An Interactive Learning Environment for Health Care Professionals*

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ABSTRACT

This article summarizes experiences to date with building and deploying a clinical simulator that medical students use as part of a 3rd year primary care rotation. The simulated microworld helps students and health care professionals gain experience with and learn meta-cognitive skills for the care of complex patient populations that require treatment in the biopsychosocial-value dimensions. We explain lessons learned and next steps resulting from use of the program by over 300 users to date.

1) INTRODUCTION

The purpose of this effort was to create a learning environment that provides experience and knowledge about the management of complex patient populations. The target users of this environment include medical students and physicians as well as allied health care professionals. A number of quite good computerized training programs are available commercially, however, virtually all of them focus narrowly on the diagnosis and/or treatment of strictly the biomedical dimension of patients' problems (e.g., see RxDx series, QMR patient simulator, or the Slice of Life videodisc). In complex patient populations (e.g., elderly, chronically ill, cognitively-impaired, aids, or dying), clinical decision making is strongly influenced by non-biomedical factors such as patient preferences, psychological, and social resources. Depending on the settings of these factors, the clinician often must alter the treatment decisions.

For these reasons we created a new clinician training environment, one useful to health care professionals seeking to learn how to think about, problem solve for, and better manage complex patient populations. In doing this, we encountered and attempted solutions to a number of decision structuring, pedagogical, human-computer interaction, artificial intelligence, and usage evaluation issues. To begin our efforts, we developed a version of the learning environment for geriatric patient populations. This paper explains the lessons learned to date.

2) HEALTH CARE FRAMEWORK

Complex patients often defy the application of a straightforward (biomedical) decision approach. For example, among other difficulties, there may be impediments to communications, and there may be written directives about unexpected care desires. There often is no way to cure them. This presents an unsettling situation for MDs used to being in control and focusing on the (biomedical) solutions. Traditional decision structuring process breaks down and they become unsure of what to replace it with.

To work with complex patient populations requires the MD to adopt a reasoning framework broader than biomedicine alone. For geriatric patients the framework includes four dimensions that must be combined to isolate the best plan of care [7]:

(1) Biological (B) -- This is the traditional area where clinicians label the etiology and physiology of the patient's complaints. For non-complex patients, treatment is linked to this diagnosis in the "fix-it" approach to medical decision making [3].

(2) Psychological (P) -- This provides insight into the patient's mental outlook, coping styles, personality, stress level, and so on. How will the patient manage current and future medical problems?

(3) Social (S) -- This dimension encompasses support the patient will receive from the immediate and larger social network around them. It also concerns the cultural and social class mores concerning care. Are there family members or others to act as caregivers? Any cultural factors?

(4) Value/Cost (V) -- The patient's beliefs, fears, and preferences about pain, stress, disfigurement, death represent an important dimension of health care decision making. What are the patient's concerns about being a cost (financial and care) burden to the

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family? What value and cost will the alternative medical intervention plans pose to the patient?

The goal of our training environment is not so much to teach the student the correct answer, but to fundamentally alter the decision processes the student uses. Thus, they must learn that in a clinical setting it is vital to collect and evaluate answers to questions along all four of these BPSV dimensions. This requires the clinician to elicit references from the patient, or a surrogate in the determination of the best possible outcome and intervention plan.

3) PEDAGOGICAL ISSUES

In the 1980s, prevailing wisdom (e.g., [1]) would cause us to design our environment to lecture the users on the biopsychosocial-values dimensions, and closely drilled them on practice cases. By the end of the 1980s, however, the medical schools in North America began to shift from instructionism to constructionism, or problem based learning. At the same time, intelligent tutoring systems fell out of favor in the field of computer science. The idea of constructivist environments caught on (e.g., see [6]).

Constructivist environments, like problem based learning (PBL), favor student-centered learning, self-discovery of clinical insights, and personally experiencing realistic patient cases albeit in a simulated microworld. The more the microworld mimics the real world, the easier the learner can transfer the lessons to actual practice. Also, in constructivist microworlds, if any tutors exist (and often they don't), they act more as facilitators, temporary cognitive apprenticeship, and meta-cognitive aids that focus on learning to learn skills.

4) INTERACTIVE LEARNING SYSTEM

The learning environment consists of (1) a case base of patients that can be visited, (2) a simulator of the patient, their support group, and clinical personnel, and (3) a graphical user interface that lets the student conduct exams, give orders, monitor progress/results, consult collaborators, update the patient record, and so on. This section presents each of these in turn. The system runs on IBM 386 compatibles with MS Windows. The system is programmed in Assymetrix Toolbook using DB III for the databases. Our architecture is generic to any of the domains mentioned in the introduction. By editing the case and databases, one can adapt the simulator to a new domain. The simulator engine and graphical user interface do not need to be altered.

The Case Base -- The case base currently consists of eight geriatric cases, each containing 100s of possible dialogue, diagnosis, and intervention options. Each case may be described in terms of a state space representation scheme where the patient's situation comprises the states, and students' actions determine state transitions. The student controls the simulator clock, so there is ample wall-clock time to explore a given state and alter one's decisions and/or interventions before simulator time advances. To manage the computing complexity, each patient case is indexed into about 6 to 10 overall states, including a starting state, a successful end-state(s), a failed-end state(s), and the remainder being intermediate states. Intermediate states, may be (1) steps in the right direction but from which the student could still branch to either a successful or failed end-state, (2) commonly committed, contra-indicated actions that are important to teach about (and that are recoverable from), or (3) default states that are reached by advancing the clock with either no interventions, or with none of the interventions that lead to the other intermediate states. If the student reaches the default state twice in a row, s/he follows the default path and terminates in a fail-state.

The Simulator -- It is one thing to learn an abstract decision structuring framework in class. It is another to know how to apply the framework in a clinic. The simulator causes the student to struggle with how to structure the biopsychosocial-values dimensions in the context of managing the patient situation.

The student begins the simulated "rounds" by selecting a patient and starting a new case. The simulator's 5 step algorithm then ensues. In step 1, the case is instantiated with 100s of pieces of information from three databases including the patient history DB, the possible orders (and exams, workups, labs, transports, etc.) db, and the canned text dialog strings of about 3 dozen possible case collaborators (e.g., attending nurse, clinical specialists, family members, attorney, etc.). In standard constructivist mode, the students browse as much of this material as they deem warranted. They can examine a teaching message from the system, but this is at the meta-cognitive level (e.g., something about decision structuring) and it says nothing about the specific way to solve the current case. In step 2 the student advances the clock, and the simulator collects the student's actions to date and helps them eliminate any violations (e.g., can't send to ER if already at ER). In step 3, the student receives a blank screen that inquires about their clinical impressions thus far. Next the case stack database (DB) is updated in step 4, and the state index is advanced. With the new state index, step 5 consults the DBs and reinstantiates the 100s of items the user previously browsed in step 1. If an end state has not yet been reached, the student returns to browse mode (step 1),

and the algorithm repeats this time showing the student the progress to date. If an end state has been reached, the case stops, the student DB gets an update, and any final case messages are loaded, including detailed explanations and in-depth on-line references for further study. If the end state is a fail-state, the attending nurse takes proper action so the patient outcome is the desired one. The student can browse the final state at their leisure and proceed to another case when ready, or terminate rounds. An example of how all this works can perhaps best be illustrated in the context of the screens the student sees.

The Graphical User Interface -- Our student interface design follows widely used conventions that many students may already know. This includes use of pull down menus, list boxes with scroll bars, push buttons, and a simple 2 column window layout. As an assist, there is also a tutorial and practice session under the F1 help key for learning to use the mouse and the features just mentioned. The main pull-down bar of the interface leaves the control of the case in the student's hands, rather than forcing them through a fixed protocol. The pull downs let the student (1) change the file to a new case, (2) access the patient chart, (3) conduct a physical, (4) examine the history of the current illness, past illness and lab results, and current and past medications, (5) order new labs and workups, instruct the patient, and advance the clock, (6) transport the patient to the ER, Hospital, LTC, or residence, (7) consult a variety of individuals, (8) inspect the teaching messages, and (9) obtain help.

In general, after making a physical, orders, transport, or consult selection from the pull-down bar the student enters a 2-column screen. The left column is a menu of further detailed selections. The right column posts the responses. These also get posted to the patient chart and history. In a future version we hope to add audio-visual features that will give the student practice in interpreting the raw data directly (e.g., actual chest xray image). Results in the right column also are stored in the patient history file for later re-browsing by the student. When the student advances the clock, the 2-column format is replaced by windows that collect the student's clinical impression, convey lab results, and offer various dialog messages (e.g., from health care professionals, the patient/surrogate, and the tutor). At the end of the case, the student pages through teaching material starting with case answers and objectives and evolving to broad principles and reading citations.

Example geriatric case, Mrs. Brown -- The nursing home nurse complains that Mrs. Brown is agitated and needs sedation (start-state, Brown-100). The patient herself is noncommunicative (in this case). Selecting FAMILY will put the student in touch with Mrs. Brown's niece, Lucy her Durable Power of Attorney for Health Care, who would explain some of Mrs. Brown's wishes. The clinician must determine that the underlying condition causing the agitation is pneumonia, and send Mrs. Brown to the ER (successful End State, Brown-200). Ordering a chest xray, oxygen, or antibiotics are successful intermediate states labelled Brown-400 and -500 that suggest the student is on the right path (another intermediate state is being added of a blood oxygen detector), but these must be reached the first time the simulator clock is allowed to advance or else they will be too late to help the patient. If the student fails to send the patient to ER after Brown-100, -400, or -500, the simulator advances the case to Brown-300. Here the student has one last chance to assess the situation and send to ER, or the case terminates in a fail state, Brown-600. If the student ends up in the fail-state, the night nurse would take over the patient's care. Thus the student would hear how the patient was brought out of trouble, and is doing better at the ER. Alternatively, if the student sent the patient to the ER, Figure 3e is a report from the ER physician, and a thank you from niece Lucy.

5) STUDENT USAGE RESULTS

To create an environment that permits exploration and self-discovery, also holds the opportunities for students to get lost, in trouble, and frustrated. To minimize these obstacles, the Director, Div. of Aging Studies & Services (Dr. Cobbs) works with the student users as they come through a 6 week primary care rotation which includes geriatrics as one of the topics. The software with the 8 cases is currently required of all 150 3rd year medical students per year when they go through this rotation. On the first day of the rotation, they get an orientation to the software and instructions to complete the 8 cases before the 6 weeks are up. They also take a pre-test of their geriatric knowledge (see below). Sometime during the rotation, they spend about 2 hours with the preceptor in a 12 person group discussion of caring for the elderly and of solving cases both in the computer, and in practice. This discussion centers around the BPSV framework, though the framework is never formally presented. On the last day of the rotation they retake the test as a post-test. Neither time do they learn the correct answers to the test.

The students generally use the computer with a set of books and articles on the table next to them. The goal of the computer program is to help the students gain experience and confidence in applying the BPSV framework so they will better be able to utilize it in practice. The results to date are promising, but also show that there are a number of improvements

needed. Let us examine a few of these results in this section and then return to the implications for improvement of the software in the last section.

To date, we have collected four types of evaluation measures from the 300 plus student users: (1) software usage patterns, (2) transfer of experiential learning across similar cases, (3) before and after usage performance scores, and (4) student reactions. We are still analyzing the bulk of this data, and can only give a few indications of what it conveys.

Software Usage Patterns -- Looking at the Mrs. Brown case, discussed earlier, in a recent sample of 18 students, 13 students (72%) reached the successful end state. Yet, 85% of these 13 visited a non-fruitful intermediate state (Brown-300) and probably got to the success-state by reading teaching messages and the nurse's suggestions, rather than by diagnostic effort. None of these (or the 5 failed students) viewed the broader framework that would have led to the correct end-state. If they had consulted the family, for example, they would have seen that the family did not want the patient to be treated by all medical means short of life-support or resuscitation. A trip to the ER would meet the needs of the family.

Only one of the students actually appeared to use the psychological framework. This student asked to look at the history of the patient, the history of Mrs. Brown's mental status as well as her psychiatric history. After referring to all of the historical information, the student examined the patient's heart and lungs and ordered her transported **immediately** to the ER. It is most interesting to note, as mentioned earlier in this paper, the software was designed to help teach a framework broader than biology alone and that the most successful student in the Brown case, attained success by doing exactly what the software is trying to teach - that is by seeing the patient in the broader reasoning framework.

Knowledge Transfer Across Cases -- One of the goals of the computer program is to have the students learn from (simulated) experience. Did they pick up any insights about the framework that they are now transfering to and using on subsequent cases? We should be able to detect if this is happening by comparing the same students' performance on a similar case. One of the 8 existing cases, that of Mrs. Johnson, bears some useful similarities to Mrs. Brown's case. Mrs. Johnson has advanced Alzheimer's disease. The students need to administer a swallow test to detect she is in the final stage, after which they must follow family directives and allow her to die in peace.

In contrast to the Brown case, the students both examined the history of the patient, including mental status and neurological, as well as consulted with family members. After doing so though, only 1 student ordered a swallow test. The rest of the students seemed to find it difficult to do nothing for Mrs Johnson, as the family preferred, and they proceeded to order a feeding tube or a hospital admission. Thus as the students progress from case to case, we do see an improvement in the process that they use for treatment of elderly patients. The software seems to lead to knowledge transfer of the framework. However, old habits die hard. The software fails to dampen the biomedicine-only tendencies instilled in the students over the years.

Performance Score Improvements -- Another goal of the software is ultimately to help the students perform better after their (geriatrics) rotation. The pre- and post-test is an instrument currently in use to determine if the students are benefiting from the rotation. The test includes (a) a self-rating of knowledge about sub-aspects of the BPSV framework, (b) a series of multiple choice and true/false questions on care of the elderly, and (c) a short geriatric case followed by a request for a list of the patient's current problems and how the doctor should help the patient for the very near future. Although it was never designed into an experiment for measuring the value of the software, we can glean some insights from the testing data.

Comparing the self-rating forms on part (a) shows the students rate themselves about 30% higher after using the software. This is a crude measure that the software seems to help the students, at least with their confidence in the knowledge. However, the computer has no impact that is measurable by multiple choice/true-false (MC/TF) tests (part b). This should not be surprising since the computer aims at experiential learning of a framework rather than memorization of facts. Finally, their answers to part (c) of the post-test reveal the students rarely structure their answers into or even show they're using the BPSV framework. This may be related to the fact the BPSV framework is never formally taught, either in the rotation or in the software (although it is discussed in the recommended readings including Dr. Cobbs' book). Not formally teaching the biopsychosocial-values framework is consistent with the constructivist pedagogy (students should discover it). Yet this pedagogy may not be ideal if it is important to transfer a stronger skill in BPSV decision structuring within the 6 week rotation, especially in light of the students' prior bias to use the biomedical-only portion of the framework. More on this shortly.

Reactions -- At the end of their rotation, the students complete a 1 page evaluation form on their experience. Comments on the software generally fall into two categories: human-computer interaction and pedagogy. The human computer interaction comments show the software is not yet working as well as it needs to. There are problems with synonym lookup, free text translation, user confusion, and saving and printing functions. In terms of pedagogy, the students frequently request more quick info, greater teaching/hinting guidance, and finer-grained evaluation.

6) DISCUSSION AND NEXT STEPS

The results presented above are leading us to a number of changes and improvements in the computing, pedagogy, and evaluation areas. The computing changes include, but aren't limited to: an alternative to the free text input of orders and requests (e.g., a pick and click form, a word wheel, or a robust style synonym checker); program and printer speedup and other efficiency improvements; more flexible entry/deletion options; and an improved on-line tutorial that helps the student understand what to get from the system. To improve doctoring skills, we are also exploring the addition of multimedia representations of (1) raw patient sign and symptom data, (2) lab results, and (3) conversational interaction with family and surrogates.

In terms of the pedagogy and instructional capabilities of the software, the students are enthusiastic about the clinical simulation and the ability to learn to react in a practical setting. The students seem to want more of an instructional approach, though, and less of a dependence on exploration and self-discovery. This is an area where a delicate balancing is required. On the one hand, we do not want to just cave in to the students' search for facts to memorize. The theory is well established that knowledge one discovers and experiences is personalized, whereas memorized facts are soon forgotten. The results of the student usage patterns and cross case knowledge transfer show that the constructivist pedagogy is having some success, plus the self-ratings on the post-test indicate their confidence is increased. On the other hand, the balance of the pre- and post-results show the students aren't learning enough meta-cognitive skills. At best, they discover and integrate only part of the BPSV framework for elderly patient care into their decision structuring processes.

To improve this situation without falling into the fact-memorization pit, we would like to add several meta-cognitive apprenticeship and temporary mental scaffolding features at key points in our environment. For example, we would like to add a meta-cognitive "influencer" lesson they can consult prior to (or during) any case. This influencer would interactively explain the BPSV framework, and point to the teaching objectives of this rotation, including references to the accompanying handout materials. In each case we would also like to add an active meta-cognitive teaching assistant that can explain the case learning objectives and how to achieve them. We would also like this agent to engage the students in two-sided argumentation, challenging them to explain and defend the framework they are using and why.

Once we accomplish these and some automated analysis changes to the software, we expect the results will begin to bear out our current beliefs that self-exploration of computerized microworlds can support medical student experiential knowledge and meta-cognitive decision structuring skills. If we reach this point we should have a teaching and learning tool that can be widely disseminated to support the ongoing clinical training of health care professionals, not just medical students, in the care of a variety of complex patient populations. By replacing the appropriate case and data bases, the Gericase simulator can teach and let students experience the biopsychosocial-values framework in any domain where its relevant (e.g., Aids, terminal cancers, and severe hypertensives), not just geriatrics. That is the larger value of our research.

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