

This Thesis, *Lessons Learned From Piloting an Early Version of a Locally Produced E-Learning Resource for Clinical-Year Medical Students: A Randomised Mixed Methods Study in Cape Town, South Africa*, presented by Vela Njisane and Submitted to the Faculty of The Harvard Medical School in Partial Fulfillment of the Requirements for the Master of Medical Sciences in Medical Education has been read and approved by:



Debra Weiner, MD, PhD



Richard Schwartzstein, MD



Stephen Reid, BSc(Med), MBChB, MFamMed, PhD

Date: May 7, 2019

LESSONS LEARNED FROM PILOTING AN EARLY VERSION OF A LOCALLY
PRODUCED E-LEARNING RESOURCE FOR CLINICAL-YEAR MEDICAL
STUDENTS: A RANDOMISED MIXED METHODS STUDY IN CAPE TOWN, SOUTH
AFRICA

VELA NJISANE

A Thesis Submitted to the Faculty of

The Harvard Medical School

in Partial Fulfillment of the Requirements

for the Degree of Master of Medical Sciences in Medical Education

Harvard University

Boston, Massachusetts.

May, 2019

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Abstract

Reputable subscription-based resources are available to students during medical school. However, they lose access to these resources upon graduation. To mitigate the issues around information access and learning during internship, a plan was made to develop and test a contextually relevant multimedia platform that could be used during medical school and beyond.

A randomised mixed methods study was conducted among clinical-year medical students (years four to six) at the University of Cape Town. Participants were randomised into 2 groups using stratified block randomisation. Group 1 participants used UpToDate (UTD) to learn about breast masses and Four Minute Medicine (4MM) to learn about jaundice. Group 2 participants used 4MM to learn about breast masses and UTD to learn about jaundice. Students then completed a posttest, a post-posttest survey, and an optional interview. The posttest scores, knowledge and confidence ratings, and user experience preference ratings were analysed. Content analysis was used to analyse the qualitative data.

Forty-nine students enrolled into the study. Thirty students (61%) completed the study and 15 students were interviewed. The differences between the UTD and 4MM breast mass scores ($p = .57$) and jaundice scores ($p = .19$) were not statistically significant. Most of the UTD and 4MM users' self-perceived median knowledge and confidence ratings improved. With regard to the user experience preference ratings, four out of the eight domain ratings

were statistically higher for 4MM. These domains were ease of use ($p < .001$), visual design ($p < .001$), interactivity ($p < .001$), and self-assessment capabilities ($p = .01$). UTD was rated as being more trustworthy ($p < .001$). From the interviews three 4MM feedback themes were identified: the ability to attract and support attention, the ability to facilitate understanding, and dependability.

Four Minute Medicine was unable to demonstrate better test performance or greater improvements in self-reported knowledge and confidence. The qualitative feedback highlighted that its educational utility and value could be improved upon by addressing key design, usability and reliability issues.

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Acknowledgements

This thesis would not have been possible without the help of those who assisted in developing the study's protocol, analysing the data, and providing feedback on the drafts of this thesis. I would like to extend my thanks to the following individuals:

My primary thesis supervisor, Dr B. Price Kerfoot, for not only providing feedback and support throughout the study, but for helping formulate the protocol and for reviewing the initial drafts of this thesis;

The thesis committee—Dr D. Weiner, Dr R. Schwartzstein, and Prof. S. Reid— for providing constructive feedback on the protocol and for their recommendations on how the thesis could be improved;

Dr J. Burger for volunteering to take on the task of developing the multiple-choice question posttest for this study;

Drs G. Chinnery, F. Malherbe, and L. Roodt for reviewing specific sections of the posttest;

Dr P. Njisane for assisting with the qualitative analysis and Dr T. Liu for reviewing the initial qualitative codes;

Technobunnies for analysing the quantitative data, Xbarstats consulting for reviewing the data and addressing my questions, and T. Kelley-Kemple and A. Cronin for taking the time to address my statistics related questions during the earlier stages of the project;

Prof. E. Panieri for offering support in South Africa;

Drs M. Thoresen and P. Njisane for reading, proofreading and commenting on the final few drafts of this thesis;

Miss A. Heller, Dr J. Kesselheim, and Dr M. AlBasri for providing support throughout the study;

My parents for funding this study and for their ongoing support;

And finally, I would like to thank all the clinical-year medical students that volunteered to participate in this study as well as the interns that were involved in the multiple-choice question posttest pilot.

This work was conducted with support from Students in the Master of Medical Sciences in Medical Education program of Harvard Medical School. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard University and its affiliated academic health care centers.

Disclosures

The Four Minute Medicine platform used in this study was started by Vela and Phinda Njisane. The content for the two topics was developed with the help of Prof. Eugenio Panieri, a thesis co-supervisor and content contributor. In this study, the initial version of the Four Minute Medicine platform was used to test key assumptions relating to its design and usefulness.

Chapter 1: Background

A number of context specific skills and knowledge gaps have been self-identified by some community service doctors working in KwaZulu-Natal, South Africa (Nkabinde, Ross, Reid, & Nkwanyana, 2013). These skill or knowledge gaps—in surgery, anaesthetics, orthopaedics, paediatrics, and obstetrics (Nkabinde et al., 2013)—may highlight some of the potential issues in undergraduate (medical school) and postgraduate (internship) education and training of junior doctors in South Africa. It is also important to note that the country's health care workforce may not adequately support its population, especially among the rural population (Ntuli & Maboya, 2017). To better address the needs of the country, there has been a push to increase the number of medical professionals (Department of Labour South Africa, 2008) and the focus of medical education has shifted from being specialist orientated to primary care and generalist orientated (Nkabinde et al., 2013). Even with quality and accreditation processes in place there is little evidence to suggest that South Africa is making improvements with regards to health outcomes and health equity (van Heerden, 2013).

E-learning is a well-known educational method that has been shown to be well-received among students (Han, Resch, & Kovach, 2013). It is an under-utilised resource which may potentially allow teaching and learning to occur regardless of one's geographical location or resources, thus facilitating the standardisation of medical curricula (Prunuske, Henn, Brearley, & Prunuske, 2016). In the low-income setting, e-learning has the potential to also assist in training more health care professionals while also improving the trainees' quality of learning (Barteit et al., 2019). Furthermore, e-learning resources may not only assist in the teaching and learning process (Burke & Snyder, 2008; El Sayed & Abdelmonem, 2019; Prober & Heath, 2012) but may also be used to effectively utilise the limited resource of time (Barteit et al., 2019; El Sayed & Abdelmonem, 2019; Prober & Heath, 2012).

South African specialists and medical educators have the potential to augment the clinical formal curriculum by collaborating to develop a contextually relevant online educational resource for their students and junior doctor trainees (i.e., first- and second-year interns). Medical students could then use these resources during medical school, internship, and beyond.

One of the reasons for e-learning use among clinicians is to answer clinical questions that emerge at the bedside (Aakre et al., 2018). A study by Egle, Smeenge, Kassem, and Mittal (2015) among medical students and residents showed that 58% of these trainees leaned toward online resource use. These resources included Google, Wikipedia, UpToDate, Medscape, PubMed, and online textbooks (Egle et al., 2015). Some of these resources are expensive and those that are free may not account for the student's or trainee's prior knowledge and training context. In addition, students who have access to subscription-based services (e.g., online textbooks and UpToDate) lose access to them upon graduation and can be left without these valuable resources during their internship and community service years.

The process of ensuring access to online medical information may alleviate education disparities that exist in the resource limited setting and may even support patient care. However, it is unclear as to what depth these students need to receive their medical information, especially those students starting their clinical rotations.

To better inform the need, feasibility, and design of such a platform, it is important to have some understanding of its potential educational value, the users' experiences, and its reception. This mixed methods study, a randomised experimental study with semi-structured interviews, aims to assess the above by piloting and comparing an early version of a locally produced online platform, Four Minute Medicine (see Appendix A), to UpToDate, an evidence-based point-of-care resource (Hoogendam, Stalenhoef, de Vries Robbé, & Overbeke, 2008).

Chapter 2: Methods

2.1 Study design

This study was approved by the Harvard Longwood Medical Area Institutional Review Board and the University of Cape Town's Faculty of Health Sciences (FHS) Human Research Ethics Committee. It is a single site randomised posttest experimental study with semi-structured interviews. For practical and logistical reasons, the study was limited to medical students at a single institution—the FHS at the University of Cape Town. All clinical-year (years four to six) medical students, who were over 18 years of age, were eligible to participate. Enrolees were randomised to complete readings or modules covering two surgically related topics, an approach to a breast mass and an approach to jaundice. The target was a sample of 100 participants, i.e., 50 students in each arm. If this was achieved, a web-based sample size calculator (Schoenfeld, n.d.) computed an 80% probability of detecting a statistically significant difference in the Four Minute Medicine (4MM) and UpToDate (UTD) posttest scores, if the difference was at least 0.57 times the standard deviation.

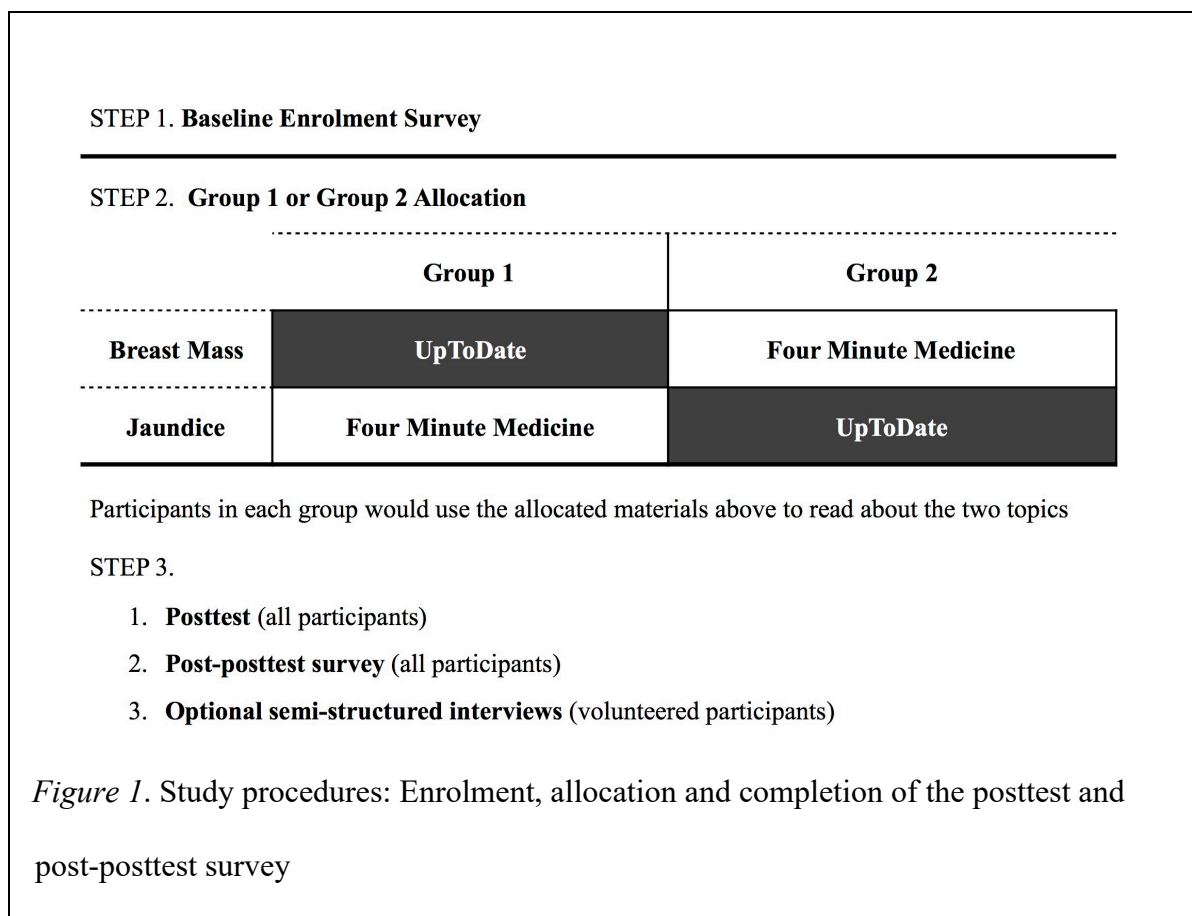
2.2 Study procedures

The study procedures consisted of three primary steps: (1) enrolment, (2) allocation, and (3) the completion of a posttest, post-posttest survey, and an optional interview (see Figure 1).

Students were invited to complete the enrolment survey via email, on-campus poster advertisements, in-class announcements, and the electronic dissemination of the pamphlets via messenger groups and student run social media pages. Upon enrolment students were assigned to one of the two groups using stratified block randomisation. The stratified block randomisation scheme was generated online by Robust Randomization App (Clinical Research APPS, 2017), where stratification was by year of study and the block size was four. Participants randomised to group 1 used UTD to learn an approach to a breast mass (referred to as breast mass in this paper)

and 4MM to learn about how to approach jaundice (referred to as jaundice). Participants in group 2 used 4MM materials to learn about breast mass and UTD to learn about jaundice (see Figure 1).

Participants then completed the posttest and post-posttest survey. Students who completed the study were eligible to receive ZAR100 compensation. They were also entered into one of three ZAR1000 cash draws. Participants who volunteered to be interviewed received an additional ZAR50.



2.3 The learning resources

The two learning resources that were compared were UpToDate, a point-of-care resource, and Four Minute Medicine, a multimedia medical education platform. Both resources make use of text, images, and other visual media. A description of each resource can be found in Table 1.

Table 1. *Description of UpToDate and Four Minute Medicine*

	UpToDate	Four Minute Medicine (preliminary version)
Description	<p>UpToDate (UTD) is a widely used point-of-care resource that has been shown to improve clinical outcomes (“About us,” 2019). It is accessible online or via a mobile application through a subscription. The content is authored and peer-reviewed by expert specialists (“About us,” 2019). UTD makes use of text and hyperlinks to images, tables, medical calculators, and other related topics.</p>	<p>Four Minute Medicine is a web-based platform that has not yet officially launched.</p> <p>It is a multimedia medical education resource for medical students and interns (postgraduate year 1 and 2 doctors) training in South Africa or the limited resource setting. Content would be written by local specialists, student-specialist partnerships, or junior doctor-specialist partnerships.</p> <p>The platform makes use of colour which is used to delineate between subspecialties and to distinguish between the approach and disease summary pages (see Appendix 1). It makes use of 2 types of media:</p> <ol style="list-style-type: none"> 1. Downloadable one sheet (i.e., two page) summaries that cover clinical approaches (type 1 summary) and specific medical conditions (type 2 summaries). 2. Approximately four-minute-long concept, theoretical and topical videos that, depending on the video, make use of video footage, animations, motion graphics, or all of the above.

2.4 Study instruments

2.4.1 Quantitative study instruments. Quantitative study instruments included the enrolment survey, which collected demographic data and baseline self-perceived confidence and knowledge ratings for the 2 topics (see Appendix B); the multiple-choice-question (MCQ) posttest; and the post-posttest survey which collected retrospective pre- knowledge and confidence ratings, the post- knowledge and confidence ratings, as well as overall resource

preference and user experience preference ratings (see Appendix C). It is important to note that confidence refers to the student's confidence in clerking a patient who has a specific sign or symptom.

The MCQ posttest. A third-party general practitioner and clinical educator developed a 30-question breast mass MCQ test and a 30-question jaundice MCQ test. The questions were developed by following learning objectives for each topic (see Appendix D). To confirm the accuracy of the question stems and responses choices, surgeons were asked to review the questions for face validity. Three surgeons volunteered—two breast and endocrine surgeons reviewed the breast mass related questions and one gastrointestinal tract surgeon reviewed the jaundice related questions. This 60-question MCQ test was then piloted among 11 medical interns. The responses and the answer key were then uploaded to the Integrity CastleRock Research software (CastleRock Corp. n.d.) for psychometric analysis. The reliability, measured using the Kuder-Richardson Formula 20, for both the breast mass and jaundice test were low. Questions that reduced the overall reliability of the breast mass and jaundice test sections were removed. The final MCQ posttest that was used in this study was made up of 30 questions, 15 breast mass related questions and 15 jaundice related questions.

2.4.2 Qualitative study instruments. Qualitative data was collected using individual semi-structured interviews. These interviews were conducted with the students who registered their interest to be interviewed in the post-posttest survey. These interviews were either conducted in person or over the phone. An interview guide was developed (see Appendix E), and its aims were to (1) determine the reasons as to why students use online resources, (2) gather student feedback on UTD and 4MM, and (3) identify the features that students would want or to look for in an online resource. Only the 4MM feedback is reported in this paper.

2.5 Outcome measures

The primary outcome measure was student test performance on a jaundice and breast mass MCQ posttest.

Secondary outcome measures reported in this paper include, the pre- and post- knowledge and confidence ratings, student user experience preferences rating for the two resources, and student 4MM related feedback.

With regards to the pre- and post- knowledge and confidence ratings, both the traditional pre-ratings (i.e., the baseline ratings collected before the intervention) and retrospective pre-ratings (i.e., the baseline ratings collected after the intervention) were collected. The original plan was to only report on the traditional pre- and post- knowledge and confidence ratings. However, upon review of the literature, a decision was made to compare both the traditional and retrospective pre- and post- knowledge and confidence ratings to the post- knowledge or confidence ratings. A study by Bhanji, Gottesman, de Grave, Steinert, and Winer (2012) referred to the traditional pre-post and the retrospective pre-post comparisons or analyses as TPP and RPP respectively. These two initialisms will be used in this paper.

2.6 Data analysis

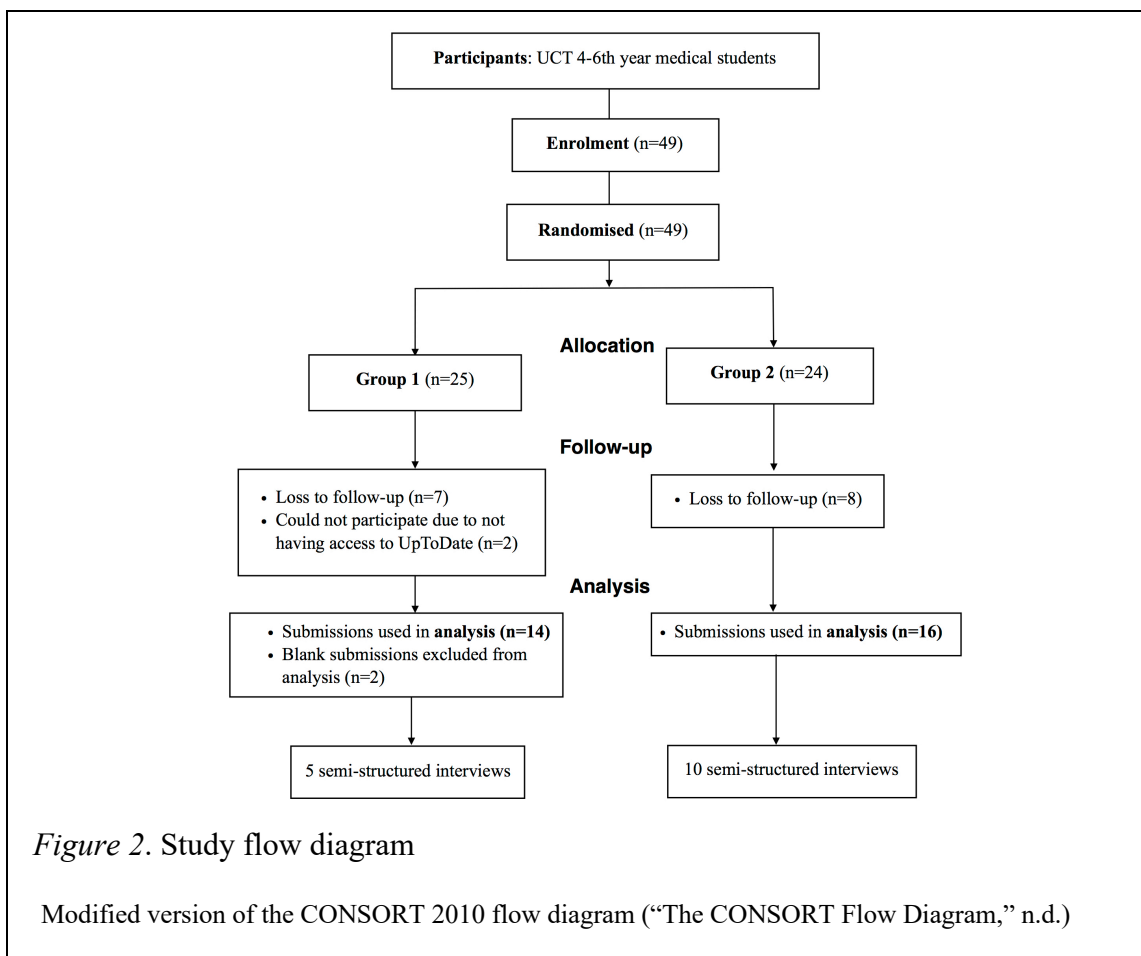
2.6.1 Statistical analysis. The Mann-Whitney U test was used to compare the group 1 and 2 (a) MCQ posttest scores, (b) traditional and retrospective pre-intervention knowledge ratings, (c) post-intervention knowledge ratings, (d) traditional and retrospective pre-intervention confidence ratings, (e) post-intervention confidence ratings, and (f) user experience preference ratings. The traditional or retrospective pre- and post- knowledge and confidence ratings, for each group, were compared using the Wilcoxon signed-rank test. This test was also used to compare the UTD and 4MM user experience and preference ratings. The median and interquartile range (IQR) was reported for all of the above-mentioned variables. Pearson's chi-squared test and Fischer's exact test was used to compare the baseline demographics, except for age, between the two groups. STATA version MP 14 (StataCorp, 2015) and STATA version IC 15 (StataCorp,

2017) was used to run these analyses. An alpha of < 0.05 was considered to be statistically significant.

2.6.2 Qualitative data analysis. Content analysis was performed on the transcribed interviews and on the feedback related open-ended survey question. The content analysis approach that was used was similar to the approach outlined by Erlingsson and Brysiewicz (2017). The difference was that this study's analysis started with open coding rather than meaning units. To generate a codebook, two coders open coded at least 50% of the interviews independently. One of the coders had their codes reviewed by a third party and they revised their codes accordingly. The individual codebooks, from the two coders, generated 35 4MM related feedback codes. Similar codes were merged, and discrepancies were resolved through better review of the data. A single codebook consisting of 19 4MM feedback related codes was generated. A single coder then used this codebook to code all of the interviews and feedback data from the post-posttest survey. Using an inductive and iterative approach, categories and themes relating to the 4MM feedback were developed by the primary coder. These themes were then collaboratively and iteratively reviewed by the two coders (with some additional third-party commentary) to generate the finalised 4MM feedback themes.

Chapter 3: Results

Forty-nine students enrolled to the study, 25 were randomised to group 1 and 24 students were randomised into group 2. Thirty students (61%) completed the learning materials, posttest and post-posttest survey. Fourteen (47%) of these students were in group 1 and 16 (53%) were in group 2 (see Figure 2).



3.1 Quantitative results

Demographics were similar between both groups (see Table 2). The only statistically significant difference was between internet access in the wards ($p = .04$), with all of the group 2 participants ($n = 16$) having access and 10 group 1 participants ($n = 14$) having access.

Table 2. Demographic characteristics of the group 1 and group 2 participants

Demographic Characteristic	Group 1 (n = 14)	Group 2 (n = 16)
Age (years), median [IQR]	23 [22–24]	23.5 [22–25]
Sex, n (%)		
Male	3 (21)	7 (44)
Female	10 (71)	9 (56)
Indeterminate/unspecified	1 (7)	0
Year of study, n (%)		
Year 4	6 (43)	4 (25)
Year 5	5 (36)	7 (44)
Year 6	3 (21)	5 (31)
Race/ethnicity, n (%)		
Black	5 (36)	4 (25)
White	4 (29)	3 (19)
Coloured	5 (36)	5 (31)
Indian	0	4 (25)
Home Language, n (%)		
Xhosa	2 (14)	0
Afrikaans	2 (14)	0
English	9 (64)	12 (75)
Northern Sotho	0	1 (6)
Sotho	0	1 (6)
Venda	1 (7)	1 (6)
Hindi	0	1 (6)
Prior degree, n (%)		
Yes	1 (7)	4 (25)
No	13 (93)	12 (75)
Completed 5th year surgical rotation, n (%)		
Yes	7 (50)	10 (63)
No	7 (50)	6 (38)
Completed 6th year surgical rotation, n (%)		
Yes	3 (21)	4 (25)
No	11 (79)	12 (75)
Access to internet at home, n (%)		
Yes	14 (100)	15 (94)
No	0	1 (6)
Access to internet in wards, n (%)		
Yes	10 (71)	16 (100)
No	4 (29)	0

Note. Percentages have been rounded off and may not add up to 100

The reported median completion of the reading materials for the breast mass topic was 100% [IQR: 100–100] for 4MM and 78% [IQR: 60–90] for UTD. Similarly, the median completion for the jaundice topic was 100% [IQR: 100–100] for 4MM and 75% [IQR: 50–100] for UTD. When learning about how to approach a breast mass, one participant from the 4MM

and UTD user groups reported that they used an external resource, while one participant (7%) from the 4MM users and six participants (38%) from the UTD users reported consulting an external resource when reading about jaundice. None of the students reported the external use of the opposing resource for any of the topics. The differences in the external resource use for both topics (breast mass and jaundice) between the UTD and 4MM users was not statistically significant, $p > .999$ and $p = .09$ respectively.

3.1.1 MCQ posttest scores. The primary outcome measure for this study was performance scores on an MCQ posttest. The median breast mass and jaundice posttest scores were higher for the UTD users. However, the differences between the UTD and 4MM breast mass posttest scores ($Z = 0.57$, $p = .57$) and jaundice posttest scores ($Z = -1.3$, $p = .19$) were not statistically significant (see Table 3).

Table 3. *A comparison between the UpToDate and Four Minute Medicine breast mass and jaundice multiple-choice question (MCQ) posttest scores*

MCQ posttest scores	UpToDate	Four Minute Medicine	Z-score	P-value
	Median % [IQR]	Median % [IQR]		
Breast mass score	77 [67–87]	70 [57–87]	0.57	.57
Jaundice score	73 [57–83]	60 [53–67]	-1.3	.19

3.1.2 Self-perceived knowledge ratings. Regarding the RPP comparison there was a statistically significant difference between the retrospective pre- and the post- knowledge ratings for both topics regardless of the resource used (see Table 4). The TPP comparison only replicated this finding for the breast mass knowledge ratings (see Table 4).

3.1.3 Self-perceived confidence ratings. Similar to the self-perceived knowledge ratings, when comparing the retrospective pre- and post- confidence ratings (i.e., the RPP comparison), a

statistically significant difference between the pre- and the post- confidence ratings, for both topics, regardless of the resource used was observed. However, when looking at the TPP comparison, a statistically significant difference between UTD's and 4MM's traditional pre- and post- breast mass confidence ratings and the 4MM jaundice traditional pre- and post- confidence ratings was observed (see Table 4).

Table 4. *A comparison between the traditional and retrospective pre- and post- knowledge and confidence ratings for the breast mass and jaundice topics for both group 1 (n=14) and group 2 (n=16)*

Self-perceived ratings	Pre-ratings		Post-ratings Median [IQR]	Traditional pre-post (TPP)		Retrospective pre-post (RPP)	
	Traditional pre-ratings	Retrospective pre-ratings		Z-score	P-value	Z-score	P-value
	Median [IQR]	Median [IQR]					
Knowledge ratings							
Breast mass							
UTD (Group 1)	5.5 [2–7]	5 [2–6]	6.5 [6–8]	-2.53	.01*	-3.33	<.001***
4MM (Group 2)	5 [2–6]	5.5 [3–6.5]	8 [7–8]	-3.53	<.001***	-3.51	<.001***
Jaundice							
UTD (Group 2)	7 [5–7]	6 [5–7]	7 [6–8]	-1.63	.10	-3.02	.003**
4MM (Group 1)	7 [6–7]	6 [6–7]	7 [7–8]	-1.88	.06	-3.35	<.001***
Confidence ratings							
Breast mass							
UTD (Group 1)	5 [2–7]	5 [2–7]	7 [4–8]	-1.97	.049*	-3.30	.001**
4MM (Group 2)	4 [3.5–6.5]	6 [3.5–6.5]	8 [8–8]	-3.27	.001**	-3.46	<.001***
Jaundice							
UTD (Group 2)	6 [5–7.5]	6 [5–6]	6.5 [6–8]	-1.06	.29	-2.48	.01*
4MM (Group 1)	7 [6–7]	6 [5–7]	7.5 [7–8]	-2.01	.04*	-3.26	.001**

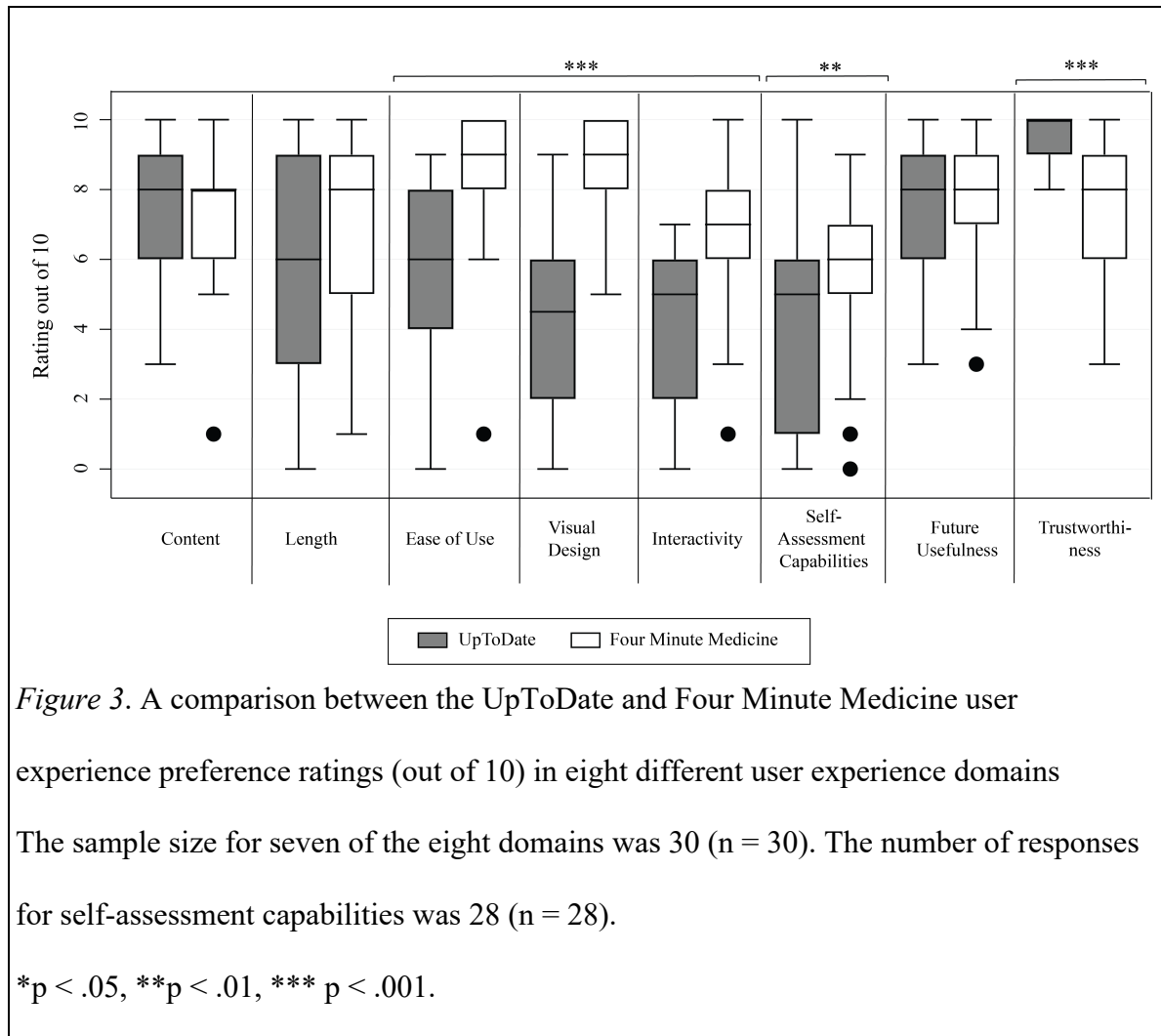
Note. The rating scale is from 0–10; UTD = UpToDate, 4MM = Four Minute Medicine

*p < .05, **p < .01, *** p < .001

3.1.4 Preference ratings

User experience preference ratings. Five domains had a statistically significant difference in ratings, these were ease of use ($Z = -3.92$, $p < .001$), visual design ($Z = -4.70$, $p < .001$), interactivity ($Z = -4.07$, $p < .001$), self-assessment capabilities ($Z = -2.66$, $p = .01$), and

trustworthiness ratings ($Z = 4.60, p < .001$), see Figure 3. Additionally, a between group analysis (i.e., comparing the ratings by participant group) showed that the differences in the group 1 and group 2 ratings, for all eight domains, were not statistically significant.



Resource preference. When asked about resource preference, 52% of the participants ($n = 29$) said that, in the future, they would prefer to use UTD and 48% said they preferred 4MM. The difference in resource preference between the group 1 and group 2 participants was not statistically significant, ($X^2(1) = 1.71, p = .19$).

3.2 Qualitative interviews: Four Minute Medicine feedback

Fifteen participants were interviewed, 10 (67%) were in group 2. With regards to year of study, 33% of the interviewees were in 4th year, 47% were in 5th year, and 20% were in 6th year. From the interviews, three 4MM feedback related themes were identified. These themes were the ability to attract and support attention, the ability to facilitate understanding, and the dependability of the resource.

Theme 1: The ability to attract and support attention. This refers to 4MM's ability generate interest and capture the users' attention for a sustained period time. Two design related elements were thought to influence attention, the resource's visual design and its succinctness. Positive visual elements included the images that were used, the structure of the document, the use of images in the videos, and the use of both text and video to deliver the learning materials. For some of the students, the colour and brevity facilitated user interest and attention. In addition, the brevity of the content facilitated the time efficient review of the learning materials. One student noted that,

“It's not quite the user interface, but the look of the Four Minute Medicine platform was really nice. I mean, it was a colourful resource, so it was easy to—physically interacting with it was easy. Text wasn't too small, things were easier to find. The structure was logical. It followed well. It was nice that the videos were quite short as well. You didn't have to take pauses in between, or pause and go do something else. You could finish a video easily in one sitting and take it in.” (Interview 4)

However, the use of colour was not favoured by all of the students. Students noted that the colour, was distracting, unpleasant or overbearing. One student suggested the use of “a less colourful background to not distract from the content/words” (survey response).

Theme 2: The ability to facilitate understanding. Four Minute Medicine's ability to facilitate understanding was said to be (a) positively influenced by its use of video, which

“helped solidify” (Interview 5) concepts, (b) negatively influenced by the lack of self-assessment tools, and (c) both positively and negatively influenced by the content depth. With regards to the depth of the content one student praised the length of the content and commented that, “I was shocked by how little it actually was and how much just that little bit would matter in terms of actually seeing, diagnosing and managing a patient. So, it was really all that I needed.” (Interview 3)

However, participants felt that 4MM only provided an overview of the subject matter. Some students found this to be satisfactory, while others felt that the lack of depth garnered confusion and unanswered questions. When commenting on the negatives of 4MM and UTD one student reported that, “I think for the Four Minute Medicine, it was too summarised, so it felt like something was missing. And for the UpToDate one, there was just too much information.” (Interview 2)

To combat the issue around the lack of depth in the 4MM content, one student suggested that,

“Perhaps greater detail in content, though this would be at the expense of increasing the length (which is currently very convenient) - maybe providing links to sources with more detailed content

Including clinical scenario MCQs and explanations at the end of a module” (Survey response)

Theme 3. Dependability. Participants found 4MM to not be dependable in many ways. This included their ability to trust the validity of the content and their ability to reliably use 4MM to supplement their formal medical school curriculum, especially in a manner that would help the pass their summative assessments. Some students reported that that they would be hesitant in using the Four Minute Medicine resource if it was not widely used, written by, and endorsed by faculty. Although in favour of some of the resource’s attributes, some students felt that they

could not use it for their formal learning. On commenting on their experience in using 4MM and UTD, one participant expressed that,

“UpToDate is great because everything is on there but UpToDate is terrible because everything is on there. It’s really, really difficult to synthesise that—or to remember everything. . . . The flipside to the Four Minute Medicine thing is that it’s exactly the opposite. It’s synthesised and it’s easy to remember and it’s fun to look at and the engaging visuals, but you could—if that was your only resource going into an exam, you’d be in a lot of trouble. It’s not enough. I think it was an interesting, subtle question the way that it was posed because where is the middle ground?” (Interview 13)

These qualitative feedback themes—the ability to attract and support attention, the ability to facilitate understanding, and the dependability of the resource could contribute to the 4MM’s ability to facilitate learning. If all of these three themes or elements are optimised, the platform’s ability to support learning may increase (see Figure 4).

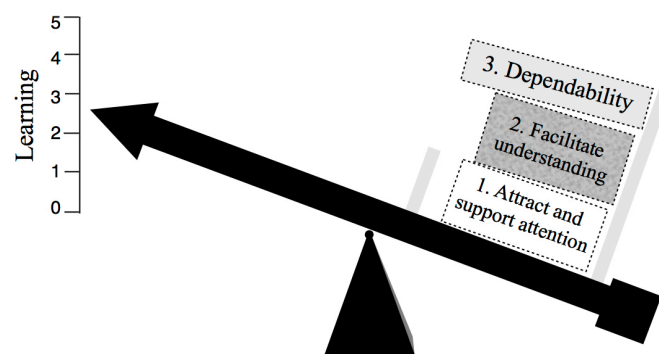


Figure 4. Graphical representation of the relationship between the Four Minute Medicine feedback themes and learning

Chapter 4: Discussion

This study compared a proposed South African based e-learning resource, 4MM, to UTD. Four Minute Medicine was unable to demonstrate better posttest performance. Additionally, the median test scores for the UTD users were higher, regardless of the topic, demonstrating that UTD users performed better than the 4MM users. However, this difference did not reach statistical significance.

The differences between the RPP jaundice and breast mass knowledge and confidence ratings were statistically significant for both UTD and 4MM. The TPP knowledge and confidence ratings could only mirror these findings for the UTD and 4MM breast mass knowledge and confidence ratings and the 4MM jaundice confidence rating. This discrepancy, the discrepancy between the TPP and RPP results, is due to the difference between the students' traditional pre-ratings and retrospective pre-ratings. This difference could be explained by the response shift bias (Bhanji et al., 2012; Geldhof et al., 2018). This bias refers to the change in the manner in which a participant interprets, understands, and therefore scores a self-evaluation question at the end of the learning exercise or intervention (Bhanji et al., 2012; Geldhof et al., 2018). In other words, participating in the intervention may provide more insight about the topic and result in a change in one's baseline ratings. An example that would relate to this study would be a student rating their confidence in clerking a jaundiced patient as a seven out of 10 at the beginning of the study. However, while going through the reading materials they may realise that they did not know much about obstructive jaundice. When they are later asked to rate themselves, they may report a retrospective pre-confidence rating of five and a post- confidence rating of eight. The TPP difference would be one whilst the RPP difference would be three.

Although attractive, Geldhof et al. (2018) report that RPP designs may be subject to error as a result of cognitive dissonance, social desirability bias, temporal self-appraisal

theory (e.g., rating one's retrospective pre-confidence as lower in order to prioritise and maintain one's present positive self-perception), and implicit theories of change (e.g., believing that there should be a difference in pre- and post- knowledge or confidence and reporting a difference when there is no difference to observe).

Ultimately, both TPP and RPP approaches have their flaws (Geldhof et al., 2018). Instead of choosing to use one, both were reported here as their combined use may represent a range in which one could potentially find the actual self-assessment score (Geldhof et al., 2018). It is important to note that these global self-assessment measures have been noted to not positively correlate with objective achievement scores (Bhanji et al., 2012). However, if these measures were compared to the students' posttest scores they may have helped identify the students' global self-assessment ability. Dory, Degryse, Roex, and Vanpee (2010) suggest that insight on individual self-regulatory ability could be highlighted through the concurrent collection of a confidence rating with individual MCQ test responses. Their study evaluated usable knowledge (high confidence in correctly answered questions) and hazardous ignorance (high confidence in incorrectly answered questions) among junior general practitioner trainees (Dory et al., 2010). Educators could use similar measures to quantify a student's self-assessment ability. They could then use this information to guide student teaching and learning by addressing student held misconceptions (Dory et al., 2010).

Even though there were no significant differences between the 4MM and UTD posttest performance or differences in confidence and knowledge that supported 4MM, there may be some merit in iteratively improving and testing the 4MM platform. Participants provided valuable user experience preference feedback and qualitative feedback that should be used to guide future instructional design choices.

Four Minute Medicine performed better than UTD in four user experience preference domains. These were ease of use, visual design, interactivity, and self-assessment

capabilities. The higher interactivity rating is in keeping with some of the literature, as video use has been linked to higher engagement (Roberts et al., 2018; Romanov & Nevgi, 2007). The qualitative feedback provided some possible explanations for these higher ratings, some of these reasons included, the layout of 4MM, its use of multimedia, and the succinctness of the content. However, the qualitative data highlighted that, although out-performing UTD in these domains, there were still major areas for improvement.

Regarding the 4MM design, two key 4MM design elements would need to be addressed—its brevity and its use of colour. For example, 4MM’s use of a coloured background was not accepted by all the participants. Amending this is important as students reported that the background negatively affected their experience and attitudes towards the 4MM platform. It may have even affected their ability to learn on 4MM, as colour has been shown to influence attention, memory, and recall (Dzulkifli & Mustafar, 2013; Olurinola & Tayo, 2015).

The 4MM content was kept short to ensure simplicity and to facilitate the delivery of high-yield information. The hope was that this would facilitate rapid review of the content, improve user confidence and knowledge on the topic, and prevent mind wandering and distractions, a known issue in e-learning (Kohan et al., 2017). Unfortunately, however well intentioned, the qualitative data highlighted that this may have negatively impacted some of the users’ understanding of the topic—especially for those that had limited prior knowledge. Ultimately, there seemed to be conflict between the depth of the content (which seemed to affect understanding and learning) and the brevity of the content (which positively affected attention and learning). The satisfaction with the platform, although not objectively or subjectively measured in this study, and learning may have been affected by these two conflicting elements. A potential solution to address the issue of depth, without compromising the platforms ability to attract and sustain a user’s attention, would be to make

use of hyperlinks, tooltip, and quizzes. Some of these tools would allow students to scale and control the volume of information that they would like to read at any given time. These tools may also further facilitate learning and engagement. It is important to note that hypermedia has the potential to negatively affect working memory (Saparova & Nolan, 2016; Yavner et al., 2015). However, their strategic use may better facilitate knowledge acquisition (Dong & Goh, 2015; Saparova & Nolan, 2016; Yavner et al., 2015) and increase 4MM's educational utility.

Even with the issues outlined above, just under half (48%) of the participants reported that they would prefer to use of this resource in the future. Unfortunately, the context in which students would find 4MM helpful was not explored. A survey among residents and medical students showed that UpToDate was preferred as a point-of-care resource but not for dedicated study, where books (textbooks or board review books) prevailed (Egle et al., 2015). It is, therefore, important to know the contexts in which students engage with web-based resources so that they can be better tailored for their learning environment and learning needs.

E-learning pilots in sub-Saharan Africa have yet to capitalise on the transformative potential in scaling medical education and improving the quality and quantity of doctors in the limited-resource context (Barteit et al., 2019). A number of reasons for this have been identified, these include the lack of technological support, the inability to show educational efficacy, and the lack of integration into the teaching and clinical context (Barteit et al., 2019). Beyond meeting student expectations, and potentially transforming education, the use of technology may also be positively correlated with self-directed learning practices (Rashid & Asghar, 2016).

There are many e-learning resources on the market, 4MM's potential value would be in adapting to meet the e-learning needs of South African institutions by supporting blended

learning and facilitating self-directed learning among the students and interns. It is, therefore, important to ensure that the future development of 4MM is done in collaboration with the universities' medical students and faculty members, and South Africa's junior doctors.

4.1 Limitations

Due to several limitations the results of this study should be interpreted with caution. Study limitations include the study's small sample size, the high attrition rate, the potential contamination between the two user groups, and the potential effect that social desirability bias may have had on the feedback that was given via the post-posttest survey and interviews.

Throughout the study multiple strategies were implemented to improve recruitment. Some of these strategies included the use of social media and messenger applications, extending the study by a month, and adding the cash draws to the compensation. Contamination was addressed by instructing participants to only use the learning materials and links that they were instructed to use. In addition, participants were asked to report any external resource use in the post-posttest survey. From the survey responses, there was no evidence to suggest contamination between the two groups. To combat social desirability participants were asked to describe their experience in using the two resources and to identify positive and negative attributes for both resources.

4.2 Future studies

Future studies in this context should aim to evaluate these resources not only at the level of the learner, but also at the level of the institution. The cost of developing these resources should also be evaluated. An example of an evaluation model that assesses the above is the holistic technology-enhance learning evaluation model (Pickering & Joynes, 2016). This model is especially ideal for institutionally developed or implemented resources as it supports a student centred approach, outlines how one should evaluate user satisfaction and impact,

and further expands on how an institutions may evaluate their return on investment (Pickering & Joynes, 2016).

4.3 Conclusion

Four Minute Medicine was not able to demonstrate better posttest scores. This study formally tested and addressed some of the key assumptions that had been made about e-learning in the resource-limited context. The main assumptions were that students prefer and learn better from brief contextually relevant multimedia materials. The biggest lesson learned was that some of initial design choices may have increased extraneous cognitive load. South African e-learning resources, or resources that have been developed specifically for its medical students, are scarce. It is, therefore, important to iteratively test and improve upon these resources so that the knowledge and skills gaps of medical students training in the limited-resource context can be adequately addressed during medical, internship, and beyond.

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Appendices

Appendix A. Four Minute Medicine wireframe



- wireframe -

Description
Four Minute Medicine is a multimedia medical education platform that aims to improve access to contextually relevant and abridged medical information.

Proposed Content
The website will host text and video content.

A. Text based content
Downloadable one sheet (i.e. 2-page) summaries.

B. Video content

1. Four-minute videos. These videos may cover approaches, diseases, procedures (i.e. a step-by step guide) or other topics of interest.
2. Self-paced online courses

Investigation

General Surgery

Medicine

Gynaecology

Obstetrics

Paediatrics

Neurosurgery

Orthopaedics

Psychiatry

Forensics

Website menu bars (including the side bar) were disabled during during the study

Search

Specialty: An approach to

Symptom or sign

definition of symptom or sign

Summary Type 1: An approach summary page to a symptom, sign or investigation

Videos

▶

▶

Related Summary

disease/condition

[Text placeholder]

Summary Type 2:

Specific Disease/condition

▶

Videos

Videos are approximately 4 minutes in duration. These videos can be: an approach to a sign, symptom, or investigation; cover a specific condition/disease; or address other non-clinical topics of interest.

Appendix B. Enrolment survey¹

INFORMED CONSENT FORM (not included)

CONTACT

Please fill in the following:

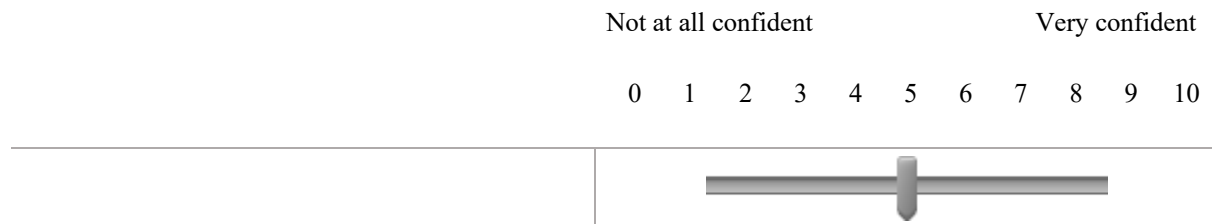
- First Name _____
 - Email Address _____
 - Year of Study in 2018 (please type: 4, 5 or 6) _____
-

KNOWLEDGE AND CONFIDENCE RATINGS

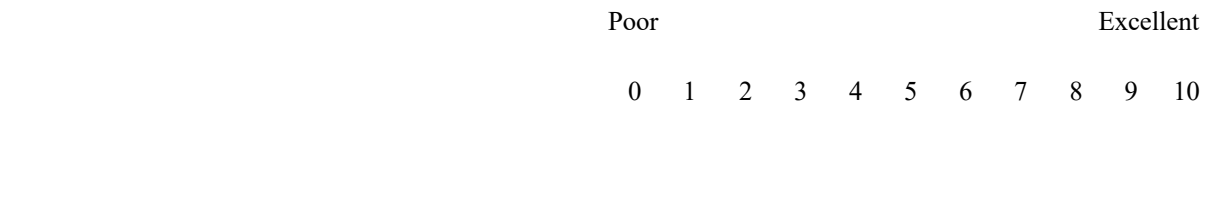
Using the slider: At present, how would you rate your KNOWLEDGE on breast masses and breast mass related diseases?



Using the slider: At present, how would you rate your CONFIDENCE in clerking a patient who presents with a breast mass?



Using the slider: At present, how would you rate your KNOWLEDGE of the causes of jaundice?



¹ Edited version of the study's survey that was generated on and downloaded from Qualtrics (versions September 2018- January 2019)



Using the slider: At present, how would you rate your CONFIDENCE in clerking a patient who presents with jaundice?

Not at all confident Very confident

0 1 2 3 4 5 6 7 8 9 10



DEMOGRAPHICS

Age

- 18–65 (select option between 18–65)

Sex

- Male
- Female
- Intersex
- Indeterminate/unspecified

Race/Ethnicity

- Black
- White
- Coloured
- Indian
- Asian
- Other

Display This Question:

If Race/Ethnicity = Other

Please specify:

Home Language

- Zulu
- Xhosa
- Afrikaans
- English
- Northern Sotho
- Tswana
- Sotho
- SiSwati
- Tsonga
- Venda
- Ndebele
- Other

Display This Question:

If Home Language = Other

Please specify:

Do you have a degree?

- Yes
- No

Display This Question:

If Do you have a degree? = Yes

If yes, please specify

What is your year of study?

- 4th year
- 5th year
- 6th year

Have you completed your 5th year surgical rotation?

- Yes
- No

Display This Question:

If Have you completed your 5th year surgical rotation? = Yes

If yes, please specify the site:

- Groote Schuur Hospital
- New Somerset Hospital
- Victoria Hospital
- Mitchell's Plain District Hospital

Display This Question:

If Have you completed your 5th year surgical rotation? = Yes

If yes, please specify when

- Block 1
- Block 2
- Block 3
- Block 4
- Block 5

Have you completed your 6th year surgical rotation?

- Yes
- No

Display This Question:

If Have you completed your 6th year surgical rotation? = Yes

If yes, please specify [sic]

- Groote Schuur Hospital
- New Somerset Hospital
- Victoria Hospital
- Mitchell's Plain District Hospital

Display This Question:

If Have you completed your 6th year surgical rotation? = Yes

If yes, please specify when

- Block 1
- Block 2
- Block 3
- Block 4
- Block 5
- Block 6
- Block 7
- Block 8
- Block 9
- Block 10

Do you have internet access at home?

- Yes
- No

Do you have reliable internet access in the wards?

- Yes, via the WIFI
- Yes, via my data plan
- Yes, using prepaid data
- No

Do you have access to: *(check all that apply)*

- Smartphone
- Tablet
- Laptop
- Desktop computer

Which of these devices do you prefer to use when studying?

- Smartphone
- Tablet
- Laptop
- Desktop computer
- None

When studying, do you use any of these digital information resources? (*check your top 3*)

- Google
- Wikipedia
- Medscape
- UpToDate
- EMGuidance
- DynaMed
- Epocrates
- Lexicomp
- PubMed
- Online Journals/Journal Articles
- Med Calculators
- Micromedex
- Other

Display This Question:
If When studying, do you use any of these digital information resources? (check your top 3) = Other

Please specify...

Appendix C. Posttest and post-posttest survey

Note. This survey² is the group 1 post-posttest survey with highlighted additions to illustrate the question or statement that would be in the group 2 version of survey. These additions have been highlighted in grey. The MCQ posttest questions are not included in this survey.

DETAILS

Please fill in the following:

- First Name _____
 - Email _____
 - Year of Study in 2018 (please type 4, 5 or 6) _____
-

30 QUESTION MCQ FOR E-LEARNING STUDY

Please try to complete under test conditions

1. Participant completes MCQs - Part 1 Breast Mass Questions
 2. Participant completes MCQs - Part 2 Jaundice Questions
-

POST-INTERVENTION SURVEY

USING UPTODATE /FOUR MINUTE MEDICINE

What percentage of the of UpToDate/Four Minute Medicine materials did you complete? (*In percent. Please fill in a value*)

% _____

How much total time did you spend using the UpToDate/Four Minute Medicine materials? (*In hours and minutes*)

- Hours _____
 - Minutes _____
-

² Edited version of the study's survey that was generated on and downloaded from Qualtrics (versions September 2018- January 2019)

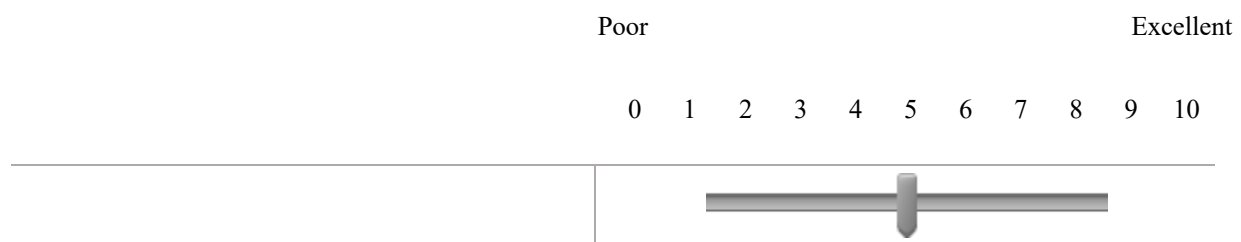
When you were reading about breast masses on UpToDate/Four Minute Medicine did you consult another external resource?

- Yes
- No

If yes, which resource did you consult?

- Google
- Wikipaedia [sic]
- Four Minute Medicine
- MedScape
- Other, Please Specify _____

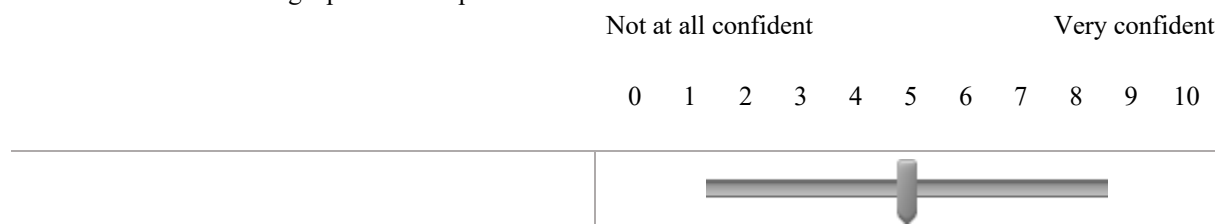
Using the slider: BEFORE you completed the learning materials how would you have rated your KNOWLEDGE of breast masses and breast mass related diseases?



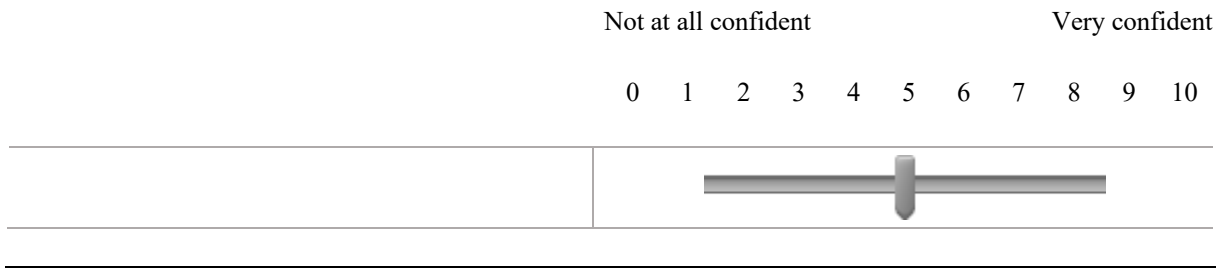
Using the slider: AT PRESENT, AFTER using UpToDate/Four Minute Medicine, how would you rate your KNOWLEDGE of breast masses and breast mass related diseases?



Using the slider: BEFORE you completed the learning materials how would you have rated your CONFIDENCE in clerking a patient who presents with a breast mass?



Using the slider: AT PRESENT, AFTER using UpToDate/Four Minute Medicine, how would you rate your CONFIDENCE in clerking a patient who presents with a breast mass?



USING FOUR MINUTE MEDICINE/UPTODATE

What percentage of the of Four Minute Medicine/UpToDate materials did you complete? *(In percent. Please fill in a value)*

- % _____

How much total time did you spend using the Four Minute Medicine/UpToDate materials? *(In hours and minutes)*

- Hours _____
- Minutes _____

When you were reading about Jaundice on Four Minute Medicine/UpToDate did you consult another external resource?

- Yes
- No

If yes, which resource did you consult?

- Google
- Wikipaedia [sic]
- UpToDate
- MedScape
- Other _____

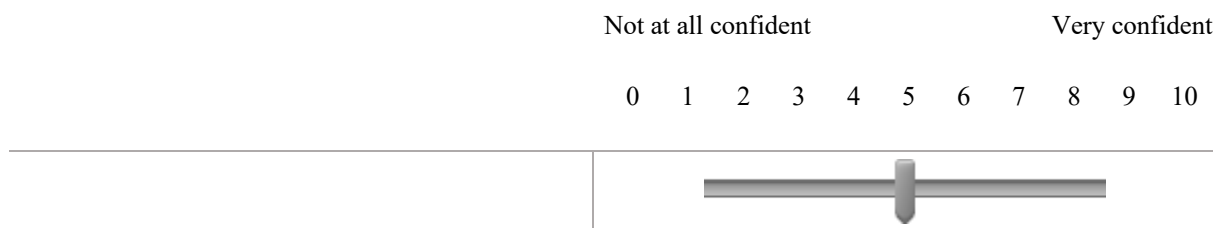
Using the slider: BEFORE you completed the reading materials how would you have rated your KNOWLEDGE of the causes jaundice?



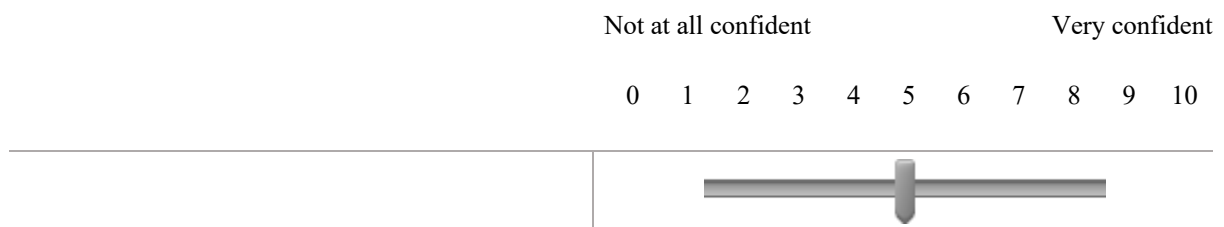
Using the slider: AT PRESENT, AFTER using Four Minute Medicine/UpToDate, how would you rate your KNOWLEDGE of the causes of jaundice?



Using the slider: BEFORE you completed the reading materials how would you have rated your CONFIDENCE in clerking a patient who presents with jaundice?



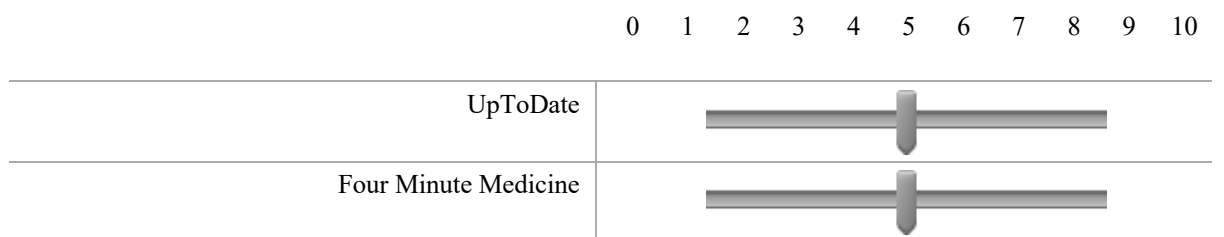
Using the slider: AT PRESENT, AFTER using Four Minute Medicine/UpToDate, how would you rate your CONFIDENCE in clerking a patient who presents with jaundice?



PLATFORM RATINGS

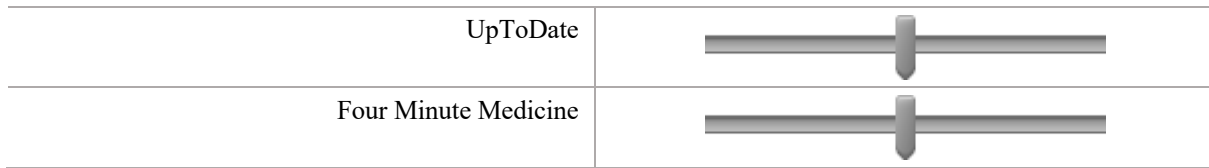
Keeping your personal preferences in mind, using the sliders, please select how you would rate each platform in the following domains:

1. CONTENT



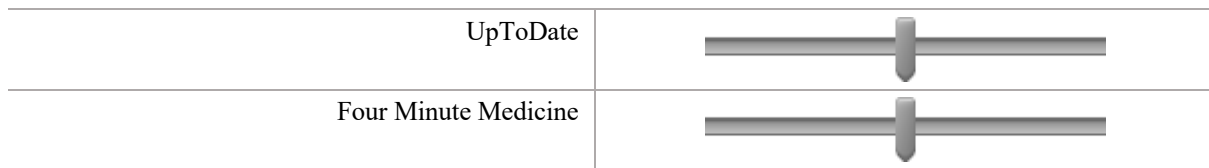
2. LENGTH

0 1 2 3 4 5 6 7 8 9 10



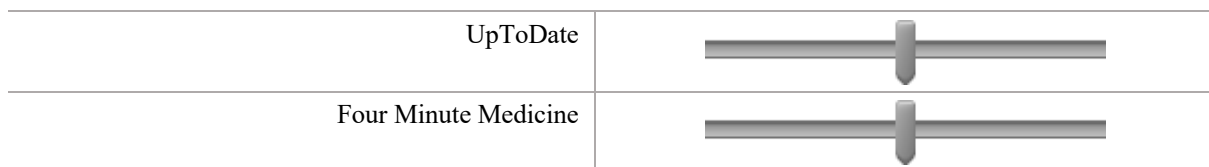
3. EASE OF USE

0 1 2 3 4 5 6 7 8 9 10



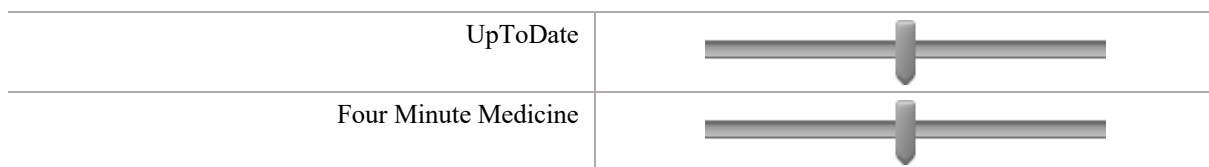
4. VISUAL DESIGN

0 1 2 3 4 5 6 7 8 9 10



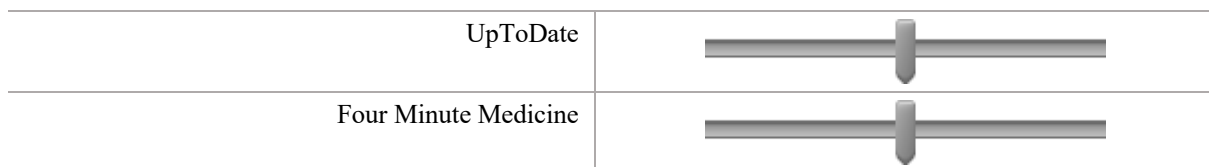
5. INTERACTIVITY

0 1 2 3 4 5 6 7 8 9 10



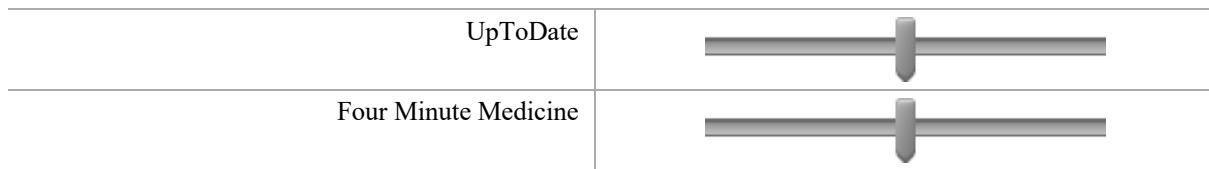
6. SELF-ASSESSMENT CAPABILITIES

0 1 2 3 4 5 6 7 8 9 10



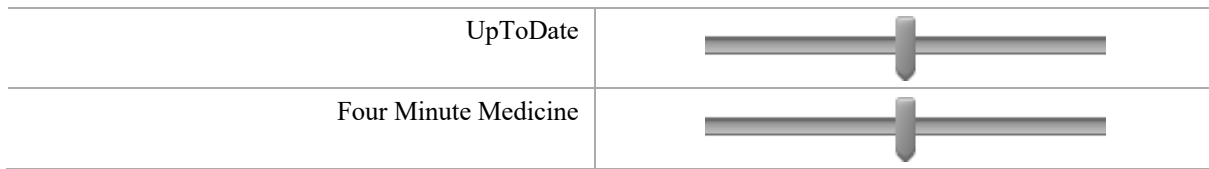
7. FUTURE USEFULNESS

0 1 2 3 4 5 6 7 8 9 10



8. TRUSTWORTHINESS

0 1 2 3 4 5 6 7 8 9 10



In the future, which if these two platforms would you prefer?

- UpToDate
- Four Minute Medicine

In what ways do you think *Four Minute Medicine* could be improved? (your suggestions would be highly appreciated)

COMPENSATION AND INTERVIEW REQUEST

Because your name will be removed from your responses above, by a third party, YOU MUST fill in your name and email in the survey that will appear on your screen after clicking the submit button below. This is the only way that the principal investigator knows that you have completed all the elements of the study. There will also be an option to volunteer to be interviewed.

INTERVIEW REQUEST AND CONTACT DETAILS

Interview Request and Contact Details

In order to gain a better understanding of the survey results, would you be willing to sit down for an interview?

- Yes
- No

To receive your R100 compensation please fill in your name and email below. The principal investigator will contact you within the next 48 hours, please respond to the request as soon as you can. *For practical purposes, you must please try to respond to the request to deliver your compensation within 2 weeks of the study end date.

Failing to do so may lead to loss of compensation.

- First Name _____
- Email _____
- Confirm Email _____

Appendix D. Learning objectives

Breast mass

After completing the learning materials students should be able to:

- i. Differentiate between the features that are suggestive of normal and abnormal breast tissue on clinical examination
- ii. Recognise red flag and malignant signs/symptoms on history and examination
- iii. Recognise the common causes of a breast lump affecting individuals of different demographic groups
- iv. Formulate a clinical and investigative evaluation of a breast mass
- v. Identify features of malignancy on breast imaging mammography and ultrasound

Jaundice

After completing the learning materials students should be able to:

- i. Differentiate between the different causes of jaundice. These causes may be classified as conditions that:
 - a. Cause Unconjugated or conjugated hyperbilirubinaemia,
 - b. Cause increased bilirubin production or impair bilirubin excretion, or
 - c. Are anatomically classified as being pre-hepatic, hepatic/intra-hepatic and post-hepatic in nature
- ii. Recognise the common causes of obstructive jaundice
- iii. Recognise features on history, examination or workup that are suggestive of obstructive and non-obstructive jaundice
- iv. Develop a diagnostic work-up to the different causes of jaundice

Appendix E. Interview guide

Note. Questions in grey are probing questions

Opening question:

Tell me about the medical student workload? How do you manage it?

Core Questions

Undergraduate Clinical Education

1. How are you taught during your rotations? What are your thoughts regarding these teaching methods?
2. How do you generally approach your learning? What are your feelings towards this approach? How did you start learning in this way? Has it changed over the years?
3. How do you approach your learning during clinical rotations? Why do you prepare in this way?
4. How do you prepare for your assessments? Why do you prepare in this way?
5. Can you tell me about the best learning experience you've had at medical school? What made this experience positive?
6. Can you tell me about the worst learning experience you've had at medical school? Why was it negative? What do you think could have made it more positive?

Intervention

7. Can you walk me through your experience with using each of the 2 platforms? (e.g. setting, feelings and thoughts) What did you like or dislike about each resource? Did you encounter any challenges?

Online Learning

8. Have you used any online resources during medical school? Tell me about that experience(s)? [sic] How did you come to know about it? What did you like about it? What didn't you like about it? How did this resource help you study? What do you think about social media?
9. Can you describe your ideal online educational platform? What would you like to see and why? What would you not like to see and why?

Closing question

Is there anything more you'd like to add that we haven't discussed?