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Regular Article

Linking the social determinants of health and disease process using concept mapping in pre-clerkship problem-based learning courses: a pilot study

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A B S T R A C T

The Social Determinants of Health significantly impact patient care, and understanding their role in the disease process and patient management is essential to high-quality healthcare. Several barriers exist to integrating social determinants of health into medical curricula, including the lack of consensus on evidence-based teaching methods. In this context, our study investigated the impact of integrating social determinants of health into pre-clerkship problem-based learning courses using concept mapping on the clinical problem-solving process. Fourteen pre-clerkship medical students voluntarily participated and were randomly assigned to control and experimental groups. The experimental group education intervention included two problem-based cases with social determinants of health-informed probes to promote linking those determinants to the disease process and develop a treatment plan using concept mapping. The control group participated in the same cases without the education intervention. Students in both groups completed post-session assignments that included two new cases, individual concept maps, and recorded reflections. Concept maps were scored using a scoring rubric. The scores of both groups were compared using the Mann-Whitney *U* test. Recorded reflections and concept maps were analyzed using reflexive thematic analysis coding method. Quantitative data analysis showed that the experimental group received significantly higher scores than the control group. Qualitative data analysis highlighted substantial differences in clinical problem-solving approaches. The control group's clinical reasoning approach focused mainly on the clinical aspects of the case. The experimental group followed a social determinants of health-informed clinical reasoning approach to patient-centered treatment plans with balanced therapeutic/nontherapeutic elements.

Keywords: Holistic patient care, Medical education, Patient-centered care, Pre-clerkship

Introduction

The social determinants of health (SDOH) are defined by Healthy People 2030—a data-driven public health initiative to identify priorities for health and well-being in the United States—as the conditions in which people are born, live, learn, work, play, worship, and age that affect a wide range of healthcare outcomes and quality of life.[1] The SDOH comprise five main domains: economic stability, education access and quality, health care access and quality, neighborhood and built environment, and social and community context.[1] The World Health Organization estimates that SDOH accounts for 30–50% of health outcomes, independent of healthcare and lifestyle choices, emphasizing the value of integration of SDOH into healthcare practice.[2] Despite the increased recognition of the importance of SDOH integration into the medical curriculum, there is no guidance on evidence-based instructional strategies and assessment tools for teaching SDOH and evaluating the impact of SDOH integration into curricula on students' performance.[3] The American Medical Association's Accelerating Change in Medical Education Consortium identified several barriers to integrating SDOH into the medical curricula. The top two barriers to teaching SDOH were the "lack of space for new concepts" such as SDOH and "the lack of skilled faculty" who are competent in delivering and assessing the SDOH content.[4]

The medical education program at Carle Illinois College of Medicine (CI MED) at the University of Illinois, Urbana-Champaign, aims to train medical students to be physician innovators by engaging students in linking primary care practice and healthcare innovation. The CI MED curriculum is structured around organ system courses, integrating basic, clinical, and engineering/innovation sciences in each course. Problem-based learning (PBL) sessions are the foundational instructional approach used at CI MED. In PBL sessions, small groups discuss and explore clinical scenarios to identify and learn basic science, clinical science, and engineering science concepts to develop a differential diagnosis, final diagnosis, and a treatment plan for the studied case.

Concept mapping is a tool that helps learners illustrate and structure knowledge by providing a graphical representation of the links and connections of concepts and ideas in various domains.[5] Concept maps are composed of concepts, connecting lines, and examples that elucidate the meaning of these concepts.[6,7] Concepts are presented in circles or boxes

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and linked by lines. Usually, concepts are presented on the map following a hierarchical order where the primary or most general concepts are at the top, moving to the most specific ones at the bottom of the map.[7] Another component of concept maps is the cross-links; these are lines on the map that represent the connections between concepts within the same concept's main category or across different concept categories/domains of the map. Concept mapping is an evidence-based tool with proven utility in both teaching/learning and assessment in medical and health professions' education.[6,8–10]

To address the challenges associated with integrating SDOH into medical curricula, we sought to incorporate the SDOH framework (as described above) in the existing PBL sessions using concept maps as an evidence-based instructional/assessment tool, as well as SDOH-specific discussion probes. This research study aims to investigate whether this educational intervention improves the clinical decision-making ability of pre-clerkship students to provide patient-centered care.

Materials and methods

Study subjects and design

Using a protocol approved by the University of Illinois-Urbana-Champaign Institutional Review Board, all first-year medical students (N = 49) during the academic year of 2021–2022 were invited to participate in this voluntary study with informed consent required. A total of 14 students agreed to participate. Participants were randomly distributed into one control group and one experimental group. (N = 7/group). Students in both groups received concept mapping training before the educational intervention. Fig. 1 illustrates the study design and implementation.

Study context and intervention

The school adopted PBL as the primary instructional method in the integrated organ system–based medical curriculum during the pre-clerkship courses. In PBL, student groups with faculty facilitation analyze a clinical case problem relevant to basic and clinical science topics addressed in the organ system course. During the PBL session, students gradually unfold a clinical case scenario following a systematic approach that starts with the chief complaint, followed by the history of present illness, other histories (e.g. medications, past illnesses, social), work-up of the case (e.g. imaging, laboratory findings), and treatment. As the students navigate the case, faculty facilitators ask students certain questions (i.e., probes) that mainly address concepts of foundational (i.e. basic) science disciplines and clinical concepts. Students actively search for answers to the probing questions during the session to discuss as a group, and they also can decide to designate certain topics they want to learn about in-depth as "learning issues." Outside the PBL session, students will research these "learning issues" using different scholarly resources, which they then explain to their peers in the next PBL session via a brief PowerPoint presentation.

The current study investigated the effect of a novel educational intervention that links SDOH to the disease process using concept mapping and specific SDOH probing questions on students' ability to design a patient-centered treatment plan that is SDOH mindful. This educational intervention was implemented as part of two PBL cases, with one during the "Digestion, Nutrition, Metabolism" course and the second during the "Endocrine, Genitourinary, and Women's Health" course. Student participants in the experimental and control groups were given a training session on concept mapping before the implementation. At the time of implementation, students in the control group completed the PBL case without curricular intervention. The probing questions for the control group were those already written as part of the regular PBL curriculum at CI MED. These questions mainly address the foundational and clinical concepts of the case and the disease process. One pre-existing SDOH probe was associated with each of the PBL cases used in this study. However, the probe didn't link SDOH to the disease process (Table 1).

Students in the experimental group were prompted by the same probing questions as the control and with an additional set of probes that specifically linked SDOH to the disease process. Examples of these SDOH

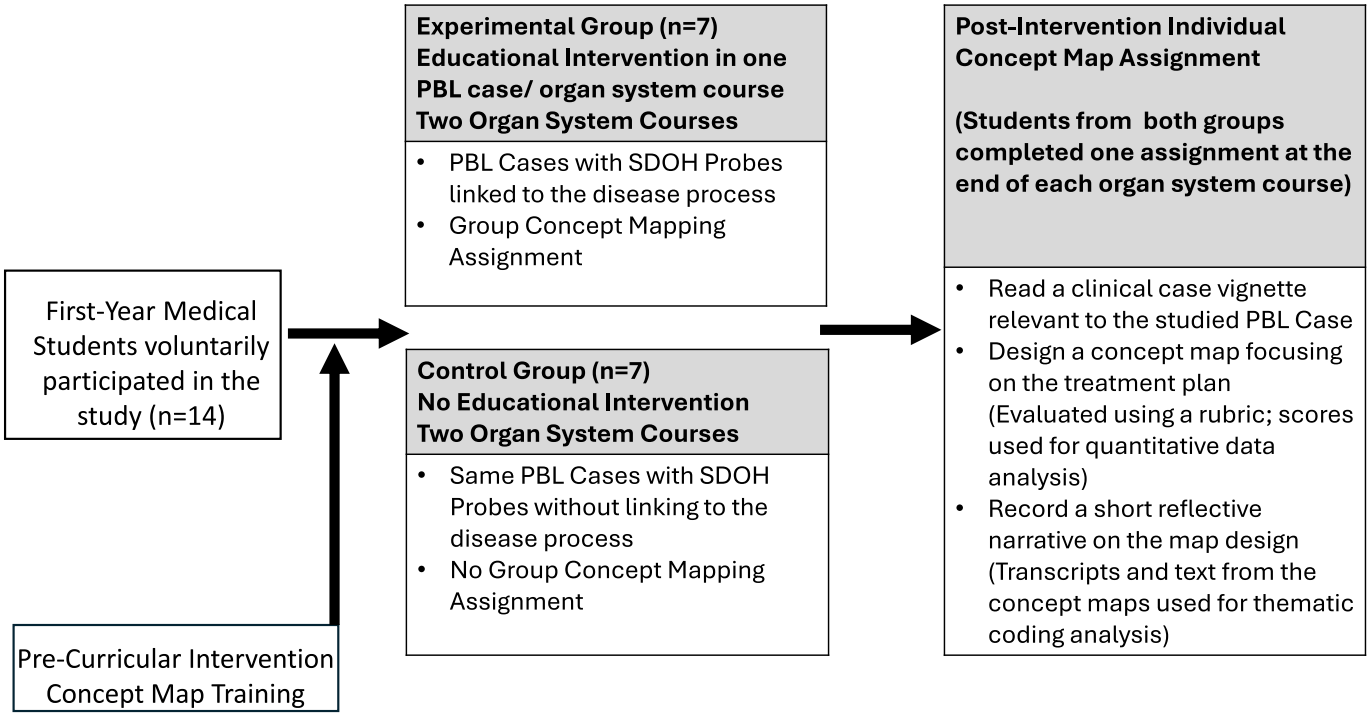

Fig. 1. Overview of the Participants and Study Design. An outline of the study design, including targeted population, pre-intervention training, description of the curricular implementation for the control and experimental groups, and post-intervention assessments. PBL: problem-based learning; SDOH: social determinants of health.

Table 1
Differences in SDOH Probes between Control and Experimental Groups.

Liver cirrhosis case	**Control group**: • Why is social history pertinent to liver disease and what may be missing from this history? **Experimental group**: • What kind of healthcare access do people in the military have? • How does being in the military increase his risk of alcohol and smoking misuse? • How do these notations indicate the racial aspect of medicine and the stigmatization of liver disease in specific populations? (linked to accessibility through equity). • What SDOH can you specifically identify for this patient, and how are they linked to the main SDOH categories? • What are the vaccination requirements for military people? • You identified smoking and alcohol misuse as factors related to the SDOH category "Social and Community Context." Can you explain the potential mechanisms of liver disease induced by cigarette smoking? Mainly focus on fatty liver, hepatic fibrosis, and hepatocellular carcinoma. • Explain the potential mechanisms of liver disease induced by alcohol misuse. • What would be your approach to discussing smoking cessation, and when do you address this conversation? • Given the patient's limited interaction with the HCV virus, how would you approach this issue and increase the patient's understanding of transmission and the need to test applicable family members? • He is not a drug user. What are the social stigmas associated with the presentation of HCV or a similar virus? • What are some of the broader lifestyle complications or limitations a patient might experience with liver cirrhosis? How do you care for this patient holistically? –Give their risk of other infections, the potential problems of the disease, etc. • What is your plan or approach for your patient's longitudinal care, considering all the associated SDOH? • Design a concept map demonstrating how the identified SDOH of the case, directly and indirectly, contribute to the pathogenesis of the patient's condition. In your design, include a treatment plan for this patient that considers relevant SDOH.
Breast cancer case	**Control group:** • What other factors besides ***family history*** increase the risk of breast cancer? o Age of menarche o Age of menopause o Hormonal use (contraception or hormonal replacement therapy) o No breastfeeding o Smoking[a] o Later age at first childbirth **Experimental group:** • What other factors from the patient's ***social history*** increase the risk for breast cancer? • You identified smoking as one of the factors related to the SDOH category "social and community context." Can you explain the mechanism by which smoking contributes to the pathogenesis of breast cancer? • Can you explain how each of the other factors from the patient's social history contributes to the pathogenesis of breast cancer? • What are some of the physiological and psychological benefits of breastfeeding? What are some of the breastfeeding and race-based stereotypes that exist for new mothers? How could those ideas impact one's engagement with their patient? (e.g., the extent of the care that is assumed or provided) • How does maternal mortality differ by race? Why is this significant? What socio-historical and SDOH inform this disparity? • Can men get breast cancer? What are the rates of male breast cancer in the United States? How would you counsel a male patient in this regard? • Other than routine mammography, what other modalities can be used for screening/early detection of a breast lump? • What SDOH factors hinder screening and early detection of a breast mass? • The patient has been prescribed ttrastuzumab (Herceptin). What is the average cost of this medication? How is the patient's accessibility to this medication factored into treatment decisions? How would this affect the patient's prognosis? • Design a concept map demonstrating how the identified SDOH of the case contribute directly and indirectly to the pathogenesis of the patient's condition. In your design, include a treatment plan for this patient that considers relevant SDOH.

Examples of SDOH-related probes used in PBL cases for control and experimental groups. Only one pre-existing probe addresses SDOH in each PBL case used for the control group. These probes didn't link SDOH to disease pathogenesis or treatment. HCV: hepatitis C virus; PBL: problem-based learning; SDOH: social determinants of health.

[a] Although smoking was provided in the probing question for the control group in the breast cancer case to stimulate discussion about its role in breast cancer, the probe didn't link smoking to SDOH.

probes are summarized in Table 1. Additionally, students in the experimental group were prompted to design a group concept map demonstrating how the identified SDOH of the case, directly and indirectly, contributed to the pathogenesis and the treatment options of the patient's condition. This group assignment allowed students to integrate all the learned concepts (basic science, clinical, medical humanities, and SDOH) relevant to the case. Students received formative feedback from the PBL facilitator on their concept map design. The experimental group completed one group concept map in each PBL case where the intervention was implemented.

Post-educational intervention assessment

At the end of each course, students from both control and experimental groups were asked to complete an assignment relevant to a newly written clinical case vignette. Briefly, students were provided with a new clinical case vignette at the end of each course, which was comparable to the ones they experienced during PBL sessions. After reading the vignette, each student was instructed to design their own concept map, focusing on the treatment plan for the patient in the clinical vignette. They were prompted to use all the relevant information from the vignette that is applicable in the treatment plan. Students had the option to create their concept maps using paper and pencil or any software tool. Moreover, they were asked to provide an audio recording of a reflective narrative explaining their thought process and concept map design. Collected students' assignments were de-identified and used for evaluation/data analysis as detailed below.

A. Concept Map Scoring, Validation, and Statistical Analysis

To assess the qualities of individual student concept maps, we created a scoring rubric based on Novak and Gowin's method.[5] All faculty

authors with expertise in clinical, basic science, and medical humanities engaged in a discussion to determine the key concepts that should be addressed by students in their concept maps relevant to the patient case diagnosis and treatment plan and linkages to the SDOH framework as part of the case analysis. A consensus was reached on using the following as the main rubric categories: organization and design, connections and links within and between concepts, linkages to SDOH framework categories, disease process analysis, and treatment plan development. The scoring rubric is presented in Table 2.

Validation of the concept map scoring rubric included a multistep process. To ensure rater agreement in interpreting the scoring rubric categories, three raters independently scored four randomly selected individual student concept maps. After comparing the raters' scores, the rubric categories and language were further refined iteratively as part of this initial process. The three raters independently scored each experimental and control group's individual student concept maps. Interrater reliability statistics were conducted to validate the developed rubric using the Fleiss kappa test and the Kappa interpretation following the Landis & Koch criteria.[11] The mean scores for control and experimental groups were calculated and compared using the independent sample, nonparametric Mann-Whitney *U* test to evaluate whether control and experimental groups differed in the various categories of the concept map scoring rubric. We used the IBM SPSS software version 28.0.1.

B. Concept Map Transcripts, Thematic Coding, and Analysis

Student-recorded reflective narratives, converted into transcripts and concept maps, were used as complementary artifacts of each student's concept map creation process for qualitative analysis.[12,13] While concept map transcripts provided a verbal description of the concept map development as students worked through each case, the actual concept maps offered a visual and text representation of case analysis using concept maps.

The reflexive thematic analysis method was used to code transcripts.[14] In reflective thematic analysis, the subjective position of those carrying out coding informs the interpretation of the meaning and the creation of coding categories and themes. Qualitative data analysis software, NVivo versions 13 and 14, was used for transcript coding and code organization. Three coders (K.M., B.M., and S.H.) worked as a group to create initial codes and then iteratively reviewed transcripts to revise and group codes into final themes. Each student concept map was then coded using coding categories developed from transcript coding. Final code counts were calculated, and code counts of the experimental and control groups were compared.

Results

Post-education intervention individual concept map scores: experimental group concept map scores were statistically significantly higher than control group concept map scores

Examples of individual concept maps created by the control group and experimental group participants as part of the post-education intervention concept map assignment are presented in Figs. 2 and 3, respectively. The total number of submitted concept map designs as part of post-intervention individual concept map assignment is summarized in Table 3. In total, 11 control group and 14 experimental group concept maps were scored using the concept map scoring rubric by three

Table 2
Concept Map Evaluation Rubric.

	Category	3 Points/bullet	2 Points/bullet	1 Point/bullet	0 Point
Organization and design (3 marks)	General organization	• Logical and easy to follow	• mostly easy to follow	• somewhat incoherent	N/A
Connections and links (3 marks, averaged)	Connections and links between primary categories and subordinate elements[a]	• All elements are accurately connected to the main categories • All linkages between elements are present • Reasoning of element linkages is present	• Most elements are accurately connected to the main categories • There is some linkage between elements • Some reasonings between element linkages are missing	• Few elements are connected to the main categories • There is no linkage between elements • There is no reasoning for linkages	N/A
SDOH (9 marks total, 3 marks each)	Main SDOH categories[b]	4-5 categories	2-3 categories	1 category	No categories mentioned
	Providing examples of main SDOH categories	4+ example	2-3 example	1 example	No examples mentioned
	Linking the example to the main SDOH category	4+ links	2-3 links	1 link	No links mentioned
Disease process (9 marks total, 3 marks each)	General disease process	All contributing factors in disease mechanisms are listed	Some contributing factors in disease mechanisms are listed	Contributing factors in disease mechanisms are mentioned incorrectly	No contributing factors in disease mechanism are mentioned
	Disease process mechanism explained	Full details of the correct mechanism are explained	Some details of the correct mechanism are explained	Mechanisms are explained incorrectly	No mechanism explanations are included
	Disease process linked back to SDOH examples of the case	4+ examples	2-3 examples	1 example	No examples
Treatment plan (6 marks total, 3 marks each)	General treatment plan[c]	The plan is correct and comprehensive, including both therapeutic and nontherapeutic treatment options	The plan is missing some elements from any of the therapeutic/ nontherapeutic options	The plan is only therapeutic	Plan is incorrect
	Plan linked back to the SDOH examples of the case	4+ examples	2-3 examples	1 example	No examples

SDOH: social determinants of health.

[a] Primary categories include, but are not limited to, patient history, diagnosis, pathology (pathogenesis, pathophysiology), and treatment. Subordinate elements include concepts from the vignette relevant to the main categories (e.g. risk factors, disease mechanism, diagnostic tests, clinical presentation, etc.).

[b] The main SDOH categories are social and community context, healthcare access and quality, neighborhood and built environment, education access and quality, and economic stability as defined by Healthy People 2030.

[c] Therapeutic: procedural, medication, and rehabilitation interventions. Nontherapeutic: patient lifestyle modifications and emotional well-being interventions.

Fig. 2. An Example of an Individual Concept Map: Control Group. This is an example of an individual concept map designed by one of the control group students as part of the post-intervention assignment. The concept map shows the integrated concepts related to the treatment plan for "liver cirrhosis" as one of the differentials of a clinical vignette provided to students at the end of the Digestion, Nutrition and Metabolism course. Note the absence of the SDOH framework. The treatment plan mainly focuses on therapeutic options and definitive treatment. The nontherapeutic options are limited to alcohol and tobacco cessation without contextualizing these within the SDOH framework. SDOH: social determinants of health.

independent raters. The mean scores were calculated for each rubric category and element (Table 4). The Mann-Whitney *U* test compared the experimental group and control group mean scores and revealed statistically significantly higher mean scores for the experimental group than for the control group for three of the four main rubric categories. These categories are as follows: overall concept map organization and design (experimental group mean score = 3.0, control group mean score = 2.7, z = 846, $P = 0.004$), quality of connections and links among disease, SDOH and treatment concept map elements (experimental group mean score 3.0, control group mean score = 2.7, z = 882, $P = 0.001$), quality of SDOH concepts and links (experimental group mean score = 5.5, control group mean score = 2.7, z = 1150, $P < 0.001$), and quality of treatment plan concepts and links (experimental group mean score 5.3, control group mean score 3.2, z = 1219, $P = 0.001$). There was no statistically significant difference between the control and experimental groups for the concept map rubric category of quality of disease process concepts and links (experimental group mean score 5.6, control group mean score 3.9, z = 863, $P = 0.065$). The total score for the four major categories was calculated as a sum, and groups were compared. The total score for the major categories for the experimental group was 22.3 out of 30 points, and the control group's mean score was 14.8 out of 30 points. The mean score differences were significantly higher for the experimental group than the control group (z = 1113, $P < 0.001$).

Interrater reliability of the concept map assessment tool

The Fleiss Kappa statistical test was used to validate the concept map scoring rubric. The test results show that there was moderate agreement among raters (Fleiss Kappa: $\kappa = 0.324$ (95% confidence interval [CI], 0.271 to 0.377), $P < 0.0005$).

Reflexive thematic analysis of concept maps: experimental group followed an SDOH mindful clinical reasoning process for designing a patient-centered treatment plan compared with a more clinically focused plan by the control group

Post-education intervention concept maps and reflective narratives of concept maps in transcript format were used as artifacts of students' concept map creation process. For the post-intervention assignment in the Digestion, Nutrition, and Metabolism course and Women's Health course, the total number of recorded reflective narratives received from both groups is summarized in Table 3. A total of N = 7 control group and N = 12 experimental group transcripts were coded. For the concept maps submitted without reflective narratives, text from the map was used in the coding process for the control group (n = 4) and the experimental group (n = 2). The overall number of items used for thematic coding

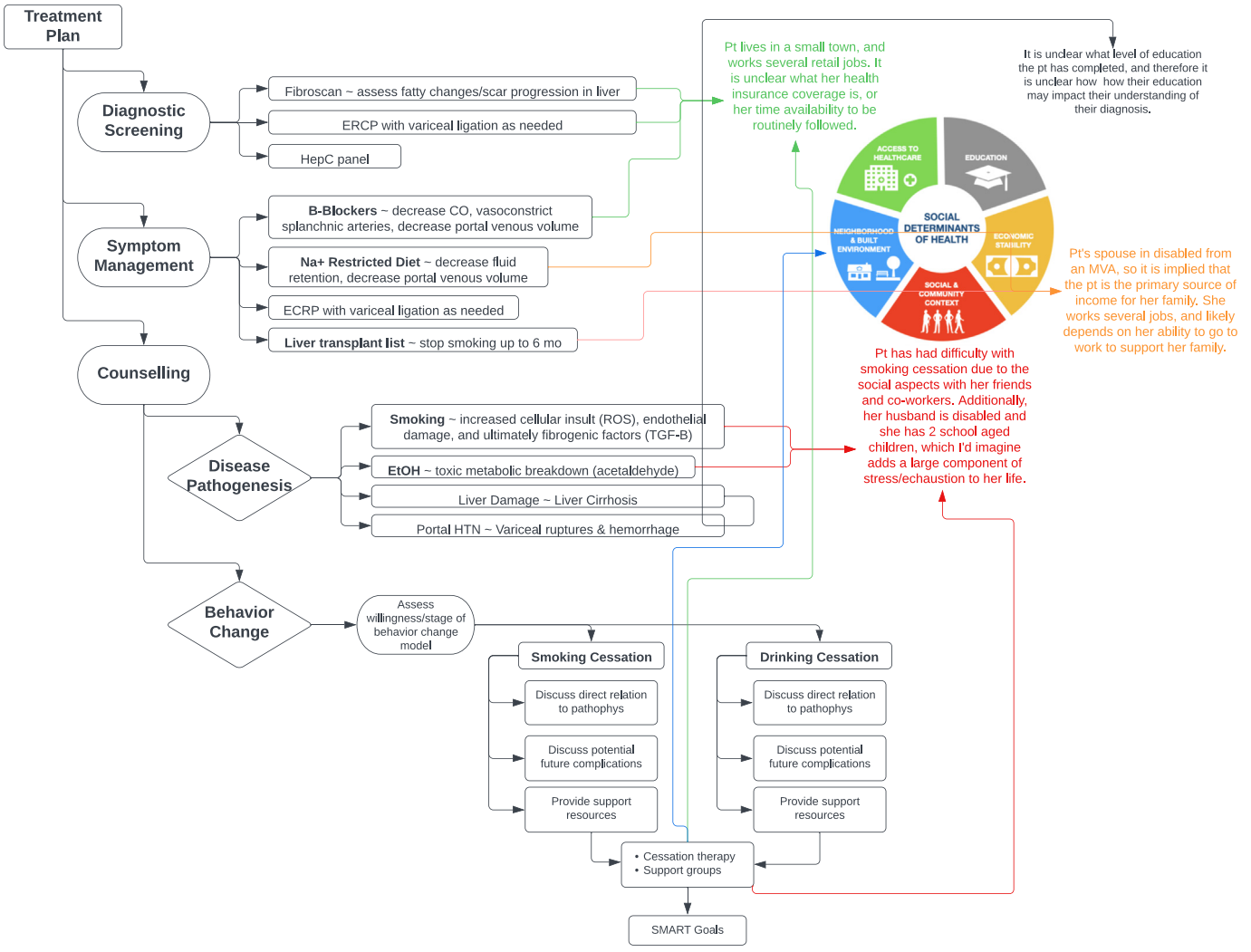

Fig. 3. An Example of an Individual Concept Map: Experimental Group. This is an example of an individual concept map designed by one of the experimental group students as part of the post-intervention assignment. The concept map shows the integrated concepts related to the treatment plan for "liver cirrhosis" as one of the differentials of a clinical vignette provided to students at the end of the Digestion, Nutrition and Metabolism course. Note the complexity of the map and that the map design is highly informed and rationalized by the SDOH framework. The treatment plan is more comprehensive, with balanced therapeutic, nontherapeutic, and definitive treatment options. All treatment options are contextualized within the SDOH framework. SDOH: social determinants of health.

analyses is (n = 11) for the control group and (n = 14) for the experimental group (Table 5).

Reflexive thematic analysis of the transcripts and concept maps revealed 14 codes categorized into three main themes: 1) framing the patient condition, 2) clinical reasoning for disease diagnosis, and 3) clinical reasoning for a treatment plan (Table 5). The primary themes align with major clinical problem-solving steps of an overall review of patient care, clinical diagnosis, and treatment plan. The codes for each theme reflect each student's clinical problem-solving process and approaches to linking clinical and patient information with the SDOH framework at each step. Code explanations highlight key differences in the degree to which students employed SDOH-informed clinical reasoning in their problem-solving process and the development of the final treatment plan (Table 5). A quote from students' transcripts is provided as a representative example for each code.

In general, experimental group concept maps and transcripts revealed significantly greater links between patient and clinical information and the full SDOH framework at each clinical problem-solving step than the control group, which only linked one or two SDOH elements in problem-solving. For example, in framing the patient's condition, 79% of the experimental group linked the full SDOH framework (code: "SDOH Mindful") compared with 9% of the control group. Thirty-six percent of the control group linked just one or two SDOH elements (code: "SDOH Example") in framing the patient case compared with 7% of the experimental group. No difference between groups was found in the codes "Disease Pathogenesis" (55% from control group vs. 50% from experimental group) and "Diagnostic Plan" (27% from control group vs. 21% from experimental group) related to the theme "Clinical Reasoning for Diagnosis." The greatest difference between the codes for the "Clinical Reasoning for Diagnosis" theme was in relation to the degree of SDOH-informed or SDOH Mindful reasoning as part of this clinical problem-solving step. Seventy-one percent of the experimental group used the SDOH framework to rationalize specific clinical diagnoses of the patient's clinical condition in an iterative process compared with 18% of the control group. In addition, 100% of the experimental group developed treatment plans that included both therapeutic and nontherapeutic options compared with the control group. While 91% of the control group included therapeutic treatment options, only 45% of the same group included nontherapeutic treatment options.

Discussion

Health inequities seen in the United States are deemed to be primarily impacted by SDOH.[15] Healthy People 2030 has devoted an overarching

Table 3
Summary of the Number of Concept Map Assignments and Reflective Narratives Submitted in the Two Courses by Control and Experimental Groups of Students.

Course/PBL Case	Control group: concept maps (N)	Experimental group: concept maps (N)	Control group: reflective narratives (N)	Experimental group: reflective narratives (N)
Digestion, nutrition, and mmetabolism (liver cirrhosis)	6	7	4	5
Endocrine, genitourinary, and Women's health (breast cancer)	5	7	3	7
Total	11	14	7	12

The total number of submitted reflective narratives from the control groups was seven. Therefore, four concept maps didn't have corresponding reflective narratives. The total number of submitted reflective narratives in the experimental group was 12; thus, 2 concept maps didn't have corresponding reflective narratives. For the concept maps submitted without reflective narratives, text from the map was used in the coding process. The overall number of items used for thematic coding analyses is (n = 11) for the control group and (n = 14) for the experimental group.

Table 4
Comparison of Experimental and Control Group Concept Map Mean Scores Using Scoring Rubric and Mann-Whitney *U* Test Results.

Main Scoring Category	Concept map scoring element (maximum score for element)	Control	ExperimentaL	Mann–Whitney *U* test results
		Mean score (N = 11 maps, 3 raters)	Mean score (N = 14 maps, 3 raters)	z, *P*
Concept map overall organization and design	Logic & flow (3)	2.7	3.0	846, 0.004
	Organization: Total score	2.7	3.0	846, 0.004
Quality of connections among disease, SDOH, and treatment concepts	All elements are accurately connected to the main categories (3)	2.7	3.0	840, 0.002
	All linkages between elements are present (3)	2.7	3.0	840, 0.001
	Reasoning of element linkages is present (3)	2.6	3.0	882, 0.001
	Connections: Total score (calculated average, max possible score = 3)	2.7	3.0	882, <0.001
Quality of SDOH concepts and links	Main SDOH categories (3)	0.3	1.4	984, <0.001
	Providing examples (3)	1.9	2.8	1055, <0.001
	Linking examples to main category (3)	0.2	1.4	970, <0.001
	SDOH: Total score (calculated sum, max possible score = 9)	2.5	5.5	1150, <0.001
Quality of disease process concepts and links	General disease process (3)	1.4	2.2	912, 0.013
	Disease process explained (3)	1.2	1.1	666, 0.749
	Disease process tied back to SDOH examples of the case (3)	1.2	2.2	1006, <0.001
	Disease process: Total score (calculated sum, max possible score = 9)	3.9	5.6	863, 0.065
Quality of treatment plan concepts and links	General treatment plan (3)	1.9	2.7	1071, <0.001
	Plan tied back to SDOH examples of the case (3)	1.4	2.6	1032, <0.001
	Treatment plan: Total score (calculated sum, max possible score = 6)	3.2	5.3	1219, <0.001
Total all	**Total score major categories (calculated sum, max possible score = 27)**	14.8	22.3	1113, <0.001

Data are presented as mean scores for each category/subcategory. SDOH: social determinants of health.

goal to SDOH, explicitly aiming to "create social, physical, and economic environments that promote attaining the full potential for health and well-being for all."[1] Reducing health disparity is a multidimensional process requiring change within all societal levels to address the SDOH.[15] Considering SDOH throughout the clinical decision-making process allows the healthcare team to determine critical contributors to the disease without isolating them from pathogenesis. This would result in higher-quality patient-centered care tailored to patients' needs based on the associated SDOH.

Due to the well-recognized and crucial role of SDOH in health outcomes and population health, there is an increasing emphasis on its importance in medical education. However, the earlier integration of SDOH in medical training has not yet been addressed or researched. Moreover, as discussed earlier, there are several barriers to integrating SDOH into medical curricula.[4]

We hypothesized that integrating the SDOH into medical curricula starting as early as the pre-clerkship courses allows students to develop critical clinical competencies early in their training. This integration will create significant opportunities for these future healthcare providers to be trained to apply a holistic approach to patient-centered healthcare as they advocate for treatment options that mitigate the SDOH impact on disease pathogenesis and quality of care.

Since PBL is the core instructional strategy in the CI MED curriculum and to overcome challenges associated with a lack of space/time to introduce new concepts, we sought to integrate the SDOH framework in the already existing PBL sessions in the pre-clerkship organ system courses. However, since group discussions are the basis of learning through PBL and are highly variable based on group dynamics, student discussions addressing SDOH factors in clinical cases are variable. This variability hinders students' ability to master the identification of relationships between SDOH and other aspects of the studied patient condition, including clinical diagnosis and treatment. Therefore, in this study, we sought to use concept mapping and SDOH-specific probes to intentionally integrate the SDOH framework and its concepts into PBL sessions. Intentional SDOH integration into PBL sessions where pre-clerkship students are in the early stages of developing problem-solving skills is hypothesized to create a foundational understanding of the framework. To test this hypothesis, we also used the concept mapping tool to assess the impact of this integration on students' ability to solve a clinical case problem by designing a patient-centered treatment plan.

Based on the results presented earlier, this innovative use of concept maps in this study helped increase our understanding of how each medical student interpreted and navigated the clinical scenario given in the post-intervention assignment at the end of each course. Our concept maps evaluations revealed that students in the experimental and control groups designed individual concept maps with variable emphasis on SDOH and disease pathogenesis. The total average concept map scores for the experimental group were significantly higher than that of the control group (Table 4). This suggests that our educational intervention positively impacted students' ability to build connections among SDOH concepts, disease processes, and treatment plans. The presence of no significant differences in concept map scores between both groups in the

Table 5
Reflective Thematic Analysis Results: Major Themes, Codes, and Coding Frequencies.

Major Themes	Relevant codes and code explanations	Control (N = 11)	Experimental (N = 14)
		Percent of concept maps/narratives showing link to code	Percent of concept maps/narratives showing link to code
Framing the patient's condition	**SDOH mindful** The student used both the SDOH framework (i.e. main categories and relevant examples) and clinical information to outline the patient's clinical condition in an iterative process, demonstrating an understanding of the role of SDOH in the patient's clinical presentation. ***Example quote:*** *"We're going to focus on not only the treatment plan but also the various social determinants of health that go into making sure that the patient is endurant with their treatment plan and has access to the right resources for their treatment plan."*	9%	79%
	SDOH example The student mainly used vignette clinical information to outline the patient's condition, mentioning limited SDOH examples (e.g. alcohol use, and smoking) without further integrating the SDOH framework and demonstrating its role in the patient's clinical presentation. ***Example quote:*** *"I decided to start with social determinants of stress, occupation, family, IV drug use, tobacco, alcohol, diet, and exercise given in the vignette."*	36%	7%
	Differential options The student used differential options based on vignette clinical information to outline the patient's condition. ***Example quote:*** *"I focused on three major clinical conditions that I thought could be at play here."*	27%	14%
Clinical reasoning for diagnosis	**Differential diagnosis** The student explained differential diagnosis options and provided a rationalized discussion of reasoning for specific diagnoses of the patient's clinical condition. ***Example quote:*** *"In the center, I've got liver cirrhosis, which is one of my differentials for this patient. And then what's feeding into this differential is the etiologies that can cause this disease."*	36%	14%
	Disease pathogenesis The student discussed mechanisms of disease pathogenesis leading to a specific diagnosis or differential diagnosis of a patient's clinical condition. ***Example quote:*** *"NSAIDs do inhibit COX1, which decreases PGE1. We also have excess NADH production by alcohol dehydrogenase to metabolize her alcohol consumption."*	55%	50%
	Diagnostic plan The student discussed diagnostic options to reach a specific diagnosis of the patient's clinical conditions, including those in the vignette or additional ones. ***Example quote:*** *"I thought first it was important that we obtain a fiber scan to look at liver changes. I also wanted to perform an endoscopy to look at any variceal ruptures that may have occurred."*	27%	21%
	SDOH example The student mainly used the clinical information from the vignette to rationalize a specific diagnosis of the patient's clinical condition with mentions of SDOH examples, such as (alcohol use and smoking) without further integration of the SDOH framework or explaining its role in guiding the diagnosis of the patient's condition. ***Example quote:*** *"I put alcohol use as one of the contributors toward potential liver cirrhosis. Also, she smoked a half pack of cigarettes* per *day for the past 20 years, and again, that is one of the possible contributors to liver cirrhosis."*	36%	7%
	SDOH mindful The student used both the SDOH framework (i.e. main categories and relevant examples) and clinical information to rationalize a specific diagnosis of the patient's clinical condition in an iterative process, demonstrating the student's understanding of the role of SDOH in the patient's clinical presentation. ***Example quote:*** *"We'll be kind of focusing in on the social and community context aspects of this case in particular because it is highly important to her presentation and disease pathogenesis."*	18%	71%
Clinical reasoning for treatment plan	**Categorizing the treatment plan based on differential diagnosis** The student discusses treatment options depending on the differential diagnosis (used when the student has more than one differential in their map) ***Example quote:*** *"Within the medical treatment, there were some different therapies that would be beneficial for multiple of the clinical conditions we are considering."*	27%	21%
	Therapeutic treatment targeting prevention/progression The student discusses the therapeutic options (pharmacologic and/or surgical interventions) that would or could have prevented the progression of the disease. ***Example quote:*** *"We want to run a hepatitis panel to see if she actually does have hepatitis, and that's why she has cirrhosis. If that's true, starting antiviral therapy and also to abstain from hepatotoxic substances, particularly NSAIDs."*	91%	100%
	Nontherapeutic treatment targeting prevention/progression The student discusses the nontherapeutic options that could have prevented/will prevent the progression of the disease (e.g. nutrition, lifestyle modification, support groups, counseling, etc.). ***Example quote:*** *"Our patient needs to have enough healthcare access to be able to*	45%	100%

(*continued on next page*)

Table 5 (*continued*)

Major Themes	Relevant codes and code explanations	Control (N = 11)	Experimental (N = 14)
		Percent of concept maps/narratives showing link to code	Percent of concept maps/narratives showing link to code
	understand what hepatotoxic medications to avoid, to have a good rapport with her primary, to understand which herbal remedies might affect her."		
	Definitive treatment Student explains definitive/curative treatment for the patient's condition (e.g. liver transplant in case of end-stage liver cell failure). ***Example quote:*** *"And finally, we can put her on a transplant list."*	55%	71%
	SDOH example The student mainly used the clinical information from the vignette to rationalize treatment options with mentions of SDOH examples, such as (alcohol use and smoking) without further integrating the SDOH framework or explaining its role in guiding the treatment plan. **Example quote:** "For alcohol and tobacco, just cessation therapy or counseling to help reduce the patient's intake of those substances."	45 %	36 %
	SDOH mindful The student used both the SDOH framework (i.e. main categories and relevant examples) and clinical information to rationalize treatment options in an iterative process, demonstrating the student's understanding of the role of SDOH in the patient's clinical presentation. ***Example quote:*** *"It is really important, again, to consider her education level. We're not sure what her level of education is, but we need to be certain that she understands at least the surface-level extent of how her behaviors lead to her disease."*	18%	100%

Qualitative data analysis revealed three main themes and relevant codes for each theme. The definition of each code and a supporting quote from students' transcripts are provided. The counts of codes within each theme are presented as a percentage for both control and experimental groups. SDOH: social determinants of health.

category "*Quality of Disease Process Concepts and Links*" can be explained by the fact that in the post-intervention assignments, students were asked to design a concept map that focuses on the treatment plan. Therefore, not many students from both groups included detailed outlines/explanations of the pathogenic mechanisms in their map design (Table 4 - *Disease Process Explained subcategory*). However, within the same category, the experimental group scores were significantly higher than the control group scores in the other two subcategories (i.e., *General Disease Process and Disease Process tied back to SDOH examples of the case*). These findings emphasize that our educational intervention still helped students touch base on the general pathogenic concepts in relation to SDOH. Moreover, these findings highlight that this educational intervention provided students with a better opportunity to understand the role of SDOH in the disease process by linking the general pathogenic concepts to the SDOH framework and relevant examples.

Initial concept mapping training before the implementation of this study was provided to students in both groups to decrease variability in students' ability to design a concept map successfully. However, results indicated that overall, the experimental group scored higher than the control group in the category of concept map "organization and design." In our concept maps evaluations, we noticed that students in the experimental group followed a relatively more systematic approach in illustrating the treatment plan using interpreted information from the vignette and categorizing concepts into several domains, including the patient's history, etiology/risk factors, general disease process/pathogenesis, and the SDOH framework (e.g., Fig. 3). This approach resulted in more coherent and logical map designs that were relatively easy to follow compared with those of the control group where students tend to be more abstract in using concepts in their map designs (e.g., Fig. 2) without linking concepts to SDOH. These observations could explain the difference in concept map scores between both groups in the "Organization and Design" category. Another explanation for this finding is that experimental group students underwent a group concept map design as part of the educational intervention, which allowed them to have better practice with concept map creation. It also allowed students to work as a team to learn SDOH and associated concepts. The ability to practice as a team contributed to a more significant maturation of skills to create foundations/best practices for concept map design. These were then applied to the individual maps as was apparent in the experimental group maps and reflections.

The experimental group students were more cognizant in interpreting and linking the SDOH information from the given vignette (e.g., information relevant to the main categories of the SDOH framework and specific examples within each category) to other clinical information (e.g., history, chief complaint, clinical picture, etiologic factors, etc.). They coherently translated this information into their map designs. This resulted in conscious and consistent employment of the SDOH main categories, thoroughness of SDOH examples, and increasing complexity of links/cross-links between these and the treatment plan options, hence the significant differences between both groups in the rest of the scoring categories.

Concept mapping is also a metacognitive strategy used to facilitate and assess learning and comprehension of knowledge, as well as to foster meaningful learning, which is deeply rooted in constructivism.[5,9] Implementing concept maps in teaching resulted in a noticeable shift in the nursing students' thought process from linear to multilevel thought and the development of a deeper understanding of the material.[16] Thus, in addition to assessing students' knowledge construction through concept map design, we sought to assess their thought processes by conducting a qualitative data analysis of their reflective narratives on their map designs. Overall, students in this study displayed unique creativity and connections of clinical concepts using concept map as a learning tool to demonstrate their critical thinking process. These findings align with several other studies that provided evidence supporting the role of concept mapping in promoting knowledge construction, critical thinking/clinical reasoning, and the tool's utility in assessing these skills.[17–24]

The thematic coding analysis portrayed how the experimental group implemented the SDOH framework to introduce/outline the case and guide their clinical reasoning for the diagnosis and treatment plan. The experimental group transcripts revealed an iterative and deep thought process of profoundly interpreting information from the clinical scenario to relate the SDOH factors to the disease pathogenesis and treatment options. They consistently explained the role of the SDOH framework/examples in the patient's condition at different levels, starting from etiology/pathogenesis to a detailed, well-rationalized treatment plan categorized to factor in options that mitigate the impact of SDOH.

The significantly higher numbers of "SDOH Mindful" codes by the experimental group in all themes (framing the patient's condition, clinical reasoning for diagnosis, and clinical reasoning for treatment plan) in comparison with those of the control group highlighted the impact of our educational intervention on enhancing students' clinical reasoning skills through the deliberate implementation of the SDOH concepts/framework in clinical problem-solving. It is worth noting that whenever the experimental group students used or discussed SDOH examples and their roles in the patient's condition/treatment, we did not code this as "SDOH Examples." Instead, we coded this as "SDOH Mindful" simply because the use of these examples by the experimental group was extensively iterative and coherently weaved into their narratives, which revealed a strongly rationalized, SDOH-informed thought process for clinical reasoning. Also, we wanted to distinguish between the thoughtful use of SDOH examples and the mere mention of these examples in the narratives without coherently integrating them in guiding the clinical reasoning process. Therefore, the counts for the "SDOH Examples" code by the experimental group appear to be much less than that of the control group. However, this doesn't negate the experimental group's extensive use of SDOH examples in their designs and narratives. In fact, the experimental group students expanded their examples beyond just smoking or alcohol, contrary to what the control group did. For instance, the experimental group students used examples relevant to other SDOH categories, such as (patient education, supporting cost, childcare, and transportation), with integration throughout reflections and continued linkage back to the concepts. Moreover, they factored these examples into their treatment plans, particularly for the prevention of disease and its progression; hence the counts for the codes "Therapeutic Treatment Targeting Prevention/Progression" and "Nontherapeutic Treatment Targeting Prevention/Progression" under the "Clinical Reasoning for Treatment Plan" theme in the experimental group are significantly higher than these of the control group.

The control group mainly followed a clinically focused case outline and clinical reasoning processes (which is expected given the proper medical education training); with sporadic mentions of limited SDOH examples (i.e. alcohol and smoking) that do not necessarily follow the SDOH framework or its use in guiding/rationalizing the diagnosis or treatment plan. For instance, students in the control group, whenever they mention "alcohol" or "smoking" in their designs and reflective narratives, address these from the perspective of risk factors and disease epidemiology without making the connection to the relevant SDOH category (i.e. social and community context) or other categories. Moreover, they rarely provide a deep discussion of the role of these two examples in the pathogenesis of the patient's condition and/or guiding the treatment plan.

These findings suggest that our educational intervention fostered the development of a holistic approach to patient-centered care that expands beyond symptomatic/complication and definitive treatment options that are mainly medicinal and/or procedural.

Furthermore, it is highly probable that the engineering-based medical education at CI MED synergized with and increased our educational intervention's impact on students' problem-solving abilities. Student training on innovative mindsets as an approach to clinical practice enhances students' clinical problem-solving competencies by creating transformational solutions. The successful integration of the SDOH framework is thus speculated to inform students' innovations to mitigate the social factors impacting high-quality healthcare.

Strengths and limitations

This study demonstrates several strengths, one of the most notable being implementing a randomized controlled study design and a mixed-methods approach to data analysis. However, what truly sets this study apart is its novel and innovative approach to intentionally and mindfully integrating the SDOH framework into the medical curriculum. This approach, which overcame challenges associated with SDOH integration as reported by The American Medical Association's Accelerating Change in Medical EducationConsortium, is a testament to the potential for innovation in medical education.[4] Most importantly, our intervention significantly improved students' understanding of complex clinical scenarios and enhanced their problem-solving abilities by adopting a coherent clinical reasoning process that is SDOH-mindful toward holistic patient-centered care.

One of the main limitations of this study is the small number of participating students. Several factors have contributed to this, including the small size of CI MED classes (n = 60–64/class). Additionally, at the time we conducted this study, there were several other medical education research projects going on at the same time, which might have posed some bandwidth limitations for students to participate in our study because first- and second-year medical students are the solely targeted population for these types of studies. Therefore, we plan to implement this educational intervention as an integral component of our curriculum and PBL sessions to test its effect on a broader scale without putting any pressure on students to feel that they should do additional work on top of the expected academic activities. Re-testing the impact of our educational intervention on a larger scale would enhance the reliability and productivity of our results.

We also recommend testing this approach by other medical institutions; one of the limitations of generalizing testing of our educational intervention is that PBL might not be part of these schools' curricula. However, concept mapping is easily integrated into various instructional methods other than PBL. It would be plausible to see the outcomes of applying this educational intervention across multiple learning contexts besides PBL. Lastly, for logistic purposes, we were only allowed to test our intervention in one PBL case per organ system course for a maximum of two courses. Therefore, a more longitudinal study is recommended to test the maturation effect in association with the impact of this intervention. Expanding this implementation to clinical clerkships would also be valuable in testing the learning outcomes of this intervention in a more practical clinical context where there are more interactions with patients and other healthcare providers in real-life scenarios.

Future directions

This study revealed the benefit that the integration of concept mapping into pre-clerkship PBL sessions has on student learning of SDOH and its relation to disease pathogenesis and the design of treatment plans. Further research on the impact of this proposed learning style is encouraged to help shape medical education so that students can build a more foundational knowledge base of social determinants to create more patient-centered healthcare. One recommendation for further research includes the integration of concepts relating to systemic racism in health care to enhance student understanding and acknowledgment of this significant social justice issue.[25,26] Medical programs that utilize PBL as a core learning method for students are encouraged to replicate this study to increase sample sizes and achieve multi-institutional results to further solidify the efficacy of the proposed educational intervention. Similar integration of concept mapping and SDOH into other health professions' educational programs is also recommended to determine efficacy across various training programs. Implementing this requires high-quality concept map training for educators and students following the Novak and Gowin foundation of concept mapping to properly utilize the tool in learning and assessment.

Integrating the SDOH framework in the clinical phase of medical curricula is recommended to create a more longitudinal emphasis on its importance and help students see the framework modeled by physicians to appreciate its value and relevance in clinical practice.[4] Additionally, we propose providing professional development opportunities for academic and clinician educators to train them in how to integrate SDOH into medical curricula and assess the outcomes of this integration,

especially since one of the main barriers to teaching SDOH is the lack of trained faculty.[4]

Conclusion

This study provides an evidence-based mechanism for integrating SDOH into pre-clerkship medical education. The implemented educational intervention enhanced students' ability to have a holistic view of the patient and provide a patient-centered treatment plan by applying SDOH-informed clinical reasoning.

Ethical approval

This study, approved under protocol number 22698, met the basic ethical standards outlined by the University of Illinois Urbana-Champaign Institutional Review Board regarding the protection of human subjects.

Author contributions

- Kellie Mullany is a fourth-year medical student at CI MED (Class of 2025). She organized data, contributed to data analysis/representation, wrote the grant proposal and mid-term/final reports, and contributed to writing the manuscript under the supervision of Dr. Hegazy.
- Dr. Barbara Masi is a former Director of Assessment at CI MED and is now at Icahn School of Medicine at Mount Sinai. She guided/wrote the IRB application, contributed to writing the post-intervention assignment, led the qualitative and quantitative data analysis, and contributed to manuscript writing.
- Dr. Jaya Yodh is a teaching professor, Biochemistry Discipline Lead, and Co-Director of the Lifespan Health Curricular Thread and co-Director of the Foundations, Digestion, Nutrition and Metabolism and Synthesis and Summary courses at CI MED. She contributed to the concept mapping training, wrote the post-intervention assignment, and reviewed the manuscript.
- Dr. Imanni Sheppard is a teaching assistant professor at CI MED and the Co-Director of Biomedical Ethics and Humanities Curricular Thread. She collaborated on writing the specific SDOH probes of the PBL cases and the post-intervention assignment. She also reviewed the manuscript.
- Dr. Grace Park is a teaching associate professor, Block-1 Director, and Director of the Health Systems Science Curricular Thread at CI MED. She contributed to the concept mapping training, writing the post-intervention assignment, and reviewing the manuscript.
- Dr. Samar Hegazy is a teaching assistant professor, Histology and Pathology Discipline Lead, the Course Director for Respiratory and Literature Reviews in Pathology Courses, and Co-Director of the Lifespan Health Curricular Thread at CIMED. She is the faculty advisor of Kellie Mullany, the student awardee of the Society '67 trainee grant. She developed the idea, design, and implementation plan of this project. She contributed to the concept map training and wrote the IRB application, the SDOH-specific PBL probes, the post-intervention assignments, and the manuscript. She also facilitated the experimental group PBL sessions and contributed to data analysis/presentation.

Disclosures

- Kellie Mullany, first author and trainee awardee of the Society '67 of the Association for Academic Pathology, was a first-year medical student when this study was implemented for the class of 2025. Therefore, Kellie was placed in the control PBL group to avoid conflicts of interest. Furthermore, Kellie's concept map assignments were excluded from evaluations and data analysis.
- This project's idea, design, and implementation plan were part of Dr. Hegazy's academic work within the Master of Education in Health Professions (MEHP) program at Johns Hopkins University.

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Declaration of competing interest

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