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MEDHAX: A Digital Resource 'By Students, for Students' to Enhance Integrated Learning in Sociocultural Health for a Preclinical Medical Cohort

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MEDHAX: A Digital Resource 'By Students, for Students' to Enhance Integrated Learning in Sociocultural Health for a Preclinical Medical Cohort

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Abstract

The disciplines of Evidence Based Medicine (EBM) and Health Sociology (HS) are essential to the practice of person-centred medicine. However preclinical medical students often struggle to comprehend the relevance of these disciplines to their future practice, potentially leading to a neglect of obtaining essential knowledge to assist their future patients. To address this challenge, three supervised rural medical students co-designed and developed the online peer learning resource, MEDHAX. This 'by students, for students' interactive, dynamic, and graphically appealing digital platform engages learners through case-based integration and clinical application of EBM and HS concepts, tailored for a rural setting. Seven tutorials were created, encompassing video tutorials, interactive modules, revision notes and self-assessment quizzes. Evaluation surveys were used to guide resource improvement, with 39 responses to the pilot evaluation and 39 responses to the subsequent full evaluation. Survey analysis indicate that student users considered MEDHAX to be highly useful, engaging, and even 'lifesaving', with the overall rating change in content understanding pre- versus post-MEDHAX engagement showing a significant mean change of 2.4 points (95% CI 1.7 to 3.1; $p<0.0001$). Website analytics indicate that the resource was accessed not only by the geolocation of the intended cohort but was shared and accessed globally. A student co-design approach for creating online integrated and person-centred education resources significantly improves student satisfaction, understanding of EBM and HS concepts and increases access to relevant cutting-edge education for preclinical medical students.

Keywords

Peer-assisted learning, online resource development, evaluation, educational equity, Evidence-Based-Medicine, Health Sociology, rural and remote learning, preclinical medical education

Key contributions

1. A 'by students, for students' approach to developing tailored EBM and HS materials for preclinical medical students improves student engagement and satisfaction in these subjects.
2. An integrated case-based approach is a highly effective method for consolidating and revising Evidence-Based Medicine (EBM) and Health Sociology (HS) concepts.
3. Delivery of innovative digital learning materials that are accessible across devices may help to overcome any inequities in educational resource distribution.

Introduction

The Australian medical workforce has a shortage of medical practitioners in regional and remote areas (Department of Health, 2013). To address this, Monash University's Medical School implemented a rurally based medical program to increase the supply of rural doctors (Department of Health, 2013). This medical program has a preclinical foundational year, followed by three clinical years. Preclinical medical education aims to integrate theory and practical components alongside early clinical experience (Australian Medical Association, 2023). During this phase, it is vital that students develop solid foundations in Evidence-Based Medicine (EBM) and Health Sociology (HS). EBM and HS are complementary disciplines (Glasziou et al., 2008) essential to practising person-based medicine. HS highlights important elements of care such as social disadvantage and subsequent health inequities, particularly notable in a rural setting (Martinez et al., 2015). EBM is an essential discipline to ensure current research and best-practice form the basis of person-centred clinical practice.

While there are a variety of online medical learning resources available, few cater specifically to preclinical students, especially with regards to understanding EBM and HS concepts. Preclinical students find it difficult to identify how EBM concepts are relevant and applicable in practice, due to limited exposure to the clinical environment (Ellaway & Bates, 2018; Ilic & Forbes, 2010; Mangold et al., 2019). While HS has a more obvious person-centred care focus, students misunderstand the challenging nature of the clinical application of the subject. Indeed, a common mindset among preclinical medical students is that EBM and HS have lesser importance to medical school learning compared to other more traditional curricula such as physiology, anatomy, and pharmacology, anecdotally referred to as 'high yield' subjects by students (Maggio et al., 2016). Reduced student engagement in EBM and HS during the preclinical years can affect student knowledge and learning in concepts that are critical to practising medicine (Smith et al., 2016).

Therefore, to actively assist the preclinical cohort of students to bridge the gap between the clinical utility of EBM and HS, and to address student disengagement in EBM and HS, a 'by students, for students' web-based resource was developed. With explicit and encouraging guidance from faculty experts as well as practising clinicians, three supervised rural medical

students co-designed and built MEDHAX (www.medhax.com). This paper explores the co-creation, roll-out, evaluation, improvements and importance of this online tool. The IDEA-ARC model (Purvis et al., 2024) is used to present the process and findings of this study, as it is a useful framework to clearly articulate research.

The IDEA-ARC model (Purvis et al., 2024) is an acronym identifying seven research phases. The 'IDEA' component Identifies the problem, Drafts the research question(s), Explores methodologies, and Agrees upon the final research process. The 'ARC' component Applies the chosen methods, Reflects, refines and/or evaluates the research that has been undertaken, and Communicates the results.

For the 'IDEA' component of this research, the identified problem was the lack of student engagement with EBM and HS concepts. A targeted resource that would improve levels of student focus and cultivate a deeper appreciation for the importance and relevance of these subjects was identified as a possible solution. The proposed method to better engage students in EBM and HS concepts, was the creation of a web-based resource, which can be used to supplement and strengthen existing curricula. Digital learning has provided new opportunities for teaching and learning that augment traditional face-to-face approaches, and transformations in pedagogy are currently taking place as a result (Richardson, 2010; Smith et al., 2018; Wade et al., 2019).

A well-established method for creating educational content for students is the 'by students, for students' peer-teaching approach. This innovative technique has significant benefits including enhancing student engagement and increasing learning effectiveness and was thus employed in the development of this EBM and HS resource (Allikmets & Vink, 2016).

The involvement of medical students, who had all completed the preclinical phase of the medical curriculum, was a crucial element in the creation of the MEDHAX resource. Student inclusion provided important insights around the learning needs of other students and a relevant student perspective of the entire preclinical curriculum. Student contribution lessened the divide inherent within the hierarchical education system. This model of student and teacher collaboration allows for the development of teaching materials for subjects such as EBM and HS that specifically targets medical curriculum requirements as well as directly addressing student learning needs (Krych et al., 2005).

The name 'MEDHAX' was chosen by the student co-creators to further emphasise the concept of educational 'hacking', whereby previous student learning experiences of preclinical subjects are deconstructed to reproduce innovative ways to achieve the same depth of understanding in a more focused and efficient manner. The notion of 'hacking education' stems from a desire and deep-rooted passion for learning, drawing people together with a shared goal to develop and create suitable resources (Smith et al., 2016; Smith et al., 2018) which is reflected in the

construction process of MEDHAX. A scaffolded learning approach (Hogan & Pressley, 1997) is employed in MEDHAX to allow students to systematically complete components in order to allow for sequential learning and consolidation of knowledge (Bridges et al., 2015).

This study describes how MEDHAX, a 'by students, for students' learning resource for preclinical students to embrace EBM and HS concepts, was designed, iteratively developed and evaluated. We will also demonstrate the value of a 'by student, for student' approach to ensure relatability and usability. Specifically, the research questions were:

1. What was the design process involved in the co-creation and development of a pre-clinical online learning resource for EBM and HS concepts?

The pilot and full evaluation sought to answer:

2. In what ways did the learning resource increase student engagement and learning of EBM and HS concepts?

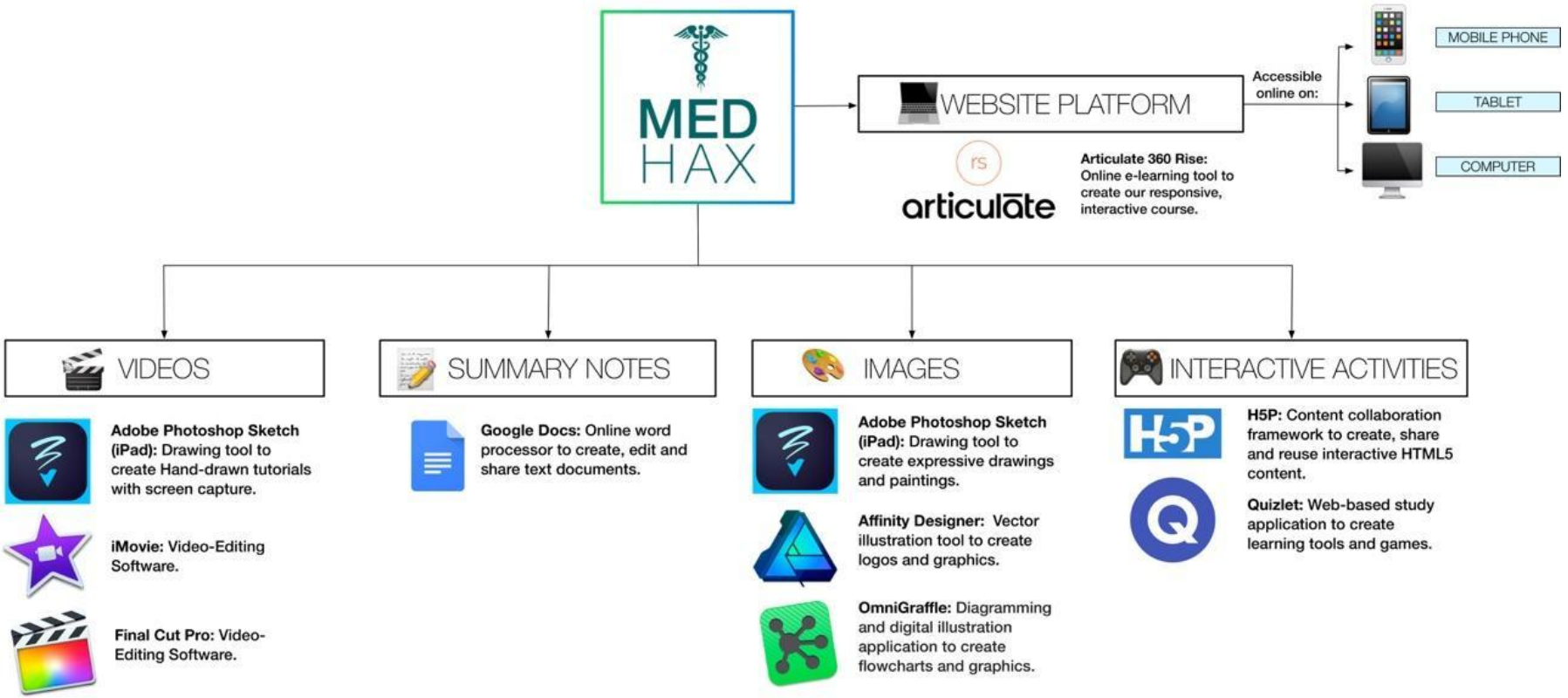
Methods

Research question 1: Design and co-creation of MEDHAX

MEDHAX was developed on the website platform Articulate Rise 360® (Global Inc, New York, USA), which is an interactive and flexible digital platform suitable for designing educational learning materials. Appealing whiteboard animated graphics (Schneider et al., 2023) were created by one of the student co-creators and incorporated into a tutorial video for each case study. Interactive activities were added to consolidate learning from the case. The whiteboard animated tutorial videos were hand-drawn and recorded using an Apple iPad Pro (2017), which were edited using Adobe Photoshop Sketch® version 4.9.0 for iOS (Adobe Systems Inc., California, USA). Further editing was performed using iMovie version 10.0.6 for macOS (Apple Inc., California, USA) and Final Cut Pro version 10.4.6 for macOS (Macromedia Inc., California, USA). The interactive activities associated with each case were custom made on H5P© (Joubel, Troms, Norway) and Quizlet (Quizlet Inc., San Francisco, California, USA), the associated summary notes were created using Google Documents (Google LLC, California, USA) and images were created with Adobe Photoshop Sketch version 4.9.0 for iOS (Adobe Systems Inc., California, USA), OmniGraffle version 7 for macOS (The Omni Group, Washington, USA) and Affinity Design version 1.8.3 for macOS (Serif Ltd., Nottingham United Kingdom). A visual summary of these programs and software utilised can be found in Figure 1.

Figure 1

Software used in the Development of MEDHAX



Research Question 2: Evaluation methods of the MEDHAX Resource

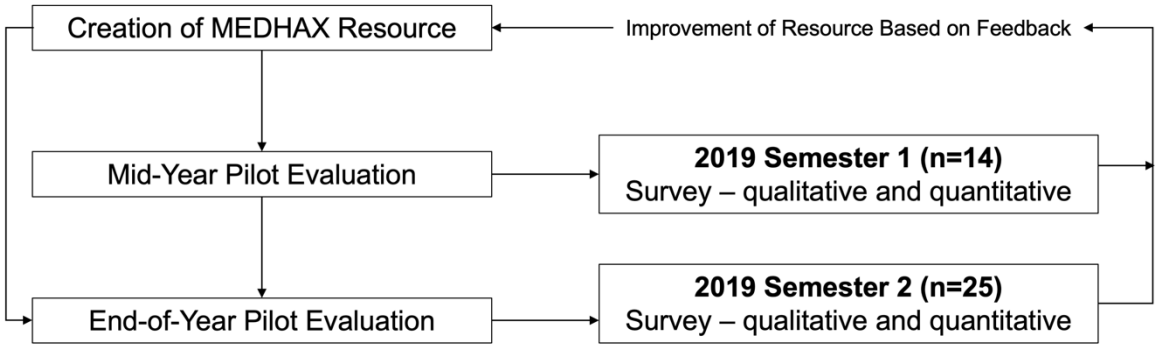
The methods applied in the evaluation of both the pilot and revised MEDHAX resource as well as the analysis and discussion of findings are described using the ARC component (Apply, Reflect, and Communicate) of the IDEA-ARC model (Purvis et al., 2024).

MEDHAX Pilot evaluation

The MEDHAX pilot occurred in two phases, as summarised in Figure 2, demonstrating the iterative process of the MEDHAX website design based on two pilot surveys undertaken following its initial release in the 2019 teaching year.

Figure 2

Creation and Evaluation of MEDHAX during its Pilot Implementation in 2019



MEDHAX was initially introduced in mid-semester one 2019 to a cohort of 100 graduate-entry preclinical medical students at the rural campus of a large Australian university. MEDHAX was promoted in classroom settings and over social media to inform students about its potential for learning and study assistance. A pilot survey was initially undertaken at the end of semester one 2019 to ascertain student usage and engagement with MEDHAX, with the intention of improving and refining the resource in future iterations. Ethics for the survey was approved by Monash University's Human Research Ethics Committee #18052. The semester one pilot survey was created using Google Forms (Google LLC, California, USA) and contained two questions (scored from 1 to 10) where students rated the contribution of MEDHAX to their learning and the likelihood they would recommend MEDHAX. Three free-text boxes asked: "what aspects of the resource were most useful or valuable?", "how would you improve this resource?", and "any general comments".

A second-phase pilot survey sought additional information on student usage, engagement and satisfaction pertaining to the usefulness of MEDHAX at the end of the preclinical year in 2019.

The second survey was simplified to target information on MEDHAX usefulness and assessment outcomes. The survey, conducted via Qualtrics© (Provo, UT, USA), contained two questions (scored 1 to 5) where students rated the usefulness of MEDHAX and considered how it contributed to assessment outcomes. There was also an opportunity to provide additional comments in a free-text box.

Qualitative analysis of data from the pilot was conducted on the combined free-text responses from both surveys. Using thematic analysis (Braun & Clarke, 2021; Braun et al., 2019; Clarke & Braun, 2018), the student-research team (JZ, AL KY), supervised by the academic team (AM and MS), conducted an analysis of these initial findings. Thematic analysis was chosen as the method for analysing our qualitative findings because it is an inductive method which allows for the active immersion of the researchers into the research process (Clarke & Braun, 2018). Thematic analysis is a widely used method of qualitative data inquiry due to its comprehensibility and flexibility and proved a useful method for our study, particularly for the student-researchers (Braun et al., 2019). To thoroughly analyse the data, we became very familiar with the data set, reading and re-reading the quotes, followed by searching for themes or patterns in the data in an interpretive and meaningful way to make sense of the responses.

The analysis of the pilot survey responses facilitated an iterative process of design and development though which areas outlined by students that needed improvement could be refined (Figure 2). Additionally, new features and cases were added to this improved MEDHAX design. Feedback from faculty experts in medical education at the university, and from academic delegates following national and international conference presentations, further enhanced the resource.

Full Evaluation of the revised MEDHAX resource

The preliminary student evaluation and broader medical educator feedback led to the revised version of MEDHAX, launched at the beginning of the 2022 Australian academic year. A mixed-methods evaluation was undertaken during 2022 through to mid-2023. This evaluation was approved by Monash University's Human Research Ethics Committee as an amendment to the original pilot ethics #18052.

PULTS Survey

The *Perceived Utility of Learning Technologies Scale* (PULTS) survey (Herbert et al., 2017), is an evaluation tool validated specifically for technology-integrated online learning environments, making the PULTS an appropriate evaluation tool for MEDHAX. PULTS was developed and validated within the University of New South Wales by the Faculty of Medicine's Blended Learning Project (Douglas & Chapman, 2023; Herbert et al., 2017; Torda & Shulruf, 2021; Wade et al., 2019).

The PULTS survey consists of fourteen questions (Appendix 1):

- Questions 1-9 focus on various aspects of utility of the learning technologies, engagement, and feedback (6-point scale questions with 1=strongly disagree to 6=strongly agree)
- Questions 10-12 assess perceived understanding before and after exposure and the overall value of the relevant learning technology (an 11-point rating scale with 0=least understanding to 10=most understanding)
- Questions 13-14 are open-ended qualitative questions about the educational resource and allow for any suggested changes as a peer-review process

The PULTS survey (Herbert et al., 2017) was embedded into the online MEDHAX site. The PULTS link survey was available at the end of every case-study, enabling feedback from any user, and enabled users to provide feedback on one or more cases. The embedded PULTS survey also allowed feedback from users external to the targeted student cohort which enhances the reach and relevance of the tool.

PULTS data was graphed and analysed using GraphPad Prism® (GraphPad Software, 2023). PULTS questions 1-9 are presented as percentages and graphed on a stacked bar graph. Analysed data from PULTS questions 10 and 11 is presented as a change in overall rating pre- versus post-MEDHAX engagement and graphically displayed as violin plots incorporating the mean, 25th-75th centiles and minimum and maximum values. Normality of PULTS questions 10 and 11 data was confirmed by Kolmogorov-Smirnov test and visually using a Q-Q plot. Differences in Q10 pre- versus post-engagement was tested using a two-tailed Wilcoxon signed-rank test with statistical significance set at $p<0.01$.

Thematic analysis of the qualitative PULTS comments was undertaken by the three senior academic authors using a phased process of iteratively checking, reflecting and consolidating themes based on consensus in order to establish broad thematic categories (Braun & Clarke, 2021; Braun et al., 2019; Clarke & Braun, 2018; Renjith et al., 2021). The PULTS evaluation for the revised MEDHAX resource was supported by website analytics which enabled further longitudinal data collection of student interaction and engagement with the online learning resource.

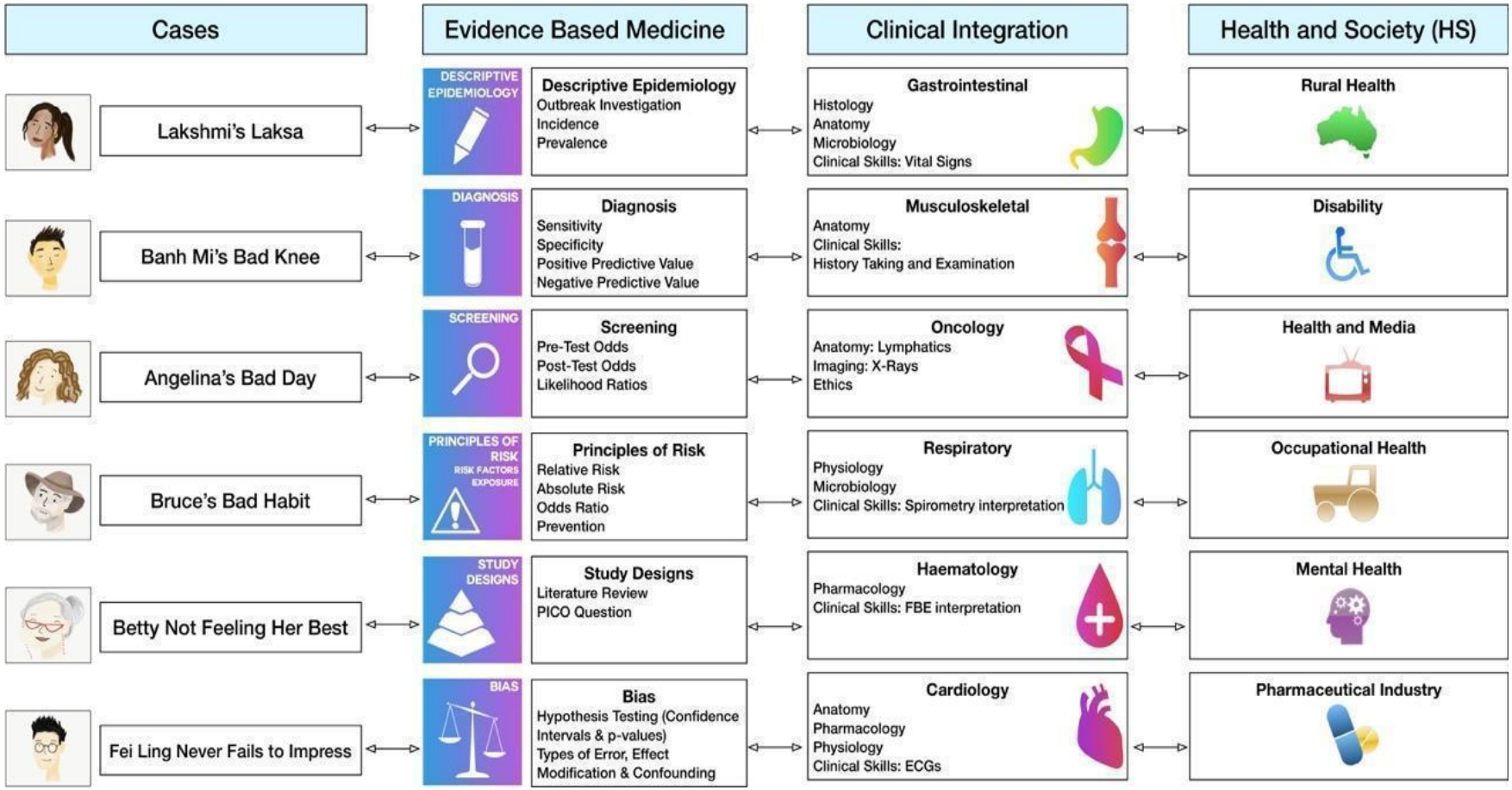
Results

Research Question 1: Co-creation of medical educational resources ‘by students, for students’

MEDHAX was iteratively co-designed and developed by students and supported by academic staff. The resource consisted of six uniquely designed cases with the addition of a seventh case post-pilot evaluation. Each case was tailored to explore and emphasise specific EBM and HS concepts directly derived from university curricula (Figure 3)**.**

Figure 3

MEDHAX Content Map Presenting Clinical, EBM and HS Concepts, Contextualised within Person-Centred Cases

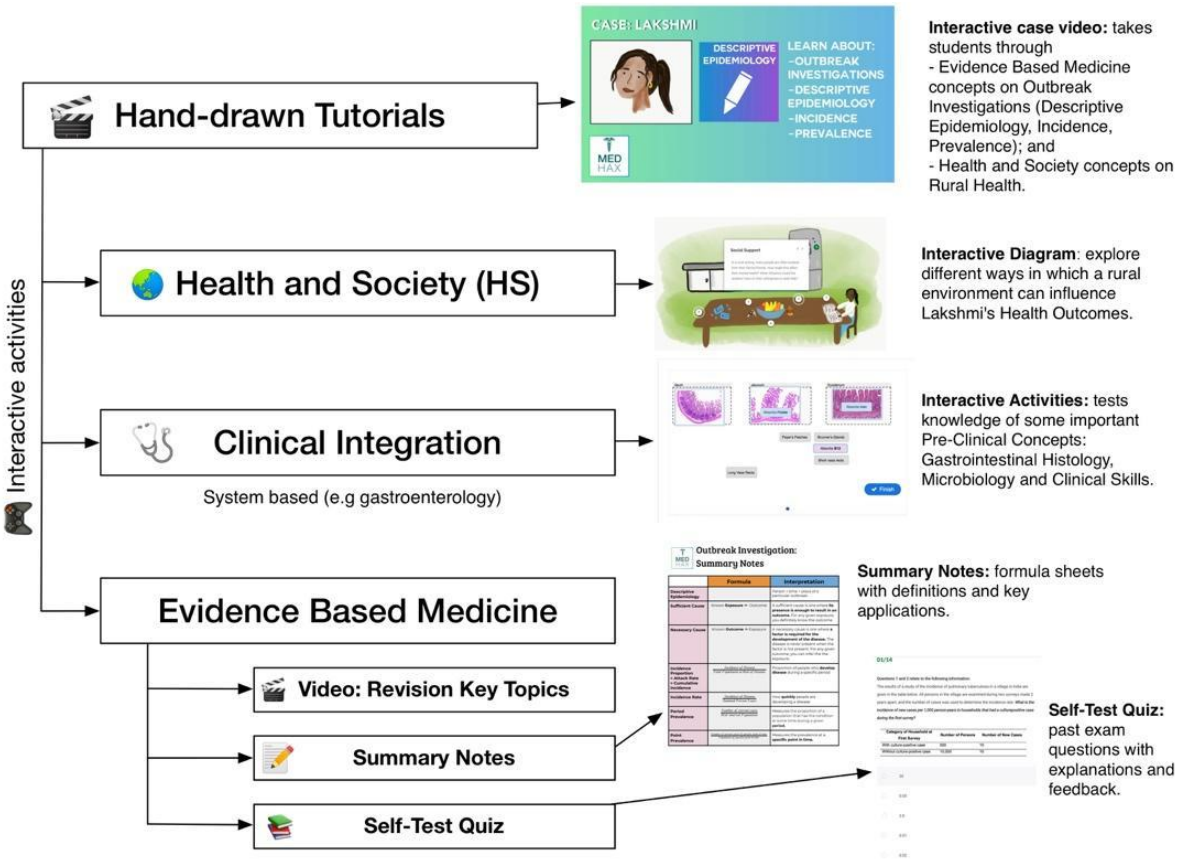


The MEDHAX Cases

The creation and production of each MEDHAX case followed a systematic approach as described in Figure 4. Each character-based case study was designed to highlight applications of EBM and HS concepts in a clinical setting by addressing specific selected components of the EBM and HS curriculum while integrating these with notions of person-centred care. The EBM and HS principles were mapped against a case history and the supportive materials required to consolidate the learning from the case. Utilising the 'Lakshmi's Laksa' case as an example, the storyline follows an outbreak investigation (EBM concept) in a rural setting (HS concept). In the animated video tutorial, personal details of Lakshmi and her business are intertwined with the explanation of EBM Outbreak Investigation concepts to cement the importance of focusing on the person within society. Other aspects of the curriculum, such as gastrointestinal anatomy, microbiology, and histology, are also explored using the interactive activities, to showcase the integration of EBM and HS with the rest of the course material.

Figure 4

Production Development of a MEDHAX Case Demonstrating how EBM and HS Concepts are Clinically Relevant



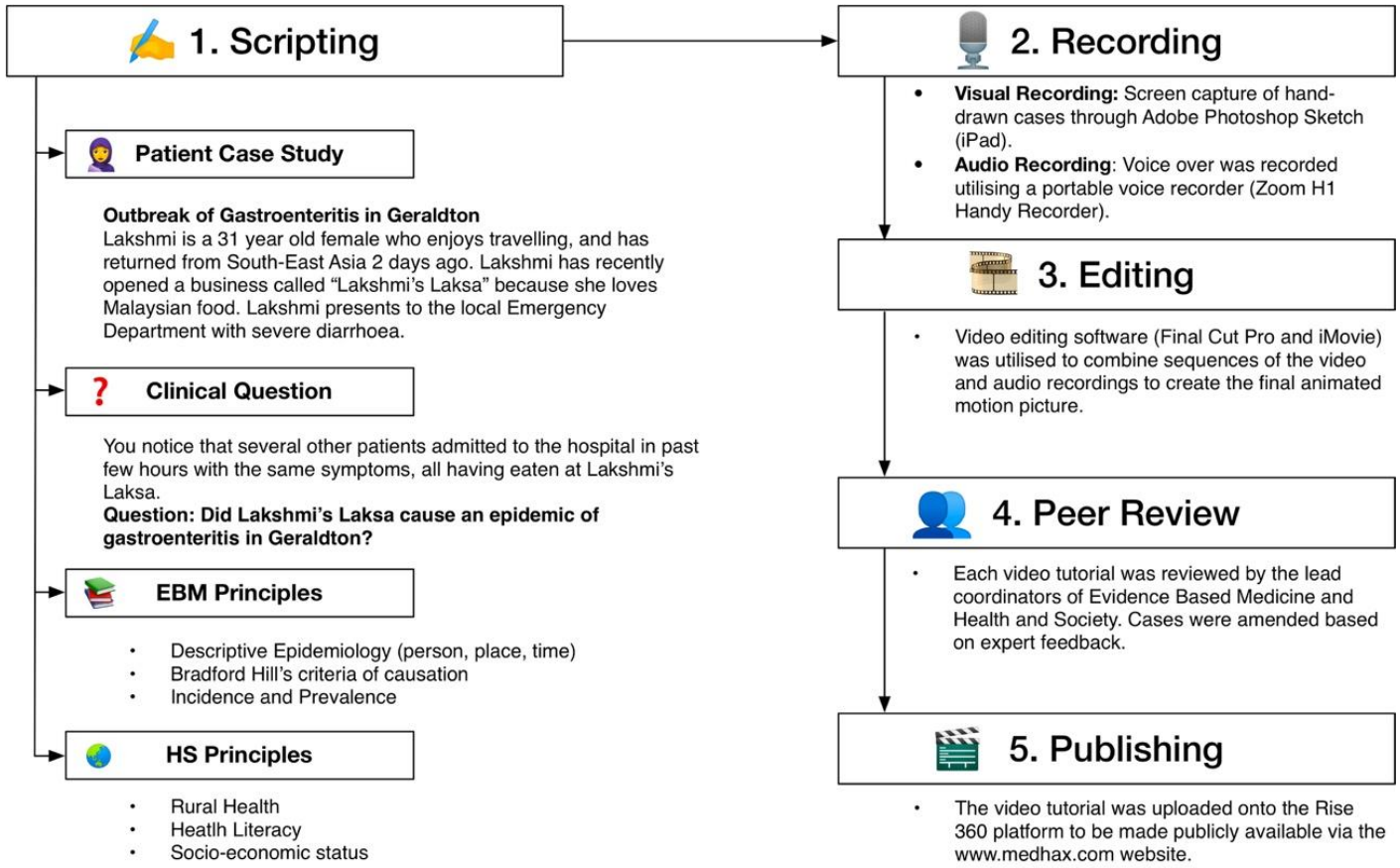
Each case was developed using a stepwise process involving scripting, recording, editing and peer review before its release online (Figure 5). The accompanying learning consolidation material varies from case to case but often involves interactive activities such as quizzes, information matching, interactive diagrams as well as other web links for further consolidation, to enable students to gauge and evaluate their own learning.

Practising clinician perspectives were also incorporated into MEDHAX to assist in the contextualisation of the clinical application of the EBM and HS concepts. Clinicians were recruited using a snowball sampling technique from our university and its affiliated hospital teaching staff. The medical students on the MEDHAX research team interviewed these clinicians face-to-face or through video calls to gather their insights regarding the real-life importance and applicability of EBM and HS concepts. Students using MEDHAX can refer to these clinical perspectives to further their understanding of the relevance of these topics to their future healthcare practice.

Each MEDHAX case module is available to access via a main landing page, which provides information about the topics covered in each case. This approach enables the students using the resource to select which cases are most relevant to their individual learning needs at particular times. The main page also provides introductory material detailing the purpose of MEDHAX, access to clinician interviews related to the importance and application of EBM and HS and links to a MEDHAX evaluation form.

Figure 5

Video Production Process of each MEDHAX case, from Script through to Publication



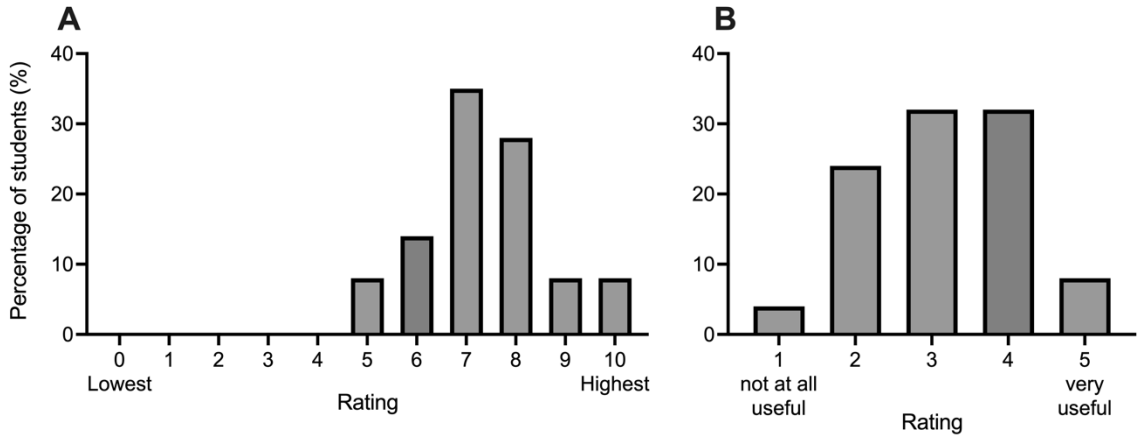
Research Question 2: Evaluation of MEDHAX Resource

Evaluation of MEDHAX Pilot

Overall, 39 students participated in the two pilot evaluation surveys, 14 from semester one and 25 from semester two (Figure 6). Quantitative data from the semester one survey shows that 79% of students (n=14) scored between 7-10 when asked, “How likely is it that you would recommend MEDHAX?”. With an average score of 7.4 out of 10, this indicated that most students view MEDHAX as a valuable resource worth recommending to their peers (Figure 7).

Figure 6

Likelihood of *Student Recommendation of MEDHAX (n=14) and (B) Students’ Rating of the Usefulness of MEDHAX to their Studies (n=25)*



The Semester 2 pilot survey shows that when students were asked, “How useful was MEDHAX for your studies?” 73% (n=25) scored between 3 and 5 with an average score of 3.13 out of 5. Responses demonstrate that students generally regard the MEDHAX platform as a beneficial resource for assisting with the learning of EBM and HS concepts (Figure 6B).

Open-ended qualitative responses to the pilot survey questions elicited five major themes: clinical relevance, student engagement, concision, accessibility, and quality improvement. For the pilot surveys participants were coded ‘P’ plus their participant number (for example, P1).

1. Clinical Relevance

Many participants reported that clinical relevance and application were the most valuable aspects of the MEDHAX resource. For example, “*The case studies were good, the examples helped me apply the concepts in real life”* [P1].

2. Student Engagement

Most participants found the case-based video tutorials highly engaging and interactive. One participant in response to the question "[w]hat was most useful?] stated:

> *[a]ll of it! Most especially the videos (easy to understand, with great animations!) and accompanying summary notes. The practice exam questions that follow really help consolidate the content. It was also cool to read/hear about clinical perspectives on EBM and Health and Society from practising doctors*. [P3]

3. Accessibility

The accessibility and intuitive user interface of the resource was another highly recommended aspect of the MEDHAX platform. As one participant noted, "*[t]he past exam questions and the side menu interface was really easy to navigate",* while another participant stated that they "*[l]oved the layout and cases*" [P12].

4. Concision

A fourth key theme drawn from the pilot survey responses related to the clear and concise nature of the resource. Students appreciated the ways in which the concepts covered by MEDHAX were clarified in simple ways with one participant summarising the experience of using the resource as "*[s]uccinct and engaging*" [P8].

5. Quality Improvement

The final theme that emerged from the analysis of the pilot survey responses, was the notion of quality improvement for the resource. One participant commented that "*MEDHAX was helpful, however some components were not complete for the Health and Society sections and some of the EBM answers were wrong. Otherwise, a good, quick revision tool*" [P2].

Overall, the themes indicate positive student perspectives on, and engagement with, MEDHAX, with the predominant theme for many students being the 'clinical perspective' aspect of the resource. An important theme identified in the pilot survey was the need for quality improvement in terms of correction of minor errors, particularly in the quizzes and summary notes. In summary, what can be drawn from thematic analysis of the survey data, is that students found MEDHAX to be quick, easy and efficient to use; that it was an excellent and interactive revision tool; and was even described as "*lifesaving"* [P6].

The feedback elicited from students further adds to the iterative dimensions of the research process where the resource is viewed not as a static entity but a dynamic tool that responds to student needs and suggestions thus strengthening the notion of a 'by student, for student' resource developmental approach. This feedback also reflects the fact that the resource was still in its preliminary phase at the time of the pilot survey. All comments and suggestions were considered as part of the development of the revised MEDHAX resource.

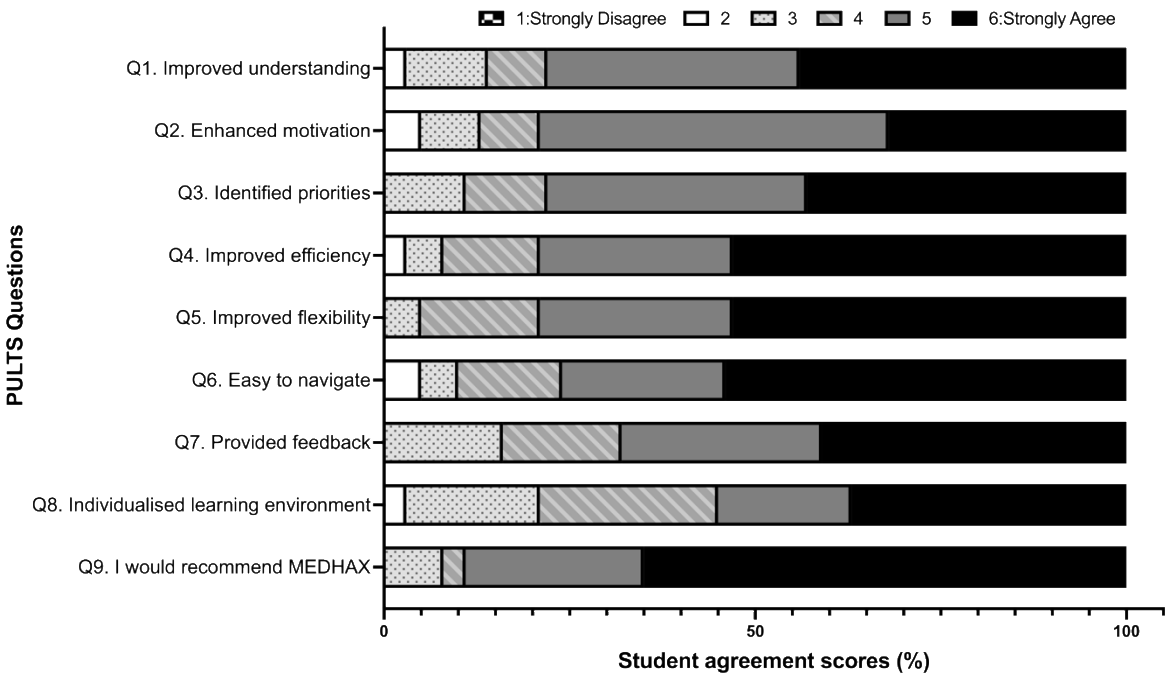
Revised MEDHAX Evaluation

After the initial pilot evaluation, the validated embedded PULTS survey yielded an additional 39 responses across the six MEDHAX scenarios. Not all participants completed all six scenarios, but all gave feedback on at least one scenario. The results for the various PULTS survey sections are outlined below.

Responses to Questions 1-9 of the PULTS survey (Appendix 1) involved the rating of MEDHAX as an educational tool. The 39 collated responses to these nine questions are displayed in Figure 7.

Figure 7

Combined Responses Rating MEDHAX as an Educational Tool

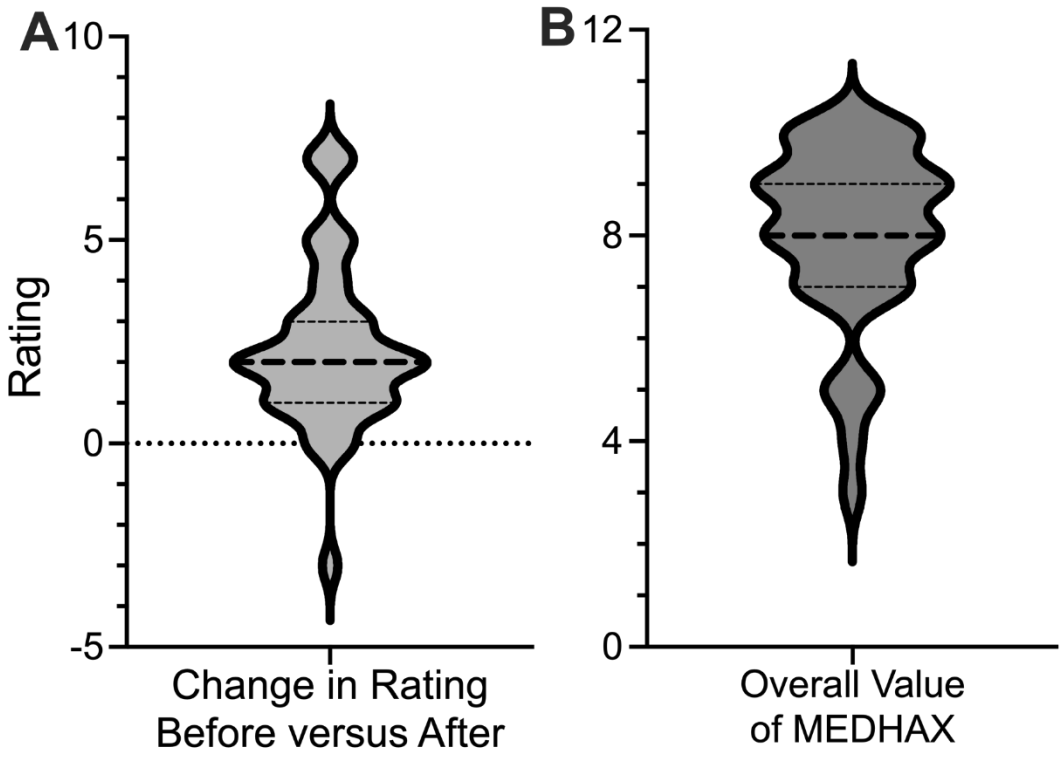


As evidenced by the results outlined in Figure 7, feedback on MEDHAX was very positive. Participants rated the following level of agreement (agree or strongly agree): 79% (n=38) indicated that MEDHAX improved their understanding; 76% (n=38) indicated an enhanced learning motivation; 81% (n=37) indicated that the resource identified priorities for their learning; 79% (n=38) said that the resources met their needs for flexibility in learning; 68% (n=37) said the resource was easy to navigate; 57% (n=37) indicated that the resources enhanced their learning; 89% (n=38) appreciated the individualised learning environment; and 89% (n=38) said they would recommend MEDHAX to others.

Responses to Questions 10-11 of the PULTS survey measured student understanding of EBM and HS concepts as rated pre- and post-engagement with MEDHAX. Question 12 asked students to rate the overall values of MEDHAX to their learning. A rating of 10 indicates a high level of understanding of MEDHAX concepts. The collated responses are shown in Figure 8.

Figure 8

Students' Rating of their Understanding after using MEDHAX. (A) Change in Understanding Rated on the PULTS Pre- and Post-Engagement with MEDHAX (n=37); and (B) Overall Value of MEDHAX to Student Learning (n=37).



Using the 10-point PULTS rating scale, participants rated their understanding of EBM and HS on average 4 out of 10 (95% CI 3.3 – 4.7) prior to working through the MEDHAX scenarios (n=37), which improved to an average of 6.4 out of 10 (95% CI 5.7 – 7.0) post MEDHAX engagement (n=37). The overall rating change in understanding of EBM and HS content pre- versus post-MEDHAX engagement showed a significant mean change of 2.4 points (95% CI 1.7 to 3.1; $p<0.0001$) (Figure 8A), indicating an increase in perceived student understanding of EBM and HS content. Feedback on the overall value of MEDHAX had an average rating of 8 (95% CI 7.4 – 8.6) (n=37) (Figure 8B), highlighting that the students valued the usefulness of the resource in aiding their understanding of EBM and HS concepts. The following qualitative responses highlight student feedback on the usefulness of MEDHAX as a preclinical learning resource and suggest some areas for improvement.

Three themes emerged from the qualitative responses to PULTS question 13 on what was liked most about the educational resource: learning environment; knowledge integration; and quality improvement (peer review). While these themes overlap somewhat with the themes identified in the pilot study, it was considered important that analysis in the developed resource be inductive and not driven by the pilots' themes. Different but complementary themes arose across the development and evaluation phases of the resource (five initial themes in the pilot studies that condensed into a final three themes). It should also be noted that the initial pilot thematic analysis included several one-word themes, which Braun et al. (2019) caution against; thus, in the evolution of themes, the final themes are slightly more nuanced.

The following section outlines the final three themes that were elicited from the qualitative PULTS data with exemplar student quotes. For the PULTS qualitative evaluation of the revised MEDHAX resource, participants were coded with an 'E' plus the participant number (for example, E1).

The first theme identified related to the student learning environment and incorporated their learning preferences and the way the resource delivered learning materials in students' preferential style. This theme is similar to the themes of accessibility and concision from the pilot studies. E4 appreciated the "…*quick snappy videos that focussed on some of the key distinctions that can be confusing, especially with the use of diagrams/pictures/scenarios"* [E4]. Concomitant with the theme of accessibility from the pilot studies, E1 explained that the resource "*was easier to understand from a student's perspective*", demonstrating how the resource is student friendly and accessible. Further enhancing accessibility and engagement (again similar to the pilot studies), students appreciated the gamified learning approach inherent in MEDHAX, with E10 noting, *"[T]he drawings and emojis were encouraging and made the learning more fun".*

The second theme identified in the qualitative data was knowledge integration which benefits students through consolidation of their learning for review and revision purposes. One participant commented that*, "[T]he video was really clear and useful and the questions were a great way to cement the knowledge"* [E6]. Another student noted that: *"[I]ntegrating the different subjects together provided good revision as well as made it more interesting* [E10]. Circling back to the importance of a 'by students, for students' approach, E10 also rationalised that:

> *[d]espite it feeling like an 'extra thing' to cover, the fact that it's peer produced makes me think 1) it's all revision 2) hearing the 'high yield' content that you've chosen to highlight from pre-clinical will make me remember it more next time I hear it. Thank you*!. (E10).

Further, the incorporation of complex concepts was also identified in the data and describes the ways in which EBM and HS content is integrated into the curriculum. This integration

overcomes the propensity for EBM and HS to sit siloed in the medical curriculum, as one participant explained, "[i]*t took such complex concepts and helped me understand it so easily! … Also love the extra resources bringing everything together. MEDHAX has been amazing, thank you guys so much! Amazing for exam prep"* [E15]. This theme further reflects the notion of clinical relevance highlighted in the pilot studies.

The final question on the PULTS survey related to suggestions for quality improvement to the MEDHAX tool by peer learners using the peer generated learning resource. Students provided suggestions on how to make improvements, proofreading, requests for more worked solutions, technical aspects on screen navigation and ideas for future development of cases. For example, students requested more practice questions and question banks, summary sheets and more detailed answers to improve the resource. As an affirmation, the findings on this section directly overlap with the fifth theme identified in the pilot qualitative analysis and further enhances the importance of peer review and involvement in learning materials and processes.

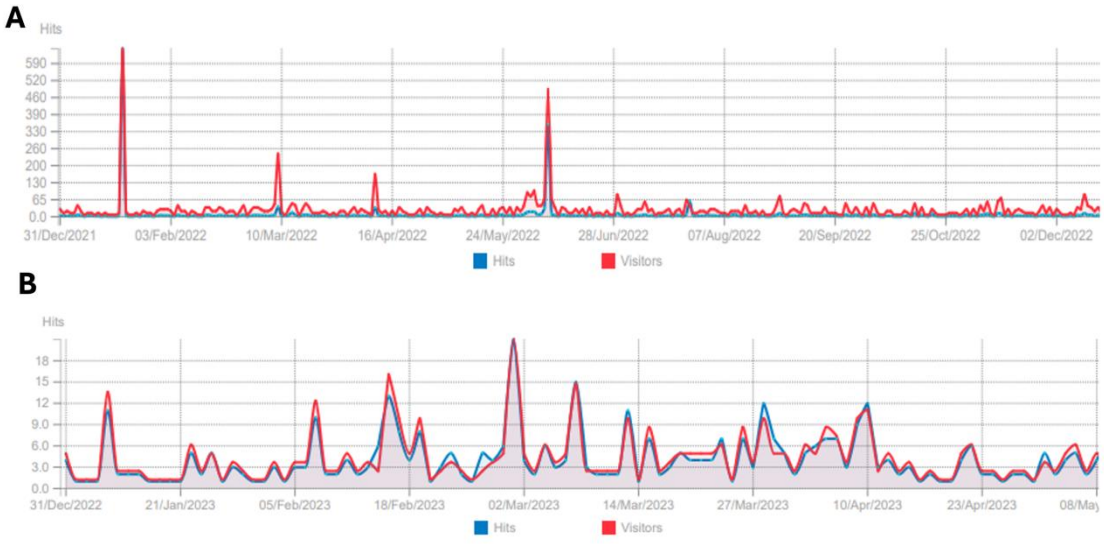
Website analytics

Website analytics were undertaken on the use of the digital resource. At the time of writing, there were 3,616 total users over 2022 to 2023, with 1,559 of these being unique users.

Analytics identify unique visits per day (Figure 9). Of interest, spikes in use parallel across both years and relate to semester- and mid-semester examination periods.

Figure 9

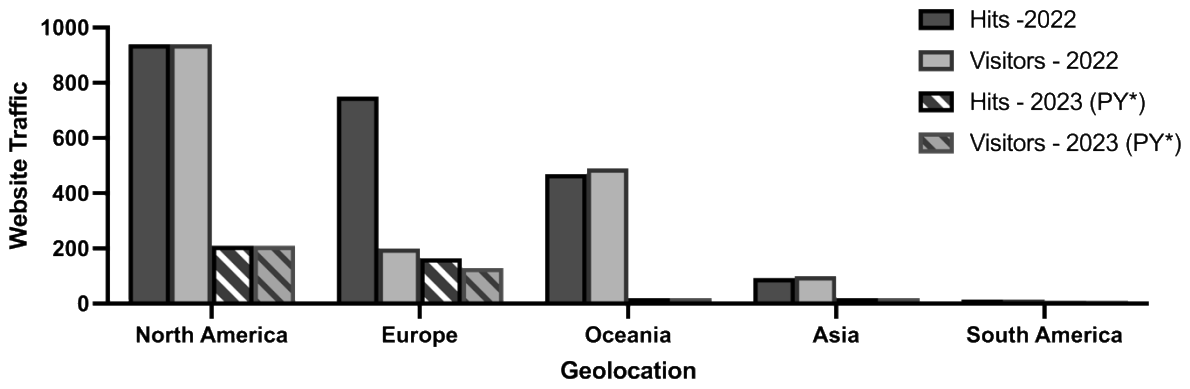
*MEDHAX resource: (A) Unique Visits per Day across 2022; and (B) 2023 (*Partial Year to Date - May 2023)*



Most interestingly and encouragingly, are the geolocation analytics of the unique users (Figure 10). While the resource was developed for medical students enrolled in a rural Australian institution, the geolocation analytics indicate a global reach. In 2022, visitors to the resource were from North America (encompassing Canada), Europe, Oceana, Asia, and South America. In 2023 to date, the order of external engagement has been North America (encompassing Canada), Oceana, Europe, Asia, then South America.

Figure 10

*Geolocation of Users of MEDHAX in 2022 and 2023. * Partial Year to Date - May 2023.*



Discussion

The identification of a need to create a resource to improve student engagement in EBM and HS concepts aligns strongly with the IDEA component of the IDEA-ARC model (Purvis et al., 2024). The initial research question asked what the design process was for the creation and development of a pre-clinical online learning resource for EBM and HS. A structured process guided the design of such a pre-clinical online learning resource, encompassing case development, platform selection and content curation, all following a 'by students, for students' approach.

The rollout of the online pre-clinical learning resource involved pilot testing and feedback, refinement and iteration, and final deployment and implementation. The resulting evaluation explored whether the resource increased student engagement and learning of EBM and HS concepts. The results, communicated using the ARC component of the IDEA-ARC model (Purvis et al., 2024), found that the online learning resource was ultimately successful in enhancing student engagement and understanding of these concepts.

Strong student engagement with MEDHAX underscores the value of a 'by students, for students' approach in developing rich and meaningful medical education content. The co-creation of learning resources with medical students offers a unique opportunity for student-

designers to draw on their own experiences when learning EBM and HS topics, and to reflect on what they might have found useful to better understand and comprehend certain important pedagogical concepts. This collaborative approach also enables the medical students designing the resource to share their own approach to digesting complex topics and applying them in more relatable way for their peers. The design of a resource created 'by students, for students' ensures that other students can utilise this resource through critical periods of their medical studies, emphasising its innovative development and design allowing for consolidation and review of important concepts covered within the resource's parameters.

Moreover, it is evident that a 'by students, for students' approach to developing teaching materials improves overall student understanding, engagement, and satisfaction. The involvement of students in curriculum development takes advantage of expert educators' knowledge alongside students' experiential understanding of the learning experience (Mai et al., 2020). The co-creation of learning materials is further strengthened by including student users in the quality improvement cycle and peer participation in the ongoing renewal and review of the curriculum. In the deployment of MEDHAX, the detailed feedback provided by students shows that they engaged extensively with MEDHAX and conceptualised refinements to increase its learning utility. The themes that emerged from the quality improvement suggestions indicate that the intention of MEDHAX was well targeted with students using the resource, as originally intended, to consolidate their learning and revise for exams. The desire for improved flow of questions, worked examples and more revision questions demonstrate that peers consider MEDHAX worthy of ongoing development. Such detailed peer-review will ensure that ongoing quality improvements maintain and increase the utility of MEDHAX for future pre-clinical medical student cohorts. This strategy ensures longevity and student ownership in the move from co-creation to co-ownership of educational resources.

Qualitative and quantitative results indicate that students engaged effectively with MEDHAX throughout the academic year and used the platform to contextualise, consolidate and revise concepts relating to EBM and HS. As the analytics attest, MEDHAX has also been accessed globally, indicating a reach beyond the intended cohort. Based on these findings, several implications and recommendations are outlined.

The quantitative PULTS responses showed measurable improvement in the students' self-rated understanding of EBM and HS concepts pre- and post-MEDHAX engagement, with students indicating that MEDHAX was highly valuable to their overall learning. This was supported by the qualitative responses from both the pilot surveys and PULTS evaluation which indicate that MEDHAX provided students with engaging revision material and an opportunity to understand the clinical application and relevance of EBM and HS as foundational concepts in medical practice. As illustrated from student responses, linking EBM and HS concepts in a clinically relevant way is important for student learning but not

necessarily a natural 'fit' as outlined in the literature (Maggio et al., 2016). The themes of student engagement and learning environment showcase that having wider student approval in a 'by students, for students' approach ensures relevance and relatability of the tools and materials. The theme of concision from the pilot studies also highlights the requirement that a resource needs a good, clear instructional design so that students not only *will* engage, but *can* engage, which is critical in supporting their learning (Koszalka & Ganesan, 2004). In addition, clear explanations of learning materials ensure that students can learn without feeling that their learning has been compromised by missing important elements or concepts in the course. This important student concern may lead them to perceive that there is a deficit in their knowledge base; a point which reflects the knowledge integration theme of the PULTS evaluation (Evans et al., 2016).

Further, the delivery of innovative digital learning materials that are accessible across devices may help to overcome the inequity of educational resource distribution in rural, remote or isolated areas. For rural medical cohorts who also experience increased distance from teaching sites and limited numbers of peer study groups and senior mentors, online resources such as MEDHAX can help equalise access to appropriate and useful educational resources. It is also recommended that the EBM and HS pre-clinical curriculum teaches core concepts through a rural lens, to allow all students to consider the clinical application of this content within a rural and regional context. MEDHAX, therefore, serves to help level the accessibility of educational resources through enabling *all* students to consider the clinical application of EBM and HS content within a rural and regional context (Ray et al., 2018).

While MEDHAX was revised for its relaunch in 2022, the initial resource was accessible to students and used from 2019 onwards during its iterative phases of development. This was of particular relevance during the social restrictions associated with the COVID-19 pandemic which resulted in a heavy reliance on online teaching to optimise and sustain the educational environment (Bridges et al., 2015). Given the increased use of online learning resources during the COVID-19 pandemic (Karsenti & Charlin, 2008; Sandars et al., 2020), there is a continued need for resources like MEDHAX to engage pre-clinical medical students with the clinical environment while training them in essential areas such as EBM and HS. It is recommended that flexible online learning environments are created to enable students to access content regardless of geographical location (Hogan & Pressley, 1997), as well as supporting students in their self-directed learning (Wu et al., 2021).

Moreover, the integration of person-centred care in clinical cases is essential for teaching EBM and HS concepts (Maggio et al., 2016). Resources such as MEDHAX empower medical and other healthcare professional students, even early in their pre-clinical training environment, to develop and integrate person-centred care in their future clinical practice. The pandemic severely restricted the face-to-face interaction of medical students in both the pre-clinical and

clinical phases, impacting their exposure to, and development of, person-centred care. Issues relating to the social determinants of health and social justice issues are even more relevant during current times of social, political, and economic upheaval that many communities are experiencing. Further, without the research to tackle these issues, enhance treatments and investigate best practice and scientific endeavour, health professional students will not be appropriately prepared for their future practice. MEDHAX provides students with a tailor-made, on demand resource created by students for their peers that ensures that high quality holistic learning can be maintained in the essential areas of EBM and HS, despite constraints in flexible learning (Willems, 2005).

Limitations

There are several limitations in our research design. One limitation is the small number of cases under evaluation. The intent had been to integrate further student designed cases into MEDHAX. However, the impact of COVID-19 on rural-based teaching and learning is still being felt as staff and students continue to adjust. The original student designers have now progressed through their medical studies and into prevocational training. A way to strengthen this area of limitation is to build the evaluation into an ongoing short annual research project for student enrolment to further develop and refine the resource, thereby expanding the case study bank, and ensuring currency and relevance. A second limitation is in the evaluation processes. Staff capacity limited recent evaluations of the resource even though it is still promoted and used by current student intakes. Factoring this into workloads as an annual cycle would benefit.

A further limitation in the evaluation data is that no specific demographics were collected from those providing feedback, particularly where the engagement was from overseas. This made it unclear which comments were from medical students undertaking the course, or from external users. Finally, funding to assist not only the student development of new internationalised cases suitable for the now global reach of MEDHAX would be beneficial, along with funds to cover the ongoing license purchases of the development software used.

Conclusion

The ‘by students, for students’ digitally co-created resource of MEDHAX has successfully enhanced the teaching and learning of pre-clinical EBM and HS concepts. ‘By students, for students’ online learning resources such as MEDHAX have been shown to successfully complement and strengthen existing curricula, supporting deeper knowledge integration. Designed and refined by students for their peers, online resources like MEDHAX empower learners to take ownership of their education. Both local and global engagement with such resources highlights their value beyond the pre-clinical years. Online resources exemplified by MEDHAX have the potential to equip future medical professionals with stronger EBM and HS knowledge, ultimately contributing to better informed and more integrated person-centred care.

Conflict of Interest

The author(s) disclose that they have no actual or perceived conflicts of interest. The authors disclose that they have not received any funding for this manuscript beyond resourcing for academic time at their respective university. The authors also advise that *no* AI was employed in the development of this manuscript.

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APPENDIX 1 - Adaptation of the Perceived Utility of Learning Technologies Scale (PULTS)

Rating of MEDHAX as an educational tool. Instructions: Please complete the sentence:

1. MEDHAX improved my understanding of the topic.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

2. MEDHAX enhanced my motivation to learn about this topic.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

3. MEDHAX helped me to identify priorities for my learning.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

4. MEDHAX made my learning more efficient.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

5. MEDHAX met my needs for flexibility in my learning.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

6. MEDHAX was simple and straightforward to navigate.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

7.MEDHAX provided feedback that enhanced my learning.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

8. MEDHAX provided an individualised learning environment.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

9. I would recommend MEDHAX to others.

    Likert scale: 1 = strongly disagree → 6 = strongly agree

10. Please rate your understanding of EBM and HS topics BEFORE you used MEDHAX.

    Likert scale: 0 = least understanding → 10 = most understanding

11. Please rate your understanding of the topic AFTER you used the educational resource.

    Likert scale: 0 = least understanding → 10 = most understanding

12. Please rate the overall value of the educational resource for your learning.

    Likert scale: 0 = not useful → 10 = extremely useful

13. Please comment on what you liked most about the educational resource.

    [open text entry]

14. Please comment on what you would like to see changed in the educational resource.