Contextualized questioning to scaffold learning from simulations

Cindy Hmelo\textsuperscript{a, *}, Roger Day\textsuperscript{b}

\textsuperscript{a}Graduate School of Education, Rutgers University, Graduate School of Education, 10 Seminary Place, New Brunswick, NJ 08903, USA
\textsuperscript{b}Pittsburgh Cancer Institute, University of Pittsburgh Medical Center, Pittsburgh, USA

Received 7 December 1997; accepted 23 November 1998

Abstract

Computer-based clinical simulations have a long history in medical education. Often they are used to provide practice in diagnostic skills or for evaluation. A different approach to medical education is problem-based learning which helps students learn biomedical science as they solve problems in a small-group, student-centered environment, with minimal guidance by a facilitator. We have merged these techniques of simulation and problem-based learning. Our strategy has been to situate questions within a simulation, thus setting the context for collaborative problem-based discussions. These questions are designed to help the students focus on the important aspects of the case and to bridge the gap between clinical skills and conceptual science knowledge. Moreover, these questions serve to model the kinds of questions students need to be asking themselves to further their understanding. The discussions of these questions help provide a shared context for learning. This paper reports on a field-based study in which we implemented this approach with first-year medical students. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

A basic tenet of medical education has been that students should learn the basic biomedical sciences as a tool for solving clinical problems. However, clinical knowledge and basic sciences have traditionally been taught independently. Anchoring science in clinical contexts has been
increasingly recognized as important so that learners will be better able to access science knowledge when solving clinical problems as well as helping them understand how science can be a tool in problem-solving (Collins, Brown & Newman, 1989). One way of integrating basic and clinical science has been problem-based learning (PBL) in which students participate in facilitated discussions of medical cases (Barrows, 1985; Hmelo, 1995). Another method has involved using computer-based patient simulations to provide students with exposure to a variety of diseases and practice in diagnostic skills (Friedman, 1995). We have developed a third approach that combines these instructional modalities by embedding contextualized questions in simulations, providing grist for facilitated discussions. We report here on a field-based pilot study to evaluate the feasibility of merging these approaches to address both sociocultural and cognitive issues.

In problem-based learning, students learn through solving simulated patient problems with a facilitator who guides the learning process rather than providing information. The students identify the learning objectives that arise out of the problems, engage in self-directed learning, and bring their new knowledge back to revisit the problem. A limitation of these patient simulations is that they are often paper-based and offer feedback to the learner only in the form of the collaborative discourse.

Computer-based simulations offer users dynamic feedback and process traces that can be used to review and reflect on their performance (Collins et al., 1989; Levin & Waugh, 1988). Because different users will have different traces and see different events, collaborative discussion of the simulation experience offers learning opportunities as students coordinate multiple points of view. They provide a rich experience for students. However there are problems with simulations that may make using and learning from simulations difficult because novices do not yet have the clinical experience to interpret many test results and understand their relevance (Friedman, 1995). The cognitive overhead of the clinical tasks can make it difficult for students to make the necessary connections between basic biomedical science and clinical issues. Software-realized scaffolding is a strategy that can help learners deal with the complexity of these simulations (Collins et al., 1989; Guzdial, 1994; Hmelo & Guzdial, 1996).

For both PBL and simulations, the goal is often the same—to help students anchor the study of biomedical science in a concrete clinical case. Our work has involved integrating simulations with PBL tutorials in the domain of cancer biology. Cancer biology is a difficult area for students to understand as one needs to understand it at multiple levels: the visible signs and symptoms in a patient, the genetic mechanisms, the cell growth regulation system, the cell and molecular biology, and the interaction of tumor cells with host factors such as the immune system. The global behavior of a complex system is often incomprehensible even when the pieces of the system are fully understood in isolation so it is important to help students understand how these different levels are related to each other (Chi, DeLeeuw, Chiu & LaVancher, 1994). Our simulation and questions were designed to help students bridge these different levels and to set the context for collaborative discussion. Using simulations alone does not ensure learning. Rather, students must reflect on their actions to construct usable knowledge. Scaffolding can be provided to help the students learn from the simulation and not just solve the problems posed (Guzdial, 1994; Hmelo & Guzdial, 1996). We provided scaffolding in the form of questions embedded in simulations. We hypothesized that having
students consider these questions ahead of time would help the facilitators guide the PBL discussions. To make collaborative discussions more meaningful, the questions were designed to: 1) help ensure that students have some common ground for discussion; 2) support the emergence of their skills at gathering and interpreting clinical data; and 3) help the students focus on the educational objectives.

The notion of using questions to help students learn has been used in other systems. Several hypermedia systems use questions to help direct students towards learning-appropriate goals (Schank, Fano, Bell & Jona, 1993; Jacobson, Maouri, Mishra & Kolar, 1996). Other learning environments use questions as part of computer simulations to help focus student attention on relevant aspects of the simulation, to model the kinds of questions students should be learning to ask, and to help make their thinking visible and thus an object for reflection. The Computer as Learning Partner curriculum (CLP), uses questioning as part of the Scaffolded Knowledge Integration framework as they ask students to make predictions and interpret the results of their experiments (Hoadley, Hsi & Berman, 1995; Linn, 1996). The CLP project found that it was important to use questions to help students reflect on how the experiments they did meshed with their everyday experiences. Questions may also be used to focus online collaborative discourse in the Multimedia Forum Kiosk (Hoadley et al. 1995). Topics for discussion in this system are multimedia science materials. The questions in CLP help make thinking visible and model the kinds of questions that students need to ask to 1) become lifelong learners; and 2) integrate their everyday models with canonical scientific models.

BGuile uses questions to help scaffold learning scientific inquiry skills in biology (Sandoval, 1997; Tabak, Smith, Sandoval & Reiser, 1996; Tabak & Reiser, 1997). The students are placed in a simulated laboratory environment and use questions to help them construct scientific explanations. What is interesting about this system as well as the CLP system is that the software is not self-contained (Linn, Songer & Eylon, 1996). In other words, the software helps create the context, but equally important are the discussions among students and the teacher facilitation of student learning. In the use of contextualized questioning, we also do not expect students to do all their learning while interacting with the software. Instead, the simulation and embedded questions are meant to provide the context for a facilitated, collaborative dialogue.

Both problem-based learning and clinical simulations are similar to Goal-Based Scenarios (GBS) (Schank et al. 1993). All these pedagogical approaches involve students in learning-by-doing. In the design of a GBS, an artificial goal is invented for the learner. Medical students come to their learning environment with a set of shared goals: to learn what they need to become a doctor. One of the key elements of GBS and PBL is that learning will occur as the student discovers learning needs in order to solve the problem they are working on. These two environments differ in regard to the source of the information to meet those needs. In a GBS, this information is provided in the form of expert stories and explanations. In PBL and simulations, this information is entirely external to the computer. Students may use reference texts, computer databases, expert consultations and discussions with their peers. This helps the students develop the self-directed learning strategies they need to become lifelong learners (Hmelo & Lin, in press). In contrast, in a GBS, the learner is interacting with agents embedded in the system. In PBL as well as BGUILE and CLP, there is an emphasis on the social construction of knowledge as the simulations set the context for collaborative discussions.
2. The case of Mrs. Buchanan: Designing contextualized questions

We developed two computer simulations based on a paper case used for PBL in previous years. It is the case of a woman with breast cancer that is initially treated (in simulation 1) but later spreads to her bones (in simulation 2). The simulation was developed with the Dxr authoring system (Myers & Dorsey, 1994). The students are able to conduct an extensive interview with the patient, use a variety of tools to obtain physical exam results, and order laboratory tests (Fig. 1). This interface, like other educational hypermedia systems, contains a multimedia database that provides access to the information about the patient case (Ferguson, Bareiss, Birnbaum & Osgood, 1992). As the students work through the case, they are asked to keep track of their hypotheses and refine them as they move from one portion of the patient encounter to another, e.g., from the interview questions to the physical exam. In addition, the authors of the case can link questions to specific pieces of data or place them at the end of the case. In the Mrs. Buchanan case, we did both. For example, after students view the breast biopsy, they are asked to explain why the growth pattern was altered (Fig. 2).

The questions were designed to help the students understand the implications of the findings, focus on those that were particularly important, and to encourage them to reflect on causal mechanisms that would cause normal function to become abnormal. Work on self-explanations has demonstrated the importance of helping students connect the specific examples to more general scientific principles, leading to better understanding (Chi et al., 1994; Chi, Bassok, Lewis, Reimann & Glaser, 1989).

One of our guiding assumptions is that deep reasoning is fostered through contextualized answering of questions; first individually, and later collaboratively. Based on research in
cognitive science, we have identified certain kinds of questions that are intended to promote deep thinking (Table 1) (Graesser, Langston & Baggett, 1993; Graesser & Person, 1994). An *interpretation* question asks the learner to describe the significance of a particular sign, symptom or event. Interpretation is a descriptive process that is likely to describe how the alterations in structure and function are related to the particular clinical findings. Deeper levels of thinking are fostered through asking students for explanations. A *causal antecedent* question asks the learner to identify the causal events that led up to the current state. A *causal consequence* question asks the learner to predict the consequences of an event or state. In this kind of question the learners must also justify their prediction by explaining why they believe that result will occur. Causal antecedents and consequence questions should help students make the more complex mapping between the different levels at which cancer biology can be represented. Consequence questions should also help students make connections between

![Contextualized question](image)

**Table 1**

<table>
<thead>
<tr>
<th>Question type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation</td>
<td>What is the significance of the mammogram results?</td>
</tr>
<tr>
<td>Causal antecedent</td>
<td>Why do some of the factors in her history predispose Mrs. Buchanan to developing a mass in her breast?</td>
</tr>
<tr>
<td>Causal consequence</td>
<td>What if you gave Mrs. Buchanan a single drug regimen rather than the combination of 3 drugs</td>
</tr>
<tr>
<td>Expectational</td>
<td>What would you expect to happen to Mrs. Buchanan if she only had surgery? Why?</td>
</tr>
<tr>
<td>Enablement</td>
<td>How is tamoxifen helpful as adjuvant therapy for breast cancer?</td>
</tr>
</tbody>
</table>
clinical information and causal mechanisms. An *expectational* question asks why a specific event did or did not occur. This might logically follow a causal consequence question as a student is asked to reconcile their predictions with actual events. These kinds of questions are used in BGuile and the CLP curricula to scaffold the scientific inquiry process (Tabak & Reiser, 1997; Linn, 1994). An *enablement* question asks what object, agent, or processes allows some action to be performed and how they accomplish their actions. Enablement questions that follow interpretations may help get students thinking about the mappings between overt clinical manifestations and pathophysiologic processes. These questions need to be carefully constructed and mapped onto the objectives that the problem designers have for the specific problems.

In the remainder of this paper, we report the results of a pilot study in which we implemented the simulations with the contextualized questions in the PBL tutorials at the University of Pittsburgh School of Medicine. Both qualitative data and quantitative data were collected to examine the feasibility of using this approach to enhance learning.

3. Methods

3.0.1. Participants

The participants in this study were 36 University of Pittsburgh first year medical students. Student volunteers were recruited so as to have four intact tutorial groups and their facilitators. Two of the groups were randomly chosen to be the experimental group and two were used as the controls. The students received $30 gift certificates for participating. One student was not able to complete the study due to clinical obligations.

3.0.2. Instruction

The experimental group received a one-hour orientation to the patient simulation software. This session introduced the students to the DxR interface with another simulation. Students learned to use the software without difficulty. They then spent about one hour prior to their tutorial session using the patient simulation and answering the questions. We provided a one-hour training session for the facilitators of the experimental group to explain the rationale for this approach and to suggest how they might facilitate the discussion. During their two-hour tutorial sessions, the students discussed the answers to the questions in addition to the case. The students went through a second patient simulation and discussion cycle later in the week. The control group used the normal paper case that is similar to the case that the experimental group used. Students had these tutorial sessions in addition to 10 h of lecture each week.

3.0.3. Data collection

As the students worked on the program, log files of their interactions were maintained. These log files contain a record of all interactions, the times they occurred, and any text entries.

---

1 The students had already been divided into groups for the PBL tutorials that were part of their curriculum. We selected groups in which all students had volunteered to participate.
the students made into their on-line notebooks and hypothesis lists. Two of the four groups were videotaped. Observers were in each tutorial group and detailed field notes were taken to record those observations. In addition, the first author observed one of the experimental groups as they worked on other problems before and after the problem used for this study. These notes were examined to see how well the classroom part of the intervention was implemented.

After the second tutorial session, the students in both groups were asked to summarize Mrs. Buchanan’s case as if they were presenting her to other physicians. These summaries provided information concerning whether the contextualized questions helped students focus on the critical aspects of the problem. The students’ summaries were parsed into individual signs, symptoms, and tests. Each segment was coded as an observed fact or an inference. It was also coded as to whether it was “critical” information (identified by a cancer specialist) from the case or not. This task was a surprise to the students. Such incidental recall measures are used as a measure of what students are attending to as they solve the problem (Friedman, France & Drossman, 1991; Norman, Brooks & Allen, 1989).

Next, the students were asked to explain the cellular basis for Mrs. Buchanan’s problem. The explanations were used to examine the students’ understanding of the scientific mechanisms. We were particularly interested in whether the students mentioned the genetic basis of the cancer. Although this is not a direct part of the simulation, the questions were designed to help students focus on genetic issues. We also examined whether or not the students made mappings between the scientific mechanisms involved and the patients’ clinical findings.

Students were also given a questionnaire to ask them to evaluate the contextualized questions and the software in terms of the educational value and usability. Of necessity, this questionnaire was more extensive in the experimental PBL group than in the control group. The students rated the items on a 5 point Likert scale. Only the first three questions were comparable to the questionnaire for the control students. They were asked to explain their responses. The students also completed a set of open-ended questions.

3.1. Coding procedures for student notebooks, case summaries, and explanations

A rater blind to condition coded all of the students’ explanations and recall data.
3.1.1. Student notebooks

All the responses to the contextualized questions were recorded in the students’ on-line notebooks. These notebooks were printed out and each response was categorized according to the criteria identified in Table 2. These categories range from nonresponsive answers and simple assertions to responses that include detailed causal information.

3.1.2. Case summaries

The students’ summaries were parsed at a fairly fine grain into individual bits of information. This includes parsing between multiple treatments, sites affected by a disease, and different attributes of a sign or symptom. Each item was classified as to whether it was an observation or an inference. Observations refer to directly observed or reported information from the patient as well as the raw numbers of lab tests (Evans & Gadd, 1989). They are identical to material in the case text or are paraphrases. Inferences are clinical findings; interpretations of the observations in terms of diagnostic value (Evans & Gadd, 1989). For example a hemoglobin level of 14 would be an observation whereas the patient has a normal hemoglobin would be coded as an inference. Exceptions to this may occur when, for a particular examination or test, the case text reported unremarkable or within normal limits. In that case, an observation would be coded. Further, each item was also classified as to whether it was one of the items critical for making the diagnosis and ruling out competing diagnoses as well as if it were correctly or incorrectly recalled. The expert oncologist who helped develop the case identified these items.

3.1.3. Explanation

The students’ explanations were compared against a normative template to see which knowledge components were in their explanations (Table 3). This template was developed from the course syllabus notes and in consultation with experts in oncology. Note that these explanations did not come from the simulation itself but from the students’ independent research (using various reference texts) and the collaborative discussions with other students in their groups.

Table 3
Knowledge components in explanations

<table>
<thead>
<tr>
<th>Knowledge components in explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Genetic changes that allow:</td>
</tr>
<tr>
<td>1a) Altered percentage of cells that are active in the cell cycle.</td>
</tr>
<tr>
<td>1b) Impaired signaling pathways lead to uncontrolled growth (due to genetic mutations) and/or decreased programmed cell death.</td>
</tr>
<tr>
<td>1c) Cells to elaborate angiogenic factors to allow them to grow</td>
</tr>
<tr>
<td>2) Further changes that allowed invasion such as the ability to degrade basement membrane.</td>
</tr>
<tr>
<td>3) Changes that allow cells to enter bloodstream/lymphatic system</td>
</tr>
<tr>
<td>3a) Decreased adhesion/anchorage independence</td>
</tr>
<tr>
<td>4) Attach at distant sites and begin growth of secondary tumors</td>
</tr>
<tr>
<td>5) Tumor cells with estrogen receptors require estrogen for growth and are good candidates for anti-estrogen therapy (e.g., tamoxifen)</td>
</tr>
</tbody>
</table>
4. Results

4.1. Software use

We have 11 usable log files for the first simulation and 12 for the second simulation (out of 18 possible) because of electronic mishaps. Students used the software for a mean of 33 min (SD 16.05) on the first case and 44.92 min on the second (SD = 41.89). The variability in usage was quite high with one of the students on the second case spending almost 3 h (this student's first log file was lost when the computer crashed).

Although time on task is one measure of the extent to which the students used the software, it is more instructive to examine students' responses to the questions. This allows us to see how deeply the students were processing the questions. Questions were constructed to afford students considering causal mechanisms so we predicted that the students would provide higher level responses. The students answered a mean of 3.72 (SD = 1.42) questions on the first simulation and 9.45 (SD = 3.94) on the second. This is consistent with time on the simulation—students appeared to be getting through more of the simulation and answering more questions during the second simulation. As shown in Table 4, in the first simulation, the students' answers were largely nonresponsive and simple assertions. In the second simulation, the students were still generating a lot of low level responses but there was an increase in frequency of the higher level responses.

There was much variability in the extent to which students really thought about the questions as indicated by the depth of the students' responses to the questions. For example, in response to the question about how hormones work to prevent the growth of cancerous cells in this patient, one student wrote simply “It blocks estrogen” (S#30) whereas another student generated a much more elaborated response:

Tamoxifen is a nonsteroidal, antiestrogen, antineoplastic drug often used as an adjunct therapy in the treatment of breast cancer. Tamoxifen blocks estrogen at the receptor on the cell surface of cancer cells that require estrogen for growth and development. It is believed that subsequent to the receptor binding, tamoxifen binding to the nuclear chromatin of...
certain tissues results in reduced DNA polymerase activity, impaired thymidine utilization, blockade of estradiol uptake, and decreased estrogen response. Most of tamoxifen’s activity occurs in the G-2 phase. Cell cycling is slowed by the drug’s activity in the nucleus. Therefore, tamoxifen is considered to be cytostatic. (S#29)

This latter student provided information about clinical usage and mechanism of action of the drug, tamoxifen. He has not however tied it to the specifics of the Mrs. Buchanan case. This elaboration came from both prior knowledge and from text-based sources. Note that the simulation here is used as a stimulus to drive self-directed learning and as a context for discussion, thus it forms a piece of the learning environment but is not the entire source of learning.

4.2. Classroom observations

All four classrooms were observed but we report here on the first session in the experimental classrooms. Our interest in the observations was the fidelity with which our intervention was implemented and how the classroom was different during the course of the study. The two experimental classrooms were quite different from each other. In both experimental classrooms, the students had used the software prior to attending class. The students were asked to print out their notebooks, which would contain their notes about the case and the answers to their questions. Few students did this because of problems in the installation of software and network difficulties. Although it had been our expectation that the students would start by comparing the patient information they had from the simulation, the facilitators passed out the paper version of the case. This made the integration of the questions into the discourse somewhat awkward. In classroom B, the facilitator was not comfortable with allowing students to do most of the talking. The students in group B did not consider the questions prior to coming to class and often turned them back to the facilitator who later answered them. The discussion was generally two-way, between the facilitator and an individual student. There was no interstudent discussion. The students also did not develop any learning objectives beyond those in the course syllabus. Early in the session, one student noted that she had generated some learning issues related to risk factors for breast cancer while using the computer. Rather than starting a list of learning objectives on the board (the usual PBL model), the facilitator delivered a minilecture on that learning objective. The facilitator was an expert in the topic of the case and felt compelled to make sure the students understood breast cancer well. After the study, Facilitator B told the researcher that when the student discussion of chemotherapy came up, they did not understand it, requiring a minilecture. Facilitator B’s model of teaching was that of information provider.

The implementation went more as intended in Classroom A. In Classroom A, the facilitator gave out the paper case but also asked the students if they found additional information on the computer. Facilitator A tried to explain the importance of figuring out what was relevant. Thus his model of teaching was to help students learn the clinical inquiry process. Although the facilitator provided more information than was optimal, the information focused largely on how to approach a patient. The students’ list of learning objectives included several related to
the basic sciences. After the paper case was finished, the group went over any of the contextualized questions that had not been considered during the earlier discussion. Even though not all the students had researched the answers to the questions prior to coming to class, several had and were able to bring additional information into the discussion. The students realized that they did not understand why malignant tumors have particular physical characteristics (such as the large irregularly shaped cells seen in tumors), only that they did. In discussing the genetic mechanisms, different students brought up different aspects of genetics and regulation of cell growth, but they were always eager to get back to a discussion of the clinical aspects of the case. In this group, communication was multiway among the students themselves as well as with the facilitator. This classroom was not quite what we had expected but given the novelty of this approach to the facilitator and the students, the implementation was reasonably faithful unlike in the first section. The facilitator was non-directive with regards to the science content and he successfully encouraged productive discussions. The discussion in this group differed from the earlier and later weeks. In the other weeks, the students often had two-way conversations with the instructor rather than discussions among the group. Also, several students increased their participation in the discussion during the study compared with the other weeks that they were observed. The discussion fell short of the ideal scenario in several ways. The group discussions often focused on the clinical aspect of the simulation rather than going deeply into the science issues. In addition, the students did not bring as much outside information into the class as anticipated.

4.3. Case summaries

There were 34 usable summaries. One student did not understand the task and provided no usable data. There were no differences between the paper-based and computer-based groups on the total number of observations or inferences recalled. Students recalled a mean of 28.08 observations (SD = 12.93) and 4.85 inferences (SD = 3.19). However when the number of critical observations was computed as a percentage of the total, 78.71% of the observations were critical for the experimental group, compared with 66.05% for the controls, a significant difference ($F(1,32) = 5.85, P < 0.05, MS_e = 232.26$).

4.4. Explanations

The students generated an average of 3.69 out of 8 possible components of the explanations. There were no differences between the groups. The students’ explanations contained very few links between the science and clinical information (Mean = 0.37, SD = 0.53) with no group differences observed. There was some evidence that the experimental students were more likely to have mentioned a genetic mechanism in their explanations (Fisher’s exact test, $P < 0.06$); eight of the 17 experimental students mentioned a genetic event, compared with three of the 18 control students.

To explore the link between the students’ explanations and their use of the software, several correlational analyses were conducted for the experimental group. These analyses examined the relationship between the time that students spent on the simulations, the level of their responses, and the explanation scores. Because of the small sample size, it would be difficult to
get significant correlations so we report all correlations of 0.4 or greater as these are considered moderate. There were no correlations between time on either of the simulations and the quality of the students’ explanations. Moderate correlations were found between generating descriptive responses for both simulations and explanation quality ($r = 0.50$ for simulation 1 and 2), as well as for, on simulation 2, generating causal responses ($r = 0.53$) and with the number of questions answered ($r = 0.40$).

4.5. Questionnaire

The students rated their learning in PBL slightly positively (Mean = 3.65 on a 1–5 scale, SD = 0.60). Both groups of students felt that they were equally likely to learn clinical information in the PBL sessions (Mean = 4.10, SD = 0.55). Both groups felt a little less positive about their science learning (Mean = 3.40, SD = 1.0). The experimental students were noncommittal as to whether they preferred this to the usual method of PBL (M = 3.00, SD = 1.00). The students were however, positive about liking the computer and finding the software easy to use (Mean = 4.00, SD = 1.0 for both). The students were also positive about the value of the questions in their learning (Mean = 3.65, SD = 0.60).

The results of several open-ended questions helped illuminate students’ perceptions of the strengths and weaknesses of integrating the simulations with PBL. When asked what they liked best about our experimental approach, 47% of the students liked having the control to make their own decisions. One student noted that it helped to focus before the PBL sessions. The students complained about some general usability problems and the additional time needed outside class. When asked how the questions helped them in thinking about the case, 53% of the students noted that it helped them focus on what was important, but 27% of the students were frustrated at not knowing the answers to the questions. The students were unanimous in wanting to try this combination of contextualized questioning with PBL again. Most of the students did want to continue to include the contextualized questions (80%) and 87% wanted to continue to use the software. They did note that we needed to improve the questions and better integrate the software with the collaborative discussion (16%).

5. Discussion

Using simulations has the potential to provide a rich context for collaborative discussions. Because students may take many different paths through a simulation, it is helpful not only to have them discuss the different paths but to encourage them to reflect on common themes. As well, students may need help in focusing on relevant aspects of the rich context. We had hoped that embedding questions in the simulation would help the students focus on the important clinical information and use this information as an anchor to help them understand the science. We were partially successful in this pilot endeavor. Because of the limited nature of this intervention, the facilitators had a difficult time integrating the discussion of the simulation into the PBL tutorial. Clearly, more time is needed for training the facilitators and the students. The facilitators have varying ideas of what PBL is about and these differ considerably from the ideal model. It will be important to have a hands-on workshop for the facilitators.
and give them feedback as they try implementing the simulation-based discussions. Training facilitators to help guide the process will continue to be a critical issue.

There is a learning curve for the students as well. They need time to adjust to a new way of learning. The students needed time to get used to the software and plan for the out-of-class time needed to thoughtfully work through the simulation. This study shows that the students improved in their approach to the simulations from the first to the second simulation. The students did not fully understand that once the simulation was done, they still needed to think about the questions, do some research, and be prepared to discuss the issues. Students needed feedback about how to approach the simulations. This suggests that it is important to think about how to integrate simulations into a significant part of the course and not just a single week.

There was an issue in the mismatch between the goals of the software developers and the course facilitators. The goals of the facilitators were geared towards the clinical aspects of the case as well and so that is where they focused the discussion. Better communication is needed between the course faculty and the software development team to create a better fit between the technology and the course goals.

But despite the difficulties in the implementation, we still found some encouraging results. We were successful in helping the students focus on the important clinical information. We were less successful in helping them focus on the science although we did see the experimental students focus more on genetic mechanisms than the control group. Most encouraging is that the students feel that this approach is worth trying again.

An important research issue is developing a principled approach for constructing questions that can be embedded within the simulation for later discussion in the tutorial groups. These questions should help the students map between the clinical information, changes at the organ system level, and changes in the cell population dynamics. Part of the challenge will be to keep these questions open-ended enough so that the students have to think deeply and engage in intense discussions that help students make these linkages while providing enough structure so that the students understand what the question is asking. It may also be helpful to use these questions as models so that for later cases students can pose questions for other students because there may be greater learning gains when students generate their own questions rather than just answering questions posed by others (King, 1992). The contextualized questioning approach has the potential to scaffold students’ learning from simulations by focusing their attention on important aspects of the problem as well as modeling the kinds of questions students need to be asking themselves.

Acknowledgements

This research was supported by a grant from the National Institutes of Health. We appreciate the help of Adam Brufsky in authoring the case used for this study, and Tim Carlos for allowing us to work with the students in his course. We would like to thank Michel Ferrari, Katherine Lestock and Bill Shirey for help in running this study. We thank Kurt VanLehn, Roger Taylor and an anonymous reviewer for their helpful comments on an earlier draft.
References


