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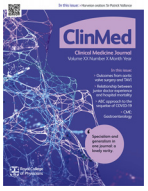

Design, implementation and evaluation of a spiral module combining data science, digital health and evidence-based medicine in the undergraduate medical curriculum: A mixed methods study

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A B S T R A C T

Background: Digital health, data science and health informatics are increasingly important in health and healthcare, but largely ignored in undergraduate medical training.

Methods: In a large UK medical school, with staff and students, we co-designed a new, 'spiral' module (with iterative revisiting of content), covering data science, digital health and evidence-based medicine, implementing in September 2019 in all year groups with continuous evaluation and improvement until 2022.

Results: In 2018/19, a new module, 'Doctor as Data Scientist', was co-designed by academic staff (n = 14), students (n = 23), and doctors (n = 7). The module involves 22 staff, 120 h (43 sessions: 22 lectures, 15 group and six other) over a 5-year curriculum. Since September 2019, 5,200 students have been taught with good attendance. Module student satisfaction ratings were 92%, 84%, 84% and 81% in 2019, 2020, 2021 and 2022 respectively, compared to the overall course (81%).

Conclusions: We designed, implemented and evaluated a new undergraduate medical curriculum that combined data science and digital health with high student satisfaction ratings.

Introduction

Data science, health informatics and digital health increasingly form part of healthcare practice and research over recent decades.[1,2] Evaluation and implementation of genomic and -omic testing in research, the role of electronic health records, clinical trials of digital health technology and understanding the strengths and weaknesses of machine learning in clinical care, are issues of increasing importance. All medical students and all doctors need to be able to evaluate and analyse data sets and evidence to equip them best for providing patient care and kept abreast of the latest advances and challenges in data-driven science, evidence and care, throughout their training,[3,4] as well as equipped to understand the methodology and interpret the results of (traditional) clinical and epidemiological research studies.

Historically, the undergraduate medical curriculum, already overcrowded,[5] has sometimes struggled to keep pace with the issues faced by new doctors, due to existing, competing content from many other areas ranging from histology and anatomy to communication skills and ethics. This is the case for health informatics, where research has demonstrated poor coverage in undergraduate medical school training in the UK and other countries, despite successive policy and research recommendations.[1,3,6,7] Similarly, inclusion of health informatics in the postgraduate medical training is limited.[6] However, there is growing recognition of the value of digital health competency for all doctors.[4] Early exposure in undergraduate training may be particularly beneficial, (as is thought to be the case with topics such as ethics, evidence-based medicine and communication skills), ensuring education of the medical workforce prior to specialty training.[8]

There are multiple examples of health informatics, data science and digital health being taught in UK medical schools, either as special study modules, standalone lectures or as intercalated degrees.[6,9,10,11] An alternative approach is to integrate new modules and courses with existing content. For example, research methods, statistics, literature review, critical appraisal, epidemiology and evidence-based medicine have often been successfully taught in this way. Student satisfaction is also better in this type of teaching.[12-14] At UCL Medical School, the 'Use of Evidence' (a module covering research methods, interpretation of clinical trials and epidemiological studies, and information management) and 'E-health' (a brief module introducing digital health) were two pre-existing modules which required updating, and there was a recognised need to develop more informatics-related content to meet regulatory standards (UK General Medical Council) for doctors[4] (Table S1).

Based on student, teacher and administrator feedback, we therefore aimed to:

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1. Co-develop a new module in the undergraduate medical curriculum ('Doctor as Data Scientist').
2. Implement the module across all year groups 'spirally' for all medical students.
3. Collect, analyse and incorporate detailed feedback for continuous improvement.

Methods

Approach: We used a Design-Based Research (DBR) approach, which must meet the five following conditions.[15,16] First, the intervention should be implemented in a real-life setting where learning normally takes place: the medical school curriculum in our study. Second, various stakeholders should be involved. In a co-pedagogic approach,[17] we co-developed the module with students, teachers, informatics researchers, librarians and doctors. Third, the design of the intervention has to be based on theoretical principles. Our module was based on principles of design, implementation and evaluation.[18] Fourth, the DBR methodology requires continuous cycles of design, evaluation, and redesign. We evaluated the module to redesign it. Fifth, it should include a mixed methods evaluation, which we conducted across the different sessions and components (Table S2).

Setting: University College London Medical School has ~2,000 students across five year-groups with ~330 students per year group. The curriculum involves both vertical (strands running across all year groups) and horizontal (specific to particular year groups) components.

Design: 'Use of Evidence' (evidence-based medicine) and 'E-health' (digital health) were 'vertical' modules which formed part of the 'Clinical and Professional Practice' curricular component which includes other diverse, cross-cutting aspects, ranging from ethics to anatomy. Based on the need to align with GMC requirements and student feedback, a new module ('Doctor as Data Scientist', DDS) was co-developed to combine and replace these two prior modules, better coordinating and integrating digital health in the curriculum, while retaining a strong emphasis on the interpretation and understanding of clinical trials and clinical and population-based epidemiological research studies. This new module was developed as a 'spiral' component of the curriculum, in which there is an iterative revisiting of topics, subjects or themes throughout the course.[19] Reinforcement in learning is a crucial feature of the spiral curriculum, contrasting with fixed content across the years. Every time a topic or theme is revisited, additional objectives and new learning opportunities are presented. We involved 14 students from different year groups, 22 staff (from existing modules and new staff), and seven doctors (of different degrees of seniority) to help to co-develop content.

Implementation: In September 2019, the module was rolled out in all year groups (except year 3 which is an intercalated BSc year in the UCL MBBS course) as a core or 'compulsory' module offered to all students, running throughout the academic year. Based on student feedback and changes in medical school requirements (eg assessment format), the content was continuously improved.

Evaluation: At the end of each session, students were invited to provide electronic feedback via Mentimeter™ in 2019–2020 and Microsoft® Forms from 2020–2021 to 2022–2023. To evaluate the course, students from three cohorts in Years 1, 2, and 4 were asked to complete a brief questionnaire following each teaching event, and encouraged to respond by (i) highlighting the questionnaire in slides at the beginning and end of the lecture; (ii) by providing both a weblink and a QR code; and (iii) by explaining how results would be used to iteratively improve the course. The questionnaire included three questions, a five-point Likert scale, and a free text box for any comments related to the teaching event. Students were asked: 1) 'Can you see the relevance of the session to your medical training and clinical practice?' and 2) 'Did you find the content interesting?' These were followed by one of three possible questions: 1) 'Did you understand the key concepts?'; 2) 'Did the live Zoom session with the tutor improve your understanding of the material', and 3) 'Did you find it helpful that the tutor was on hand to answer questions via the online forum?' The selected questions depended on the nature of the session being evaluated. Student comments were extracted from free text responses received from the questionnaire.

Analysis: The feedback was analysed by individual session, by year group, and for each year since introduction of the module. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) Version 27. Likert data were analysed by computing means, and response distributions. For qualitative analysis of free responses, the research team reviewed all qualitative data individually to identify salient themes and perform thematic analysis.[20] A.B., J.C. and N.A.-S. resolved any discrepancies to finalise theme interpretation. Qualitative data were reviewed until no new themes emerged from analysis. Illustrative quotes were collected to represent salient themes.

Table 1
5-Point likert ratings of medical student satisfaction of the doctors as data scientists (DDS) module.

	Mean satisfaction rating (out of 5)				
	2019–2020	2020–2021	2021–2022	2022–2023	Overall (2019–2022)
Year 1 (n =1,683)	***4.17 (n = 478)***	***4.32 (n = 473)***	***4.16 (n = 420)***	***4.32 (n = 317)***	***4.24***
Year 2 (n = 811)	***4.12 (n = 193)***	***4.13 (n = 243)***	***4.26 (n = 189)***	***4.11 (n = 186)***	***4.15***
Year 4 (n = 99)	***4.75 (n = 25)***	***4.42 (n = 27)***	***3.27 (n = 24)***	***3.83 (n = 23)***	***4.06***
Combined Years (n = 2,593)	***4.42 (n = 691)***	***4.27 (n = 743)***	***3.97 (n = 633)***	***4.09 (n = 526)***	***4.18***

Results

Design

DDS is delivered through a combination of lectures, large group work (LGW), and self-paced learning events (SPLs), which utilise the Articulate RISE 360 platform (See Supplementary Material). Table S2 shows the content of the DDS module, which was designed to address all of the requirements relating to infomatics, as specified by the GMC (Table S1). Due to the COVID-19 pandemic, the DDS module was changed to fully virtual format in April 2020, replacing face-to-face lectures and in-person large group work with video lectures and online tutor-facilitated activities (via Zoom™), respectively. From 2022/2023 lectures returned to face-to-face format.

Implementation

Between September 2019 and May 2023, 5,200 students participated in the DDS module (Table 1 for breakdown of student numbers by year). Students are assessed based on a final exam via Single Best Answer (SBA) Questions and other question formats (eg short answer), covering all course themes and part of a wider knowledge test for the relevant academic year.

Evaluation

Questionnaire

The mean 5-point satisfaction ratings for the 4 most recent academic years are shown in Table 1. Of all three academic years, 2019–2020 has the highest 5-point satisfaction ratings among Years 1, 2 and 4 with a combined mean rating of 4.42. Over the next 3 academic years, the mean combined satisfaction was slightly lower than for 2019–2020 but remained stable at 4.27, 3.97 and 4.09 respectively. All three year-groups had comparable satisfaction ratings of approximately 4.18. The greatest difference in satisfaction ratings was observed between 2019–2020 to 2020–2021, predominately driven by the Year 4 cohort, which decreased from 4.75 to 3.27. Further analysis by delivery format revealed

Table 2
Medical student responses to questionnaire.

	Can you see the relevance of the session to your medical training and clinical practice?	Did you find the content interesting?	Did you understand the key concepts?	Did the live Zoom session with the tutor improve your understanding of the material?	Did you find it helpful that the tutor was on hand to answer questions via the Moodle forum?
	Yes (%)				
Year 1 Overall	*99.1%*	*92.2%*	*95.9%*	*82.8%*	*62.1%*
Year 2 Overall	*95.7%*	*89.7%*	*78.7%*	*78.4%*	*71.8%*
Year 1 (2020–2021)	*98.9%*	*93.2%*	*93.9%*	*88.1%*	*71.3%*
Year 1 (2021–2022)	*99.0%*	*92.0%*	*94.8%*	*69.8%*	*60.0%*
Year 1 (2022–2023)*	*99.4%*	*91.3%*	*99.0%*	*90.5%*	*79.9%*
Year 2 (2020–2021)	*97.3%*	*85.9%*	*73.9%*	*91.1%*	*N/A*
Year 2 (2021–2022)	*93.3%*	*86.4%*	*93.4%*	*73.5%*	*56.0%*
Year 2 (2022–2023)*	*96.5%*	*96.8%*	*69.0%*	*70.5%*	*87.5%*

*Data only available for the first half of the Academic Year.

Table 3
Identified student themes derived from questionnaire free text responses.

Identified response themes	Selected quotes
1. Relevance of data science to medical school curriculum	'Good exposure to clinical trials and the data that pushes the boundaries of medicine, which is especially important in the age of evidence-based medicine.' (Year 4) '…while it was fascinating to learn about the different instruments used in [Electronic Health Records] for good quality notes, data organisation and overall for good decision making, it was a bit abstract because we ourselves aren't writing or reading any patient notes…' (Year 2) 'Learning about the statistical and hypotheses testing was really intriguing and it was good to introduce it early because it fits into a lot of research or experimental medicine.' (Year 2) 'We have learnt theory that, I think, develops into complete understanding when it is seen in actual practice. Otherwise I think it ends at 'we just know of it' as opposed to 'ah that's how it works'. So maybe if there are questions where there is a clinical case with relevant details and history and us trying to write in the details following the coding system guidance? Or something similar?' (Year 1)
2. Delivery format	'The [Large Group Work] sessions are more memorable, but I do not think teaching this topic in lectures is efficient. [Self-Paced Learning] activities might be more useful.' (Face-to-Face) (not suggesting including all of below, but one or two) - I thought the associated lecture was amazing and explained the topic really clearly - I really like the incorporation of questions into the rise, especially the SBAs- I wish all teaching material did this! (year 2) (FOR RISE SESSION 2022) I thought this was really good consolidation of the lectures and helped to organise the concepts learnt and apply them, would definitely do this again. I liked that it wasn't too long and was interactive (year 1) (FOR RISE SESSION 2022) Very organised session which was laid out really well, with key information and questions to ensure we keep engaged. Took about the right amount of time allocated to complete. 10/10. (year 1) I found the session clear and easy to work through. I feel that I have a much better understanding of the topic than I did beforehand. (year 2) The rise workbook was really engaging and good to test my knowledge from the lectures (year 2) 'Works much better as group teaching rather than lectures (provided the tutor is engaging!)' (Face-to-Face) 'This will be more engaging if it can be taught in person again.' (Online Delivery)
3. Relevance to final examinations	'The lectures were excellent but would really appreciate some practice questions.' 'More [Single Best Answer] questions to summarise the lectures at the end would be helpful…' 'I find it really useful to have multiple choice questions doted throughout the lecture as it helps me concentrate but also allows me to check whether I am understanding' 'Was good to have a couple of practice question webpages last term to practice some of the stats tests, would have been good to have a similar thing to test our knowledge of research/study designs'

that RISE workbook activities had the greatest satisfaction rating (4.33), whilst face-to-face lectures had the lowest (3.77) (Tables S3 and S4).

The results of the questionnaire shown in Table 2. Almost all Year 1 and Year 2 students were able to see the relevance of the DDS course to their medical training and clinical practice with 99.1% and 95.7% agreeing respectively. Similarly, 92.2% of Year 1 students and 89.7% of Year 2 students found the content interesting. The vast majority of Year 1 students reported an understanding of the key concepts from each teaching event at 95.9%. This number decreased to 78.7% in Year 2 students, although this current academic year, all Year 2 students agree they understand the key concepts from each learning event. A significant proportion of students in both year groups agreed that live Zoom sessions with a tutor improved their understanding of the material at 82.8% and 78.4% respectively for Years 1 and 2. However, only 62.1% of Year 1 students found it helpful to have a tutor on hand to answer their questions on the Moodle forum.

Qualitative thematic analysis

Student answers to the free response text box revealed 3 key themes as shown in Table 3. These included: 1) Relevance to Medical School Curriculum, 2) Delivery Format, and 3) Relevance to Final Examinations. Comments such as: 'Good exposure to clinical trials and the data that pushes the boundaries of medicine, which is especially important in the age of evidence-based medicine' were seen among students later in their degree course, whilst one student at the start of their medical training commented: '…while it was fascinating to learn about the different instruments used in [Electronic Health Records] for good quality notes, data organisation and overall for good decision making, it was a bit abstract because we ourselves aren't writing or reading any patient notes'. Comments related to delivery format predominantly focused on the use of LGW sessions, '…works much better as group teaching…', and the transition to a virtual format, 'this will be more engaging if it can be taught in person again.' Relevance to examinations was frequently cited by students who requested 'more [Single Best Answer] questions to summarise the lectures at the end'.

Discussion

To our knowledge, DDS is the first integrated Data Science Course that spans the full duration of undergraduate medical training. There are three main findings from its design and implementation. First, un-

dergraduate medical students are largely satisfied by the addition of an integrated Data Science Course. Second, undergraduate medical students understand the relevance of Data Science to their clinical training. Third, we show that there is variation in the perceptions of Data Science by medical students earlier in their training compared to students have begun their clinical rotations.

The impact of the COVID-19 pandemic can be seen in our results. Interestingly, students preferred video lectures and live tutor facilitated Zoom sessions to face-to-face lectures and in-person LGW. This finding was consistent with another undergraduate Data Science Course introduced by Edinburgh Medical School,[11] although this was restricted to a single year group of medical students. Whilst there was a decline in satisfaction between academic years 2019–2020 and 2020–2021, particularly amongst Year 4 students, this may represent technical issues and a collateral effect of reduced clinical experience during the COVID-19 pandemic. The questionnaire response rate dropped significantly between Year 1 and Year 4 of the course (Year 1: 1,683 responses, Year 4: 99 responses) therefore the Year 4 results are more sensitive to fluctuations due to individual ratings. Furthermore, there is significantly less DDS teaching in Year 4 of the course compared to the earlier years (Year 4: 4 sessions v Year 1: 21 sessions), which reduced the impact of the course on the students.

Our qualitative thematic analyses are consistent with the high percentages of students who agree the DDS curriculum is relevant to their medical training and clinical practice. The emergence of language-based artificial intelligence (i.e. ChatGPT), telehealth and increased usage of online platforms across undergraduate medical education could be contributing factors to these views.[21,22] Additionally, the use of selected research studies to illustrate study design and methodological concepts, with topics integrated into the horizontal curriculum may also contribute. The variation in perceptions between Year 4 students, who have begun their clinical rotations, and Year 1 and Year 2 students likely stem as a result of the structure of the medical degree. Students earlier in their degree course may find it harder to relate the material to clinical practice due limited clinical exposure, whilst Year 4 students may have more opportunities to integrate what they have learnt from the course material during their clinical rotations. A potential compromise could be to develop practical sessions with clinical vignettes, as one student suggested from our qualitative thematic analysis.

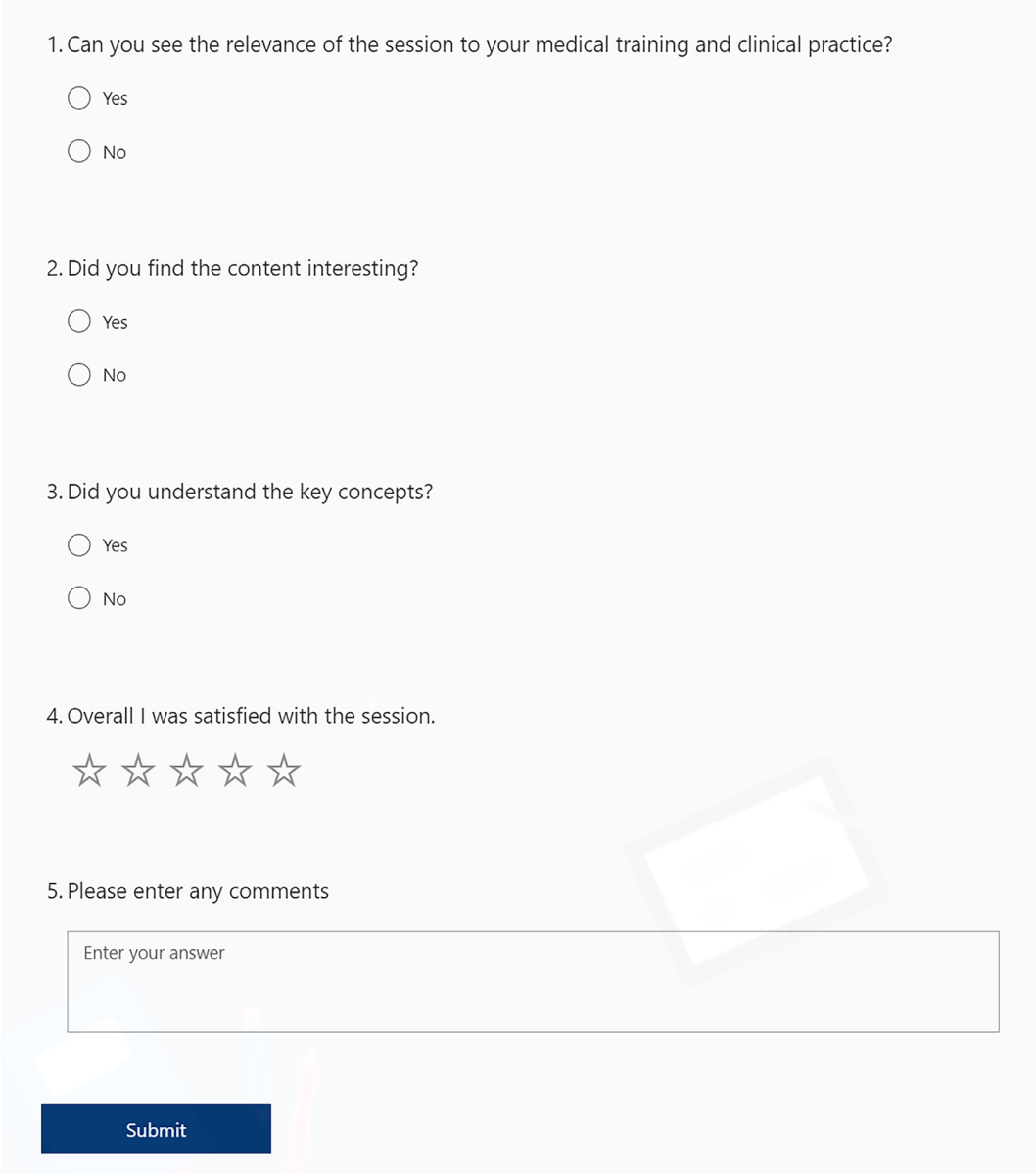

Fig. 1. Example of a questionnaire used to collect medical student feedback.

Strengths and limitations

There are a number of strengths to this study. First, as the study examined satisfaction across multiple year groups and academic years, a longitudinal perspective of medical student satisfaction could be formulated. Furthermore, the administration of the questionnaire following each learning event allowed for identification and revision of pedagogies that were less favorable to medical students. Our qualitative thematic analysis also facilitates future iterative improvements to our implementation. There are several limitations. We did not administer a baseline survey to evaluate the perceptions of medical students prior to the start of the DDS module. Moreover, we did not include all year groups in our questionnaire, eg we excluded Year 5 and Year 6. Response rates to the feedback survey varied across sessions. Given this study was conducted at a single UK medical school, our experience may not be generalisable to other countries or healthcare systems.

Implications and future directions

Our findings provide impetus for other medical schools to implement an undergraduate Data Science curriculum, which covers new data science and digital competency-related topics of increasing relevance, while retaining a strong focus on methodology and interpretation of clinical trials and clinical and population-based epidemiological research. These issues are currently in consultation phase in the UK Medical Schools Council.[23] Given that we have been able to expand and replicate the findings of the existing literature, we believe the implementation of an integrated undergraduate Data Science course is not only feasible, but essential to the training of future medical students. A recent survey demonstrated that 40% of EU-based medical students do not feel ready to enter a data-driven healthcare environment,[15] which highlights the mismatch between undergraduate medical education and the demands of clinical practice. Closing this gap will require a concerted effort among stakeholders, but given our successful implementation we hope that other medical schools will utilise our course structure as a template (Fig. 1).

A next step would be to conduct a Delphi Survey with curriculum developers and students. Local adaptation of our course template may be necessary and medical schools will each need to address their own specific needs. Distribution and sharing of course materials will help facilitate national implementation. We believe that our integrated framework provides a convenient scalable platform to meet GMC competencies,[4] which is crucial if we are to catch up with the current trajectory of data-intensive medicine.

Conclusion

We found that medical students are largely satisfied with the inclusion of an Integrated Undergraduate Data Science Curriculum and understand its relevance to clinical practice. Wider adoption of Undergraduate Data Science Curricula will better equip training physicians to practise in an increasingly data-driven healthcare environment.

Summary box

What is known?

Digital health, data science and health informatics are increasingly important in health and healthcare. However, consensus on how to integrate these areas in undergraduate medical training is currently lacking.

What is the question?

We set out to assess whether a new module regarding digital health, data science and health informatics in the undergraduate medical curriculum could be co-developed, implemented and evaluated.

What was found?

In 2018/19, a new module, 'Doctor as Data Scientist', was co-designed with input of academic staff ($n = 14$), students ($n = 23$), and doctors ($n = 7$). The module involves 22 staff, 120 h (43 sessions: 22 lectures, 15 group and six other) over a 5-year curriculum. Since September 2019, 5,200 students have been taught with good attendance. Module student satisfaction ratings were 92%, 84%, 84% and 81% in 2019, 2020, 2021 and 2022 respectively, compared to the overall course (81% National Student Survey MBBS average since 2019). Topics most highly rated by students were Artificial Intelligence, Study Designs and Measures of Disease. Examinations of all formats included Doctor as Data Scientist content.

What is the implication for practice now?

Further research should consider alternative models of digital health teaching in undergraduate and postgraduate training, but we show that these topics can be taught in a coordinated way to undergraduate medical students.

Contribution statement

A.B. has led the DDS module since inception. The module was co-designed with F.C.L., A.D.I. with management support from S.C. and UCL medical school support from F.G. and R.S. N.A.S., J.U. and IB were medical students who took the DDS module and were involved in feedback and iterative changes and improvements. N.A.S., A.B. and S.C. wrote the first draft of the manuscript and all authors provided critical input into the final version.

Ethical approval

This project received approval from UCL Research Ethics Committee 7979/003.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.clinme.2024.100207.

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