3. Research Strategy

a. Significance

Importance of the Problem. Patients from underserved populations receive a lower quality of healthcare in the United States [3, 4]. These disparities in treatment lead to more deaths and poorer health outcomes among racial and ethnic minorities, rural, low-income, immigrant, and other underserved populations [5, 6, 7, 8, 9]. While social determinants of health can help explain these findings, they do not account for all morbidity and mortality in marginalized communities. A key source of health disparities is physician-patient interactions [4, 10]. Race-related attitudes of healthcare providers play an important role in persistent healthcare disparities [11]. Limited understanding of patients who face economic, cultural, or linguistic barriers can generate negative attitudes and stereotypes which can result in social distancing and animosity, compromising quality of care [12]. Minority patients, especially those not proficient in English, are less likely to engender empathic responses from physicians, receive sufficient information, and participate in medical decision making [13]. Our long-term goal is to develop the first set of interactive virtual patients that accurately represent underserved populations and can be integrated into medical school curricula. These unique virtual patients will include natural communication and reactions to student communication allowing medical students to practice clinical encounters with guidance. Using technology to provide medical students with targeted skill development will improve interactions with underserved patients as future physicians and reduce health disparities.

Physician interactions with underserved patients. Extensive evidence documents the contribution of physician-patient interactions to health disparities. A vicious cycle can develop between physicians and low socioeconomic status patients when a patient's behavior fails to meet physician expectations (e.g., asks few questions) and the physician adjusts their own behavior (e.g., offering less information) [14]. Patients' satisfaction with their physician diminishes as similarity between the two individuals decreases on a series of social statuses (race, gender, age, and education) [15]. Race-discordant relationships, in which physicians treat patients of different races from their own, have less participatory decision-making styles, lower patient satisfaction and less positive patient affect [16, 17, 18]. Both the beliefs physicians have about patients and physician behaviors during encounters are influenced by patient race/ethnicity [19]. While most physicians do not intentionally treat underserved patients differently, automatic cognitive processing can lead to implicit bias (e.g., stereotyping), particularly when physicians have too few cognitive resources available, such as when they are tired or under time pressure [20, 21, 22, 4].

Difficult clinical encounters. Links between physician perceived difficulty of patients and underserved status is a relatively recent area of research [23] which suggests literature on difficult encounters is a source of useful information in developing interventions to improve physician-patient encounters. The structural vulnerability of patient populations, such as poor, medically uninsured, sexually stigmatized, ethnic minorities, persons with disabilities, formerly incarcerated, and persons addicted to drugs, are associated with greater perceived difficulty on the part of physicians and poorer health outcomes [24, 2]. The prevalence of nonadherence is greater in medically underserved, low-income communities [25, 26, 27], and nonadherence is a frequent source of frustration in physicians [28]. These patients often have unmet expectations [29], may be mistrustful [30, 2], and may appear noncompliant [31]. Although physicians often attribute the problem to the patient, ''difficulty'' resides in the interaction between the physician and patient [32, 33, 34] and may be tied to poor strategies used by physicians for coping with difficult encounters. Physicians make more diagnostic errors with patients they perceive as difficult [43, 44, 45]. When patients express negative emotions, physicians tend to withdraw, paradoxically escalating the situation [35]. Patients may generate resentment [36] resulting in physicians inaccurately attributing behavior to defects in personality or willpower [37, 38, 39]. The result may be excessive physician detachment as a self-protection mechanism, a response that negatively affects health outcomes [40]. Physicians may also judge patients' motives and legitimacy of symptoms [41] and may not recognize how their own background can influence patient interactions [42].

Medical education. Medical students have an increasingly negative attitude toward the underserved as they progress in their training [46, 47]. Learners with different backgrounds from their patients may not understand challenges presented by social determinants of disease [28]. Among medical students and residents, higher rates of misconceptions regarding anatomy and physiology based on race were associated with higher degree of racial bias in prescribing analgesics [48]. Our recent study found that 3rd year medical students identified difficult encounters as those with patients who were noncompliant, fearful/worried, or "not interested in their

health" while describing their own feelings as anxious, frustrated, and helpless. They tried to be empathic and patient-centered but often resorted to interview behaviors that were not well-matched to the encounter [49].

To the extent that medical education incorporates training to address disparities the focus has been on improving cultural competence. Early efforts focused on cultural and linguistic barriers framed in terms of race and ethnicity, neglecting the negative health consequences of socioeconomic status that compounds discrimination [29]. The current trend is toward cultural humility [51, 52] which regards the patient as the expert on their cultural identification and the physician as a learner. Medical school curricula increasingly integrate topics like empathy and bias as well as cultural competence [53] and structural competence, which emphasizes societal, systemic forces of racism that undermine healthcare [54]. Unfortunately, clinical medical training often occurs in low-resource environments which is problematic for patients, trainees, and early-career physicians who might feel ill-equipped to handle increased complexities of care [55]. Until standardized methods representing underserved populations are fully present in medical school curricula, students are unlikely to develop the skills needed to manage encounters with underserved patients.

Gaps in existing research. Research on underserved patients examines the roles of class, race, gender and other categories but overall focuses on fixed characteristics, such as race congruence or economic status. Most research has ignored the dynamic nature of the physician-patient relationship and the role of physician experience. In contrast, research on difficult clinical encounters has focused on patient characteristics, such as overutilization and nonadherence, but is only beginning to examine class, race, or underserved status. Theoretical understanding of connections between physician perceptions, patient characteristics, and effective management of difficult encounters is limited. We need more research that links underserved status and physician perceptions of difficult clinical encounters. The proposed project will address this gap, providing an empirical foundation for interactive underserved VPs, and contributing to the theoretical understanding of how patient-physician interactions impact health disparities.

Impact of Proposed Project. The goals of this project are first, to broaden learners' understanding of potentially difficult interactions with underserved patients to help medical students consider elements such as pervasive racism and classism that complicate what they encounter in the clinic so that they can reframe their definition of clinical difficulty, move away from patient blame, and consider it a shared dilemma. Second, we intend to help learners develop self-reflective strategies that can help them manage the emotions of panic, helplessness, frustration and resentment that are often experienced during difficult clinical encounters. Third, our project will assist learners in proactively developing a range of options in responding to such situations that emphasize empathy and out of the box problem-solving in collaboration with the patient – providing these patients with an experience that is more similar to interactions experienced with subjectively easier patients.

Our Phase II vision is an online learning system that incorporates interactive virtual patients (VP) from underserved populations augmented with artificial intelligence so they have natural communication and reactions to student communication which will allow medical students to practice clinical encounters. To promote reflective practice the system will include an automated faculty mentor that observes the medical student-patient interactions, identifies points of difficulty and guides the student to have more productive, collaborative and empathic encounters with the VP. A participatory design approach will be used to collect feedback from patients, medical students and educators once the initial algorithms are complete. The final system will be validated with a controlled, randomized evaluation to demonstrate that it improves students' ability to manage clinical encounters. In order to achieve these goals we will address four specific aims in Phase I. Aim 1 will develop a catalogue of points of difficulty in physician-underserved patient encounters based on medical student essays describing difficult encounters as well as underserved patient comments. The students' patient encounters occurred at an academic medical center serving as a county hospital and with two FQHC with underserved patient populations. The underserved patient comments are drawn from outpatient settings at the same institution. This catalogue will inform theoretical understanding of the patient, student/physician, and situational characteristics related to difficult encounters that include underserved patients and strategies for managing these encounters. Aim 2 will develop the first interactive virtual underserved patient as well as the underlying technology to automatically identify patterns of interaction between patients and students. Aim 3 will develop the prototype website including the VP. For Aim 4 we will work closely with experts at UCI and other interested medical schools (see letters of support) to collect feedback about the effectiveness and realism of the prototype VP system.

Commercialization. The proposed product, an online educational system for medical students to practice interacting with interactive underserved VPs with an automated faculty mentor has very strong commercialization potential because it combines an increasing market need driven by concerns about health disparities along with an existing market for VPs. Medical schools are required to incorporate cultural competency training. To be effective, this training needs to be realistic, high quality, and include individual feedback to encourage self-reflection. However, current options are either resource intensive or lack realism or quality feedback. Standardized patients require too much time and effort: it takes students at UCI two full days to go through just four standardized patient stations and requires faculty time to observe and provide feedback. Role-playing and group instruction are more efficient but lack realism. And many faculty lack the expertise and time to provide individual mentoring. Our product provides a better option for required cultural competency training that improves the quality of education while reducing the cost. Medical schools are our primary market. There are over 140 accredited medical schools in the US (http://lcme.org/directory/accredited-u-s-programs/), with new schools in development [56]. Secondary markets include other health science programs such as medical school residency programs, continuing medical education, nursing and dental programs. Three letters of support demonstrate that medical schools see the need for this product and are interested in using this product once it is available. These letters demonstrate that we are building a product for an existing market with strong growth potential, we understand the market, and we are in a position to reach this market.

b. Innovation

The proposed project will create new technology to give students the opportunity to practice communication with underserved patients, self-reflection, and improvisational problem-solving during clinical encounters. There are four significant innovations in this project:

- Artificial intelligence to provide the interactive virtual patient with natural reactions to students.
- Virtual patients to represent underserved populations.
- Natural language processing algorithms to create an automated faculty mentor that can monitor student-patient interactions, recognize “teaching moments”, and provide relevant guidance and strategies.
- Machine learning technologies to explore large amounts of text and identify patterns of student behavior, patient characteristics, and situations to inform development of a catalogue of difficult clinical encounters.

Virtual patients (VPs). VPs have become relatively common in medical education [57, 58]. The interest in VPs is driven by the potential to address a growing gap in clinical experiences for medical students [59, 60] and problems inherent in using standardized patients: lack of available actors to portray patients with varied backgrounds [61], inconsistency due to actor turnover, and significant costs of simulation center, faculty, and student time. A typical VP is a standardized patient scenario presented with text, images, or video. Some have limited interaction, such as the ability to click on a patient to access a text description of the chief complaint or the ability to select from a list of “canned” questions to receive patient responses. To extend VPs for use in broader education (e.g., communication), researchers have begun trying to add natural language capabilities to enable conversations that are not entirely pre-programmed [62, 63]. Initial testing shows that these VPs do not yet provide realistic encounters [60]. We propose a different approach for developing realistic interactions between students and the VP, using a hybrid of crafted scripts, communication snippets, and limited natural language capabilities. Scripts will guide the interactions into situations associated with difficult encounters and communication snippets will provide the VP with a more authentic patient voice, while the natural language capability will allow the VP to be responsive. Our goal is to give students practice interacting with underserved patients to prepare them for potentially difficult clinical encounters. We do not need the VP to converse on a range of topics, the VP needs only to produce communications that lead down realistic paths typical of difficult encounters with underserved patients. Scripts and snippets will be drawn from student/patient descriptions of clinical encounters and refined with input from experts in underserved patients and patient experience at an FQHC. We have successfully used this approach to simulate NGOs and governmental agency staff in augmented discussion groups for training military personnel to collaborate more effectively [64, 65].

Underserved virtual patients. We plan to develop the first set of VPs designed to represent underserved patients through the Phase I and Phase II efforts. In a review of over a dozen VP trainers on the market there are no examples of VPs designed to simulate interactions with underserved patients. Patient characteristics will be drawn from patients represented in essays written by medical students at UCISOM and patient comments collected from UCISOM, developed with the help of UCISOM’s Clinical Skills Center which has

substantial expertise in developing standardized patients, and reviewed by experts in underserved patient populations to insure that the VPs do not incorporate unintended stereotypes.

Automated faculty mentor. Research on automated tutors for medical students has focused on problem-based learning [66] and provides students with tips on how to proceed [67] but does not promote self-reflection or adaptive use of strategies for managing patients. We will develop an automated mentor that will monitor interactions, identify teaching moments, and offer appropriate suggestions. The automated mentor's comments will be drawn from real medical educator written comments to students to increase authenticity and relevance. We have successfully implemented a similar automated mentor for use in online discussion groups used for educating air force cadets about leadership skills [68]. We plan to develop the automated faculty mentor in Phase II to a) inform the design with faculty feedback received at the end of the Phase I, b) use patient and student feedback collected at the beginning of the Phase II, and c) manage the Phase I scope of work.

Machine learning technologies for "big data". Machine learning technologies are a powerful tool for exploring and analyzing large data sets [69, 70]. These technologies are capable of detecting patterns and similarities that are often difficult or impossible for humans to identify. We propose to use Latent Semantic Analysis (LSA) to analyze the data sets of student essays and patient comments, as well as to support the natural language capabilities of the interactive VP and automated faculty mentor. LSA is a fully automatic machine learning technology which extracts and infers the meaning (semantics) of text in large collections [71, 72]. While LSA is traditionally applied to scoring essay content the use of LSA in this proposal is an innovative application. The proposers have extensive experience creating LSA algorithms for innovative educational applications including medical education [73, 74, 75] and online learning [76]. Newer techniques, including Probabilistic Latent Semantic Analysis (PLSA) and Latent Dirichlet Allocation (LDA), have superseded LSA for some text analysis applications but empirical comparisons shows that the best technique depends on the application. Specifically, LSA is superior for mimicking human assessments of the similarity of texts [77], LDA is more precise in classifying emails, and PLSA has been shown to outperform LSA for indexing documents [78]. LSA and LDA perform similarly in classifying texts [79, 80]. LSA is the best choice for the VP and mentor because we want our system's behavior to mimic human performance and LSA will be used to judge similarity of documents.

c. Approach

In order to manage the scope of work outlined in Phase II, the Phase I effort will complete the foundational research to create a catalogue of difficult clinical encounters involving medical students and underserved patients and develop a prototype of the first interactive virtual underserved patient. This will allow us to make sure the proposed work is reasonable for a Phase I STTR effort while establishing the feasibility of the most technically challenging aspects of this approach and laying the ground work for a successful Phase II.

Tasks for Specific Aim 1: Develop a catalogue of difficult clinical encounters from both medical student and patient perspectives.

1. Create a data set from existing 3rd/4th year medical student essays. Students wrote a reflective essay about a difficult clinical encounter at an academic medical center or FQHC; e.g., , a patient missing an appointment or nonadherence which students perceived as a patient who does not care about her health. The essays include faculty comments provided as student feedback. We have almost 1,000 essays written over a 10 year period. Paper essays will be digitized and essays will have identifiers removed to anonymize students. To ensure enough data for sufficient analysis and manage the scope of work we will use a subset of 500 essays for the Phase I. Milestone: Dataset of essays ready for analysis.
2. Trained coders will code the essays under the supervision of an expert medical educator and an expert in underserved patient populations. Essays will be coded to indicate a) points of difficulty, b) student responses (emotional reactions, instrumental actions toward patients) c) patient characteristics (race, ethnicity, socio-economic status, age), d) chief complaints/diagnoses, e) student characteristics (gender, year), f) patient outcomes (behaviors or communications indicating positive/negative experiences and patient management plans) g) student outcomes as captured by self-evaluation, h) effective strategies for improving a difficult encounter. New codes will be added as needed to ensure that any unexpected topics are included. Agreement between coders will be assessed and improved with additional training to ensure that coders reach agreement of 70% or better. Milestone: Dataset including 500 essays with consistent codes for key information about situations, patients, students, and interactions.

3. Create a data set from patient responses collected using the Press-Ganey national patient satisfaction survey administered to patients at the UCI Health system. Patient comments will be filtered to best match the patients that the medical student essays are about and to increase the probability that patients are from an underserved population. Filters include: patients who saw a physician, have state supplied or no insurance, one of the 5 specialties that all 3rd year students have required rotations in and are outpatients. Comments for this health center include 50% positive comments, however we will request a balanced set with 1/3 each positive, negative and mixed comments. To manage the scope of work for the Phase I we plan to focus on a subset of 500 comments, equivalent to the number of student essays examined. Milestone: Dataset of 500 patient comments ready for analysis.
4. Trained coders will code the patient comments under the supervision of an expert medical educator, an expert in underserved patient populations, and the clinic director of patient experience. Comments will be coded to indicate a) points of difficulty such as cultural, class and structural differences that cause misunderstandings with physicians, b) patient responses, including emotional reactions c) patient characteristics (race, ethnicity, language), d) chief complaints/diagnoses, e) patient outcomes (positive or negative experience as well as patient management plans) and patient perceptions of what constitutes positive interactions. . New codes will be added as needed to ensure that any unexpected topics are included. Agreement between coders will be assessed and improved with additional training to ensure that coders reach agreement of 70% or better. Milestone: Dataset including 500 coded comments with key information about situations, patients, physicians, and interactions.
5. This “big data” task will complement Tasks 2 and 4 by using a machine learning approach to identify patterns in student essays and patient comments. We will examine semantic patterns across essays/comments using unsupervised clustering techniques to find common themes that may not be visible to human reviewers, e.g., difficult encounters that stem from the same cause or patients with similar backgrounds. This data-driven approach will reduce human bias in categorizing. After “clusters” are identified, trained coders will review and identify any similarities that can inform the coding schemes. We will also use machine learning techniques to verify that codes have been applied consistently. Milestone: Candidate groups of essays/comments for comparison to human codes identified in Tasks 2 and 4.
6. Develop a catalogue of difficult clinical encounters with underserved patients. This will include analysis of both student essays and patient comments to identify patterns that lead to difficult clinical encounters including the contributions of situations, patient characteristics, and student/physician characteristics as well as typical patterns of student/physician and patient responses, and situations leading to teachable moments and good strategies for handling situations. Milestone: Catalogue with descriptions of commonly occurring patterns of difficult and positive encounters with underserved patients and associated student/physician responses, patient comments, and outcomes.

Tasks for Specific Aim 2: Develop virtual patient.
7. Develop the patient case including a brief description of the patient along with the presenting complaint, history, symptoms, labs/results, etc. UCI’s Clinical Skills Center, a member of the California Consortium for the Assessment of Clinical Competence with a 35 year history developing standardized patients of diverse backgrounds, will consult on the development of the patient case. Milestone: Complete patient case.
8. Develop database of patient comment snippets. The VP’s interactions with students will be via a website chat window. Patient comments will be automatically selected from a database of comment snippets. These comments will be drawn from actual patient comments (Task 4), edited to be appropriate for interacting with students (e.g., adapted to be conversational), and supplemented with content specific to the patient case (e.g., description of symptoms). The patient voices will be preserved to offer the most authentic communication from the VP. Milestone: Prepared patient comments for the virtual patient.
9. Build the LSA semantic space. The semantic space is a large training set that provides LSA with a full context for evaluating responses. An optimal semantic space requires a minimum of 100,000 paragraphs of relevant text [81]. We have existing collections of text with general medical knowledge we will supplement with student writing, patient comments and text related to underserved patient populations. Note that the semantic space is not a repository of essays, rather it is a background space used to provide necessary general semantics to allow the system to understand the meaning in text. Milestone: Semantic space.
10. Develop two complementary algorithms: 1) automatically understand student communication and 2) automatically select appropriate patient comment snippets (Task 9). The comprehension algorithm will track student comments and identify semantically similar content from student essays to understand the communication. The algorithm will be developed to recognize typical patterns of interaction/situation/patient

characteristics from student writing. Then the comment selection algorithm will use the understanding supplied by the comprehension algorithm to select the appropriate comment(s) from the patient comment database. Because patient encounters proceed in somewhat predictable sequences, information about the order of topics will be used to guide the selection of patient comments (e.g., describe chief complaint, then history). Note that these algorithms will be validated in the Phase II using the completed prototype to allow us to demonstrate the algorithms in a realistic context and receive more relevant feedback from patients, students, and faculty. The algorithms will be updated based on this feedback. Milestone: A comprehension algorithm and a comment selection algorithm to automatically select VP comments.

Tasks for Specific Aim 3: Develop prototype learning system.

11. Design a website that will combine the patient case, databases of comments and comprehension and selection algorithms. The design will use visual cues to create a relevant context for interacting with the VP such as a stylized image of an exam room and patient. The design will also include standard elements for interaction including a chat window and windows for displaying labs or other medical information. The design will include an area for the addition of a faculty mentor in Phase II. Milestone: Website design.
12. Develop the website. This task includes building the actual website as well as connecting the algorithms with the databases and user interface. In addition standard website functionality will be included, such as logins. Milestone: Website incorporating the interactive VP, ready for feedback and Phase II testing.

Tasks for Specific Aim 4: Feedback from experts at UCI and other medical schools.

13. Submit the catalogue of difficult clinical encounters from both patient and medical student perspectives to thorough review from experts at UCI in medical education, health disparities, marginalized populations and patient experience. Note that reviews with UCI experts will happen throughout the process, not just at the end. In addition, the catalogue will be shared with the medical schools who provided letters of support along with a request for feedback. Feedback provided by all reviewers will be used to make updates to the catalogue of difficult encounters. Milestone: Updated catalogue incorporating expert feedback.
14. The prototype website will be shared with UCI experts as well as other medical schools. Reviewers will be asked to complete a short survey about the realism and representativeness of the VP, patient case, and interactions, along with any other feedback. Reviewer responses will be used to develop additional requirements for the VP website to be implemented at the beginning of a Phase II work effort. Note that comprehensive patient feedback, along with student feedback, will be collected at the beginning of Phase II. Milestone: Requirements for the virtual patient website.
15. **Final report.**

Each task will be handled by the team member(s) with the appropriate expertise, as shown in the table below.

Task	**Required Expertise**	**Team**	**Schedule**
1. Med student data set	Medical education, behavioral science	UCISOM	Mo 1-2
2. Code essays	Med ed, behavioral science, underserved patients	UCISOM, PC	Mo 3-6
3. Patient comment data	Med education, behavioral science	UCISOM	Mo 1-2
4. Code comments	Med ed, behavioral science, underserved patients	UCISOM, PC	Mo 3-6
5. Text analysis	Latent Semantic Analysis (LSA), Med ed	PC, UCISOM	Mo 3-6
6. Develop catalogue	Med ed, behavioral science, underserved patients	UCISOM	Mo 7-8
7. Patient case	Med ed, underserved patients, standardized patients	UCISOM	Mo 6-7
8. Patient database	LSA, Med ed, underserved patients	PC, UCISOM	Mo 6-8
9. Semantic space	LSA, Med ed	PC, UCISOM	Mo 1-3
10. Algorithms for VP	LSA	PC	Mo 6-8
11. Design website	User interface design	PC	Mo 7-9
12. Implement website	Web development	PC	Mo 9-11
13. Catalogue review	Med ed, patient experience, underserved patients	UCISOM, PC	Mo 9-10

14. VP review	Med ed, patient experience, underserved patients	UCISOM, PC	Mo 11
15. Final report	All aspects of the project	Entire team	Mo 12

To mitigate areas of potentially high risk in this project we will hold review meetings following critical milestones: a) development of catalogue of difficult encounters, b) development of VP, and c) review and feedback on catalogue and VP. The reviews will allow the team to discuss any unexpected challenges, clearly define the problems and determine potential solutions or changes in direction.