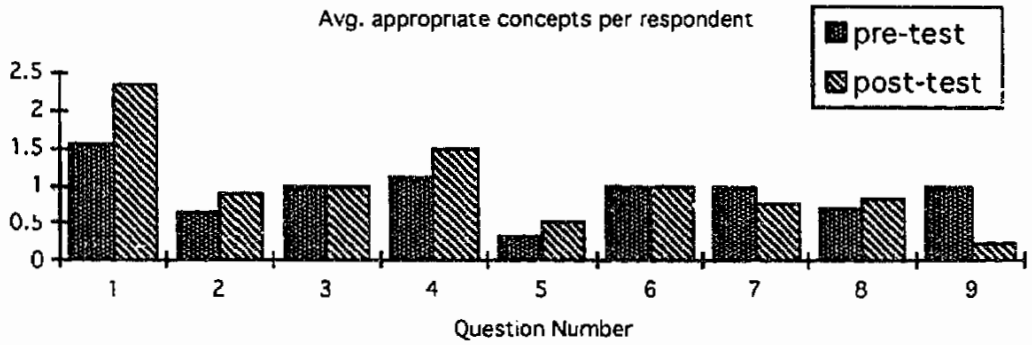
Second, the average number of appropriate concepts in the answers to the individual questions is higher on the posttests.[5]



In this study we found that Sickle Cell Counselor allowed its users to learn about Sickle Cell Disease in a short time (less than 15 minutes). Users felt more comfortable about answering questions, and were also more likely to answer them appropriately and with fewer misconceptions about the disease.

7. Conclusions and Future Work

This program is an early example of a Goal-Based Scenario (GBS), which represents our framework for implementing anchored instruction. In creating Sickle Cell Counselor we articulated the target concepts, and mapped out the relationships between these concepts and the anchoring activities. This process was tractable because of the modest pedagogical goals we could pursue in such a short interaction. For creating GBSs with much broader instructional scope (say, a semester-long course), a systematic methodology is needed, together with a suite of tools to support that methodology. We are currently engaged in the design of the methods and tools that will allow for the creation of course-level GBSs. Sickle Cell Counselor was a first step toward that goal.

[5]Respondents may not have repeated in the posttest concepts they identified in the pretest. See preceding footnote.