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Teaching cross-cultural design thinking for healthcare

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ABSTRACT

Objectives: Artificial intelligence (AI) is poised to transform breast cancer care. However, most scientists, engineers, and clinicians are not prepared to contribute to the AI revolution in healthcare. In this paper, we describe our experiences teaching a new undergraduate course for American students that aims to prepare the next generation for cross-cultural designthinking, which we believe is crucial for AI to achieve its full potential in breast cancer care.
Materials and methods: The key course activities are planning, conducting, and interpreting interviews of healthcare professionals from both Portugal and the United States. Since the course is offered as a short-term faculty-led study abroad program in Portugal, students are able to explore the impact of culture on healthcare delivery and the design of healthcare technologies.
Results: The learning assessments demonstrated student growth in several areas pertinent for future development of AI for breast cancer care. With respect to understanding breast cancer care, prior to taking this course, most students had underestimated the impact of cancer and its treatment on women's quality of life and most were unaware of the importance of multidisciplinary care teams. Regarding AI in medicine, students became more mindful of data privacy issues and the need to consider the effect of AI on healthcare professionals.
Conclusion: This course illustrates the potential benefits for AI in medicine of introducing future scientists, engineers, and clinicians to cross cultural design-thinking early in their educational experiences.

1. Introduction

Breast cancer is the most frequent type of cancer in females, impacting more than 2 million women each year worldwide [1]. In 2018, it was estimated that 15% of all cancer deaths would be due to breast cancer. While this disease is more common in industrialized countries, its rates are increasing in almost every region around the globe [1]. To improve breast cancer outcomes, early diagnosis is key. Although breast cancer screening programs have reduced breast cancer-related mortality [2], the detection process is labor intensive, since there are many women to be screened, and it is challenging given that most of those women are fortunately disease free. Likewise, despite impressive advances in breast cancer treatment (e.g. Refs. [3,4]), many limitations remain (e.g. Refs. [5,6]). Moreover, the increasing number of long-term breast cancer survivors has highlighted the extensive impact of breast cancer and its treatment on women's quality of life [7]. Given the ever increasing availability of medical data in computer-processible form [8], it is now possible to bring artificial intelligence (AI) to bear on many of the remaining challenges in breast cancer care and there is an urgent need to prepare the next generation of researchers and practitioners to do so.

AI is poised to transform breast cancer care from screening to survivorship. There is a long history of AI-related research in medical imaging for breast cancer detection and diagnosis [9,10]. Most recently, there has been a methodology shift towards the usage of Convolutional Neural Networks in breast cancer imaging [11] in response to the impressive performance of deep learning in the analysis of images of natural scenes. There is also enthusiasm for the potential of AI in breast cancer treatment, including breast surgery, medical oncology, and radiation oncology. For example, AI

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methods are being explored in radiation oncology for image segmentation, radiotherapy dose optimization, clinical decision support, and quality assurance [12]. Given the significance of appearance change on breast cancer patients' quality of life [13], the fields of oncoplastic and reconstructive surgery have long been interested in 3D breast modeling, including AI approaches, for surgical planning, decision support, and outcome assessment [14]. Clinical psychology and psychiatry are also expected to benefit from advances in AI [15,16], which will include psycho-oncology applications. Automation and robotics have been widely adopted in pharmacy, though assessment of those technologies is ongoing [17]. Current topics in AI-related research in pharmacy include drug design and discovery, robotics, and oncological treatment planning [18].

However, AI technologies in medicine have not always had the predicted impact. For example, there is considerable debate whether the computer-aided detection systems for breast cancer that were deployed in clinical practice in the US starting in the 1990s have had any benefits at all, e.g., Ref. [19]. Moreover, recently there have been some high-profile failures of collaborations that sought to apply AI to oncology in the US [20]. Concerns have also been raised about future threats to the use of AI in medicine. Finlayson et al. [21] discussed the dangers of adversarial attacks on medical AI, in which inputs are intentionally crafted to force the model to make a mistake. Finlayson et al. argue that this type of threat is only one of many possible failures in AI models since the "trust" in a system is lost when not even its developers can predict with full certainty its behavior.

Prior failures of AI in medicine and the risk of future threats for AI in medicine point to the need for more personnel at the intersection of the technical and healthcare fields who are trained in design-thinking. The international design and consulting firm IDEO defines design-thinking as "a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success" [22]. We expand on this concept to define cross-cultural design-thinking as design-thinking in the context of products that are expected to work across cultural boundaries and/or designers who must themselves cross cultural boundaries. Cross-cultural design-thinking is critical because health is a universal fundamental right [23] yet there can be considerable cultural diversity between countries and within a single country. In particular, AI applications developed for breast cancer care must accommodate cultural diversity and designers need to be able to recognize the aspects of the systems that need to be tailored for use in different cultural groups.

In this paper, we describe our experiences teaching a course that aims to prepare future researchers and practitioners in the US in cross-cultural design-thinking. In the US, medical education begins after the bachelor's degree. Hence, the undergraduate years in the US provide an excellent opportunity for giving future scientists, engineers, and clinicians a shared set of cross-cultural design-thinking skills and an appreciation of the opportunities and challenges ahead for AI in breast cancer care.

2. Teaching methods

2.1. Course overview

BME 320 International Perspectives on Biomedical Engineering Design is a "Maymester" course offered by The University of Texas at Austin (UT Austin), United States (US). Maymesters are summer academic programs in which a group of 15–30 UT Austin undergraduate students travel with a UT Austin faculty member to an international location. Maymester programs compress a semester-long 3-credit hour course into four to five weeks of intensive learning. Currently, only about 1 in 10 American undergraduates study abroad [24]. Maymesters mitigate many of the traditional barriers to study abroad, ranging from concerns about credit transfer to fears of homesickness, thus making study abroad accessible to more students, especially science and engineering students. In addition, a study abroad format is ideal for teaching cross-cultural design-thinking because the experience inherently includes what is referred to as rapid calibration techniques [25], i.e., activities that provide a baseline understanding of a new culture. For example, study abroad requires that students commute, shop for groceries, and wait in line with the locals.

The goal of BME 320 is to enable students to consider socio-technical factors in designing clinically translatable solutions. Students learn human-centered design methods to understand the people for whom they are designing and to identify actionable problem statements. The course is motivated by the design of health information systems for supporting medical decision-making, with a particular emphasis on the potential of artificial intelligence to transform breast cancer care.

The location of a Maymester course must be carefully selected to fulfill the course objectives. A key consideration for the location of BME 320 was that it should have comparable resources to the US, as opposed to a low-resource setting, so that observed differences in healthcare between the US and the program location would reflect the impact of different values on resource allocation rather than result from differences in available resources. Given the need to interact with healthcare professionals and researchers at the program location, it was also important that the lead instructor (Markey) have shared research interests with local professionals. For these reasons, BME 320 is hosted by the Faculdade de Engenharia da Universidade do Porto (FEUP) in Porto, Portugal. The course structure also leverages professional connections with the Breast Unit of the Champalimaud Clinical Center in Lisbon, Portugal.

While BME 320 is open to all disciplines, most students are majors in Engineering (Biomedical) and Natural Sciences. Most of the students have only completed 1–2 years of university coursework at the time that they participate in the program. BME 320 carries a "global cultures" flag, a designation by UT Austin that the course meets the following learning objectives that are among the skills and experiences expected for all UT Austin undergraduate degrees: "Students will demonstrate an understanding of the complexity of the perspectives of at least one non-U.S. community. Students will develop a historical understanding of at least one non-U.S. community. Students will critically reflect on their respective cultural experiences and how those cultural experiences inform their worldviews, and will recognize different perspectives and worldviews from non-U.S. cultural groups, including those to which students may belong" [26]. All UT Austin students must take at least one course that carries a Global Cultures flag.

The course activities consisted of several integrated, evidence-based instructional approaches, including reading research articles; attending professional field trips; planning, conducting, and interpreting interviews of healthcare professionals; and participating in cultural activities. Learning was assessed by self-report questionnaires completed at the start and end of the course; concept maps created at the start and end of the course; formative reflective writing assignments following each major course activity; a summative reflective writing assignment at the end of the course; and a project in which the students wrote, critiqued, and revised research abstracts.

2.2. Self-report questionnaires

Students individually performed self-assessments of their Global Learning and their Intercultural Knowledge and Competence, at the start of the course and again at the end of the course. Students were graded on completion of the self-assessments, not their self-assessed performance level. The self-assessments used rubrics from the Association of American Colleges and Universities [27,28]. For example, to self-assess Global Self-Awareness, students were prompted: "Select the option that best describes you. (a) Effectively addresses significant issues in the natural and human world based on articulating one's identity in a global context. (b) Evaluates the global impact of one's own and others' specific local actions on the natural and human world. (c) Analyzes ways that human actions influence the natural and human world. (d) Identifies some connections between an individual's personal decision-making and certain local and global issues." A limitation is that while established rubrics were utilized, data were not collected using psychometrically validated scales.

In addition, students responded to free-response reflection prompts modified from the set proposed by the University of Michigan for international programs in engineering [29]. For example, students were asked questions such as "What skills and perspectives do I hope to bring home at the end of the experience?" at the start of the course and questions such as "Think about the goals you set for yourself before you departed. Reflect on how your experiences this summer relate to what you wrote then. Provide concrete examples, when possible" at the end of the course. Note that these data capture students' self-assessment of their skills, which may or may not concur with the assessment of those skills made by an external reviewer. Regardless, educational research suggests that such reflective exercises are key for students to develop intercultural competence [30].

2.3. Concept maps

A concept map is a diagram used to organize and structure knowledge around a main idea. Concept maps have 3 interrelated components: nodes, directed lines, and labels. The nodes represent the concepts, the directed lines the relationships between the concepts, and the labels provide a description of the nature of the relationships, e.g., "leads to." The educational value of concept maps in is well-established [31,32]. Using concepts maps as a learning strategy helps students focus, transfer problem-solving skills between domains, and achieve higher scores on other assessments such as exams [33]. They can also help students in integrating or synthesizing complex ideas, and in moving beyond memorization to elaborative cognition and meaningful learning [33–35]. While the value of concept maps as a learning strategy is well-established, we acknowledge that our interpretation of the changes in the students' concept maps is inherently subjective.

At the start of the course, students were randomly assigned into small groups of 3–4 students in order to generate concept maps. Different groups were formed for each main idea, but the same group generated the concept map for a main idea again at the end of the course. Students were given a brief introduction to the process of concept mapping based on the work of Crandall, Klein, and Hoffman [36] before undertaking the task. The main ideas about which the students generated concept maps were: culture, design, breast cancer, and AI in medicine.

2.4. Reading assignments

While in-depth practice in critical reading of research articles was not feasible given the compressed timeline for this type of course, students did acquire some context through reading assignments. In order to establish introductory knowledge about breast cancer care, students were required to read reference materials from reliable sources such as UpToDate® (Wolters Kluwer, Alphen aan den Rijn, The Netherlands). Towards the goal of familiarity with current concerns about AI in medicine, the students read recent overviews, e.g. Ref. [37–43]. Students also read articles about perspectives on AI specific to different subfields of medicine (e.g., radiology [44]), with an emphasis on breast cancer care (e.g. Refs. [10,45]). In addition, students read about timely issues in AI research that are not limited to medical applications, such as adversarial attacks (e.g. Ref. [21]) and interpretability/explainability (e.g. Ref. [46]).

Class time was not specifically devoted to discussing the reading assignments. Rather, the students used the reading assignments to inform their questions for the interviews of the healthcare professionals and enhance their interpretation of both the professional field trips and the healthcare professional interviews. Students' understanding of the reading assignments was assessed through the formative writing assignments, which required that they relate the course experiences to the reading assignments, and the research abstract project, which likewise required citations to the reading assignments and other scientific publications.

2.5. Professional field trips

Students attended five professional field trips - two to healthcare facilities and three to research facilities. They visited the Breast Unit of the Hospital de São João in Porto and the Breast Unit of the Champalimaud Clinical Center in Lisbon. These facilities are very different from each other. Hospital de São João[1] is the largest hospital in the north of Portugal and key to healthcare delivery through the Serviço Nacional de Saúde (national health service). In contrast, Champalimaud Clinical Centre[2] is a private institution that does not provide care through the national health service but rather has agreements with private insurance companies.

The three research facilities visited by the class were: Centro de Investigação em Tecnologias e Serviços de Saúde (CINTESIS),[3] Associação Fraunhofer Portugal Research (Fraunhofer AICOS)[4] and Instituto de Investigação e Inovação em Saúde (i3s).[5] CINTESIS aggregates more than 500 researchers from 46 participating institutions. The field trip focused on health data and decision sciences & information technologies, which is one of the three main themes of CINTESIS. Fraunhofer Portugal is a non-profit private association founded by Fraunhofer-Gesellschaft. The core research strengths of Fraunhofer Portugal are human-centered design, artificial intelligence, and cyber-physical systems. i3s is a consortium of more than 1300 researchers from four institutions. The research groups at i3S are clustered into three programs: Cancer, Host Interaction and Response, and Neurobiology and Neurologic Disorders.

The professional field trips used in the course served as hands-on, immersive, experiential learning. There is a substantial literature base for the value of immersive learning across disciplines, in that such experiences can attract students to a field or specialty they might not otherwise explore [47,48] and promote in-place learning that enhances students' awareness of the role of the science at hand to the local community [49].

[1] http://portal-chsj.min-saude.pt/.
[2] https://www.fchampalimaud.org/.
[3] http://cintesis.eu/en/home/.
[4] https://fraunhofer.pt/
[5] https://www.i3s.up.pt.

2.6. Healthcare professional interviews

The heart of BME 320 is the planning, completion, and interpretation of interviews with healthcare professionals from both Portugal and the US. Since the students were in Portugal for the duration of the program, most interviews with Portuguese healthcare professionals were in person (Fig. 1) whereas the interviews of the American healthcare professionals were conducted by videoconference. The healthcare disciplines interviewed vary slightly between course offerings due to scheduling constraints, but the list from the most recent course offering is typical: medical oncology, nursing, plastic/onco-plastic surgery, psychiatry/clinical psychology, pharmacy, radiology, and radiation oncology. Likewise, there is some variation in the institutions from which our professional guests are recruited in order to accommodate schedules, but the majority practice at The University of Texas MD Anderson Cancer Center (Houston, Texas, US) or Champalimaud Clinical Center (Lisbon, Portugal).

The processes for planning, conducting, and interpreting the interviews with healthcare professionals was primarily informed by methods introduced to the students using the bootcamp bootleg toolkit [50], created by the Stanford d.school. Especially, the students benefited from the method descriptions: Interview Preparation, Interview for Empathy, Story Share-and-Capture, Saturate and Group, Point-of-View Madlib, and Point-of-View Want Ad. These methods were augmented by interview tips from complementary disciplines such as journalism (e.g. Ref. [51]) and our experience in using Twitter as a mechanism for generating actionable problem statements [52].

Students began the process of preparing for an interview by individually generating questions. Then, working in groups they identified themes among the questions which were used to plan the sequence of topics for the interview. Working in groups, they refined the questions and selected which classmates would ask which of the questions. During the interview, all students took notes. After the interview, the first steps toward interpretation were again performed as individuals. Each student wrote a short reflective summary (see "Formative Reflective Writing"). Afterwards, each student wrote surprising observations, quotes, etc. From the interview onto sticky notes, one concept per sticky. All of the students worked together to identify themes in the observations captured. The groups of observations were divided up for small group work. Following an approach previously described [52], and working in small groups, the students generated actionable problem statements [50] in the form of tweets.

Fig. 1. Interview of Dr. Maria João Cardoso at the Champalimaud Clinical Center.

Conducting informational interviews is a common practice in experiential learning for undergraduate students, including study abroad programs, whether as a means of exploring potential careers, work lives, and engaging in critical career networking [53,54], or to conduct their own field research.

2.7. Cultural activities

Students participated in several structured cultural activities. They went on guided tours of Porto, Lisbon, Sintra, the Douro Valley, and Peneda-Gerês National Park. The students had a short but immersive lesson in the Portuguese language, a hands-on introduction to cooking traditional Portuguese food, and a lively lesson in traditional Portuguese dances. In addition, there were numerous opportunities for semi-structured and independent cultural experiences during the 4-week program in Portugal under the leadership of a dedicated program assistant, a Portuguese student enrolled in the Faculdade de Engenharia da Universidade do Porto. For example, each of the students was assigned to a Portuguese student – a "buddy" – through the Erasmus Student Network (ESN) Porto, a non-profit international student organization that helps integrate foreign students into life in Porto, providing "opportunities for cultural understanding and self-development under the principle of Students Helping Students" [55]. Many students kept in touch with their buddies throughout their time in Portugal, allowing them to authentically experience Portuguese culture.

Similar to the professional field trips, these immersive cultural activities provided students with the opportunity to engage with the local community and culture, and consider ways in which it may relate back to their research and writing activities.

2.8. Formative reflective writing

After each professional field trip, interview of a healthcare professional, or cultural activity, the students wrote a formative reflective writing assignment. Inspired by the recommendations of Markman [56], the first component of the writing assignment was to articulate the three ideas that the student wanted to remember from the course activity. The second component prompted the students to reflect upon what they had learned about culture from the course activity. For example, after each interview of a healthcare professional, the students were prompted: "How is the culture of the country in which the subject of this interview practices reflected in their answers to the interview questions?" The writing assignment concluded by asking the student to propose a question that they would ask in a future interview of a healthcare provider based on what they learned from the course activity.

Since the students wrote reflections over several weeks, one after each course activity, the grading rubric escalated in expectation of their learning. During the first week of the course, we expected that the students' reflections would make comparisons between their experiences in Portugal and in the US. By the second week, the students were expected to not only relate their experiences in Portugal with prior experiences in the US, but also with the course activities that had been completed thus far in Portugal. By the third week, the students were expected to relate their experiences to the reading assignments as well as to their prior experiences. While we employed a pre-defined grading rubric, we acknowledge the inherent subjectivity in assessing students' reflective writings.

The literature also supports several aspects of the reflective

writing work we included in the course curriculum, also sometimes referred to as Writing-to-Learn (WTL) in STEM education [57,58]. For example, there is some evidence that critical reflection activities, such as these writing assignments, may enhance students' learning, not through such aspects as knowledge acquisition and retelling, but through higher-level transformative learning and meaning making [57]. This may especially be the case in experiential settings, such as study abroad [59,60]. For example, Hammer argues that students' unexamined study abroad experiences "will not facilitate intercultural competence development; " rather, "experience plus cultural reflection result in greater cultural insights and increase students' intercultural competence" [61]. The formative reflective writing assignments for this course were inspired by Markman's recommendations, themselves drawing on a diverse evidence base, which suggest ways to engage in metacognitive thinking and memory-enhancing skills, define and solve problems, and process information [56].

2.9. Summative reflective writing

At the end of the course, students wrote a report to reflect on their experiences in the program as a whole. In the first part of the report, they selected three photographs taken during the program and wrote a brief caption for each picture that explains how it captures an aspect of Portuguese culture. In the second and third parts of the report, they wrote brief essays on the impact of culture on healthcare delivery, and the impact of culture on the design of healthcare technologies, especially those based on AI methods. They were guided to use Rolfe's reflection model [62] in writing the essay. Rolfe's approach to reflection is summarized by the question starters of "What … ?", "So what … ?", and "Now what … ?" that correspond to advancing from a descriptive level of reflection to analysis to action-oriented thinking. While we employed a predefined grading rubric, we acknowledge the inherent subjectivity in assessing students' reflective writings.

We further expected that including photo essay components in the reflective writing assignments would deepen the learning achieved in students' experiential learning, through their engagement in the culture of Portugal, the different professional environments they visited, and the field research that they conducted via the professional interviews. Photo essays can play an important role in deepening cultural understanding and awareness as a part of that reflective process, providing often powerful imagery to document the experience [63,64].

2.10. Research abstract project

After all of the interviews with healthcare professionals were completed, each student indicated their preferences for working on a project related to the different healthcare disciplines. Taking these preferences into account, the students were assigned to small groups. Each group selected one actionable problem statement expressed as a tweet from their assigned healthcare discipline for the basis of their project. Each group proposed a solution to their chosen actionable problem statement. They summarized their proposed solution in abstract form, following the formatting requirements of a US National Institutes of Health (NIH) proposal abstract. Since the course was focused on the 'empathize' and 'define' modes of the design process [50] and the course timeline was compressed, the students were challenged to propose a solution and write it in abstract form within only a few hours. Students were encouraged to study abstracts of funded projects from NIH RePORTER [65] as exemplars.

After each group wrote an abstract, students were assigned to serve as peer-reviewers for other groups' abstracts. Each student wrote a critique for each of the abstracts they were assigned to review. The critiques followed the NIH format for overall impact, significance, innovation, and approach. To supplement the official NIH instructions on peer review, students were provided with examples of abstracts and critiques from the author's own research.

After the critiques were written, all students roleplayed as reviewers in a mock NIH study section. To prepare them for the mock study section experience, the students watched a video from the NIH about the proposal review process [66]. On the basis of the written critiques and the discussions in the mock study section, each group revised their proposed solution as summarized in abstract form. While we employed a pre-defined grading rubric, we acknowledge the inherent subjectivity in assessing students' research abstracts.

The research abstract project, the final element of the course, was intended to accomplish a number of goals: to teach students about scientific writing and communication principles, to develop these critical competencies in them as a different form of writing than the reflective assignments had involved, and to introduce them to the peer review process. Such structured grant-writing and peer-review exercises can develop these skills, and support real-world applications of research questions to problems (the focus of design-thinking), and promote critical analyses of literature, which had been encouraged throughout the Maymester [67–70]. In some cases in prior research, the peer-review instructional process was not as accelerated as in this course, but the principles and intended outcomes were similar.

3. Learning outcomes

3.1. Student demographics

There were 16 students in the offering of the course discussed in this paper. Eleven of the students were biomedical engineering majors and the other five students were majoring in other health-related disciplines such as neuroscience or public health. Seven students had completed 2 semesters of instruction at UT Austin prior to taking this course; six students had completed 4 semesters; and three students had completed 6 semesters. Half of the students identified as women and the other half identified as men.

3.2. Self-report questionnaires

For the self-assessments following the Global Learning Value Rubric [27,28], students' scores at the end of the course were significantly improved (Wilcoxon Signed Rank Test) relative to the start of the course for Global Self-Awareness ($p < 0.01$), Perspective Taking ($p < 0.01$), Cultural Diversity ($p = 0.02$), Understanding Global Systems ($p = 0.02$), and Applying Knowledge to Contemporary Global Contexts ($p < 0.01$), but not for Personal and Social Responsibility ($p = 0.15$). For the self-assessments following the Intercultural Knowledge and Competence Value Rubric [27,28], students' scores at the end of the course were significantly improved (Wilcoxon Signed Rank Test) relative to the start of the course for all components: Cultural Self-awareness ($p < 0.01$), Knowledge of Cultural Worldview Frameworks ($p < 0.001$), Empathy ($p = 0.02$), Verbal and Nonverbal Communication ($p = 0.02$), Curiosity ($p = 0.03$), and Openness ($p = 0.04$). The largest gains were reported for Knowledge of Cultural Worldview Frameworks, which is their level of "understanding of the complexity of elements important to members of another culture in relation to its history, values, politics, communication styles, economy, or beliefs and practices."

One of the free-response reflection prompts on the self-assessment questionnaire asked the students to reflect on how

their perspective on the field of science/engineering had changed. A common theme in the responses was greater appreciation of the importance of interacting with the intended users, especially healthcare professionals who would work with an AI based system. Their responses also suggested that they had developed a broader understanding of the potential roles of AI in medicine, such as that it is not limited to supporting diagnostic decision-making or to a single medical specialty.

3.3. Concept maps

The students' concept maps on the topic of "culture" most commonly showed more emphasis on history and preservation at the end of the course compared to the concept maps they had generated at the start of the course. Comparing the students' concept maps for "design" at the end of the course to those form the start of the course, typical changes were an increased use of concepts related to systematic approaches to the design process and more concepts related to constraints such as affordability. Comparison of the students' concept maps on "breast cancer" from the end and start of the course demonstrated a shift away from topics salient to lay people, such as awareness and fundraising, and towards more clinical topics. Their "breast cancer" concept maps showed an increase in familiarity with technical methods and concepts, such as medical imaging modalities, and greater appreciation for the impact that breast cancer and its treatment have on women's quality of life (Fig. 2). The students' concept maps on "AI in medicine" showed that they were more aware of technical terms, e.g., deep learning, at the end of the course relative to the start of the course. Another typical change in their concept maps about "AI in medicine" was an increased number of concepts related to the impact of AI on healthcare professionals and their interaction with their patients (Fig. 2).

3.4. Formative reflective writing

Many of the students were in awe of Portugal's long history and the awareness of history shared by many Portuguese people. Several students noted that Portugal proudly preserves displays of its history throughout the main city centers, and openly embraces the influences of other nations and peoples (e.g., the Moors). We believe that this aspect of Portuguese culture surprised our American students because the US is a very young country in comparison to Portugal, and Americans, even college graduates, are notoriously unaware of their own history, e.g., Ref. [71].

Some students pointed out the substantial geographic diversity within Portugal. Although Portugal is only about 36,000 square miles (92,000 km^2), it offers every type of landscape, from beaches to mountains, seas and rivers, nature and urbanism. We suspect that this was particularly striking to our American students since they live in Texas (268,000 mi^2 or 696,000 km^2) where changes in landscape are much farther apart.

In their visits to Sintra and Peneda-Gerês National Park, the students noticed that the access roads to those locations were narrow and poorly maintained, which they recognized as a barrier to the delivery of emergency care. While many rural Americans likewise face health disparities [72], American students from urban areas are often unaware of those issues.

The students' reflections focused on the stark differences they observed between the public and the private hospitals they visited, Hospital de São João and Champalimaud Clinical Center, respectively. While they understood that the Champalimaud Clinical Center is an elite health and research center and not representative of typical private healthcare facilities in Portugal, they were still shocked by the contrast with Hospital de São João. At Hospital de São João, the students were startled by the long lines of people waiting, people sitting on the floor to wait, the lack of air conditioning in the waiting rooms, and that some parts of the hospital (including the Breast Unit) were located in temporary construction. They found these aspects of Hospital de São João particularly unexpected in light of the high quality care provided, e.g., the breast unit is certified by the European Society of Breast Cancer Specialists (EUSOMA) [73]. At Champalimaud Clinical Center, the students were surprised by the extreme emphasis on patient comfort and the efforts made to establish a relaxing atmosphere, such as the indoor tropical garden and an exterior garden arranged to allow patients to receive treatment outdoors. Their reflections revealed that these professional field trips made them question their assumptions about the relationship between the appearance of a hospital and the functions of a hospital. The experiences also made them more conscious of the tradeoffs under different healthcare payer systems, i.e., a national health system vs. private insurance.

The students' reflections demonstrated that a key concept they learned from the interviews with the healthcare professionals and the field trips to Hospital de São João and Champalimaud Clinical Center was the importance of multidisciplinary teams [74] in breast cancer care. Some of the students had not known what a multidisciplinary team was before taking this course. Other students thought that only physicians participated in these types of meeting, and were surprised to learn that other health professionals such as nurses, pharmacists, and clinical psychologists may participate. We believe that understanding the multidisciplinary nature of breast cancer care is important to ensure that AI systems do not unintentionally disrupt the team dynamics.

It was also clear, when analyzing these reflections, that the course experiences helped the students appreciate that culture and history shape how people make choices, including healthcare choices. An highly referenced example occurred in an interview with a radiation oncologist specialist at the Champalimaud Clinical Center in Lisbon. The students learned that when patients hear the word "radiation," they often associate it with nuclear disasters, such as Chernobyl, which can lead to fear and resistance to accepting a treatment that they need. Although we cannot know how this knowledge will affect the students' professional work after they finish their education, we do know that they are now more aware of such issues.

During the professional field trip to CINTESIS, the students had the opportunity to participate in a poll regarding their opinions on data privacy, similar to what has been done with data science professionals [75]. They were surprised to discover that there was substantial disagreement even within their own small group about data privacy topics such as whether use of health data should always require consent. They also came to appreciate that there are some broad cultural differences in attitudes about data privacy, as evidenced by the recent European Union General Data Protection Regulation [76], and that those differences can have implications for developing AI for medicine, such as through "right to explanation" rules [77].

3.5. Summative reflective writing

As described above, the summative reflective assignment was divided into three sections: a photo essay; an essay relating culture with healthcare delivery; and an essay relating culture with healthcare design. In their photo essays, the students emphasized again cultural expression and display throughout the main city centers, and how they felt the Portuguese pride demonstrated through it.

Fig. 2. Comparison of students' concept maps from the start (left) and end (right) of the course for the main ideas of "breast cancer" (top) and "AI in medicine" (bottom).

In their essays about culture and healthcare delivery, the majority of the students revisited their experiences from the professional field trips to Hospital de São João and Champalimaud Clinical Center, but in a more analytic mindset since they were past the initial culture shock. The students' essays revealed admiration for Portugal's commitment to health as a fundamental human right, but also increased appreciation of the implementation challenges of a national health system. With the Portuguese healthcare system as a new frame of reference, the students were better able to identify the pros and cons of the US healthcare system. Many of the students expressed a newfound desire to play an active role in promoting changes in the US healthcare system, not just as future professionals, but as citizens through voting, talking with peers, creating posters, organizing discussion sessions, posting on social media, joining student organizations that support this type of cause, and other actions.

In their final essays, the students were prompted to reflect on the impact of culture on the design of healthcare technologies, especially those based on AI methods. The students' essays demonstrated an increased recognition of the importance of empathy in the engineering profession, especially with respect to designing systems that will be acceptable to intended users. In particular, there was greater recognition of the importance of considering the healthcare workers who will be impacted by the addition of AI technologies, not just their patients. Some students noted that the interviews revealed substantial variation in the healthcare professionals' openness to AI technologies. They also realized that some healthcare areas, such as Psychology/Psychiatry and Nursing, require more human contact, not only for the patient's comfort, but because of the complexity of interpreting nonverbal cues. Finally, several students discussed the SMARTSKINS[6] project, an AI system being developed to analyze pictures of moles taken with cell phones, which they learned about in the professional fieldtrip to Fraunhofer Portugal. A key motivation for SMARTSKINS is the need to prioritize patients for referral to a dermatologist, given the limited number of dermatological appointments available through the national health service. Initially, some students could not appreciate the purpose of the SMARTSKINS project based on their experience of the US healthcare system. Later, when the students had more understanding of the wait time concerns in the Portuguese National Health Service, they realized that the problems for which AI solutions are needed are culturally-dependent.

[6] http://smartskins.projects.fraunhofer.pt/index.html.

3.6. Research abstract project

At the start of the research abstract project, the students generated actionable problem statements that captured needs and insights identified from the interviews of healthcare professionals. The bootcamp bootleg materials suggests some methods for formulating actionable problem statements, like creating a Madlib or want ad [50]. However, we have found that formatting the actionable problem statement as a tweet resonates better with our students [52]. There were no additional constraints on the tweet format, i.e., students could present the actionable problem statement as plain text, meme, or GIF. However, it was clear that the students gravitated strongly towards making memes. The meme format gives them the opportunity to combine textual and visual elements to pack a stronger emotional punch (Fig. 3).

The students were divided into groups, which represented four of the interviewed areas: Pharmacy, Psychiatry, Radiology, and Surgery. Each group chose an actionable problem statement for which they would propose an AI solution. The Pharmacy group proposed a system that aimed to reduce polypharmacy in elderly oncological patients. For that, they planned to create an AI system to aid pharmacists in the evaluation of the medications taken by a patient. They would generate a personalized questionnaire, based on the electronic health record data of the patient, from which they would collect the patient's feedback on possible conflicts they were experiencing. To tackle the difficulty of diagnosing mental illnesses, the Psychiatry group described how they would apply AI techniques to vital signs and body movements to help the physicians to identify possible symptoms of mental disorders. They were inspired to do so in part because of the emphasis on nonverbal cues in the interview responses. The radiology group was excited by recent work on deep learning applied to mammography for breast cancer detection and diagnosis. They identified reducing false-positive imaging results (as compared against biopsy results) and model explainability as important points for further development. Finally, the Surgery group aimed to decrease the likelihood of patient postoperative dissatisfaction after breast reconstruction. They proposed an AI system to analyze preoperative and postoperative patient satisfaction data, create personalized reconstruction models, and display information to patients using mixed reality technology. We note that all of the groups proposed tools for supporting healthcare professionals, not supplanting them. We think this stems from their increased concern for the impact of technology on healthcare workers and new awareness of the importance of multidisciplinary care teams.

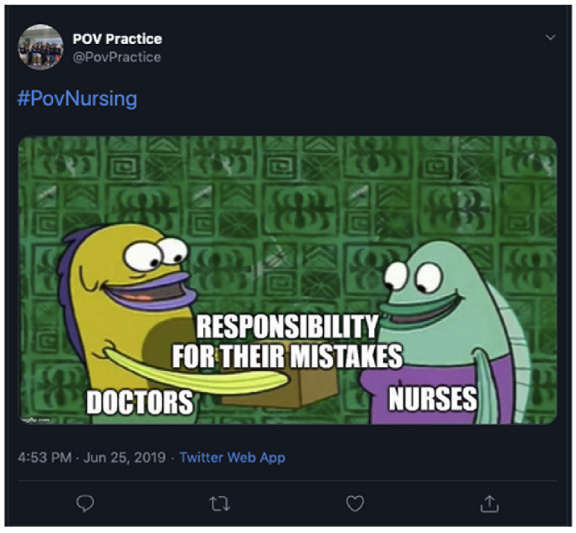

Fig. 3. Example of an actionable problem statement reported as a tweet. The tweet reveals a recognition of the complex nature of healthcare teams and how they allocate responsibility for decisions and actions, which could be important for envisioning how an AI system could be integrated into multidisciplinary care.

4. Conclusions

The students in this course reported substantial growth in global learning and intercultural knowledge and competence. They rapidly increased their understanding of Portugal and its people. For example, they observed that preserving history is a widely-shared value in Portugal. Moreover, students who had previously not known each other quickly became friends and formed productive teams.

Through interviews with both Portuguese and American healthcare professionals and field trips to Portuguese hospitals and research facilities, the students became more conscious of the tradeoffs under different healthcare payer systems, i.e., a national health system vs. one based on private insurance, and the implications for the technologies needed. These experiences also inspired many students towards active roles in promoting changes in the US healthcare system.

Most of the students had previously been unaware of the importance of multidisciplinary teams in breast cancer care. They gained a greater appreciation for the impact that breast cancer and its treatment have on women's quality of life. They also became more thoughtful of attributes of healthcare beyond diagnostic and treatment effectiveness that impact the experience of healthcare, such as wait times.

Students increased their knowledge of systematic approaches to the design process and became more cognizant of constraints such as affordability. Prior to this course, most of the students had not given much consideration to data privacy in healthcare or its implications for developing AI systems. Finally, the students expressed increase recognition of the importance of empathy in the science and engineering professions, especially with respect to considering the impact of future AI systems on healthcare professionals.

Ethical approval

Approval was not required for the information reported in this manuscript.

Declaration of competing interest

None of the authors declares a conflict of interest.

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