Patient-based interdisciplinary e-learning with reflection: Experiences of biomedical science, allied health and complementary medicine students

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E-learning modules were developed to enhance student engagement, reflection and interdisciplinary learning in pathology courses undertaken by students from the biomedical science, allied health and complementary medicine disciplines. The modules focused on generating multi-disciplinary and team-based solutions to diagnosis, prognosis, and treatment and management of patients. At pre- and post-intervention, we analysed the students' experience of three themes: e-learning, reflection and interdisciplinary learning. Flexibility and ability to reinforce understanding of course content were identified as main advantages of e-learning but a lack of direct support was a common concern. Visual aids and interactive assessments were suggested to improve online experiences. Although all students had a positive preconception of all themes prior to the intervention, the delivery of the modules significantly improved students' perception on how e-learning deepened their understanding of course materials via reflection and interdisciplinary learning, with both aspects serving to create a holistic learning experience.

Implications for practice or policy:

- Course learning outcomes can be improved by e-learning, flexible delivery and reflection of prior courseware through enhanced student engagement.
- Course coordinators may need to consider the redesign of their units to achieve interdisciplinary learning outcomes and promote the importance of a holistic approach to healthcare.

Keywords: e-learning, reflection, student engagement, patient care, interdisciplinary, pathology, mixed methods

Introduction

An excellent healthcare system relies on the efforts of a multi-disciplinary team of professionals to provide a holistic and effective approach to patient care. Therefore, embedding opportunities for students studying biomedical and health sciences to reflect on the role of their intended profession in a broader health context within the curriculum is integral for an authentic learning experience. We developed interactive e-learning modules to incorporate interdisciplinary learning and reflection of prior curricula via patient-based case studies. The modules were linked to active-learning workshops and online supportive resources, where biomedical science (BM), allied health (AH) and complementary medicine (CM) students worked in groups from varying disciplines. The modules also integrated assessments and feedback checkpoints to encourage students to showcase their future profession and its role in patient healthcare, providing them with a holistic view of how different professions can work together to problem-solve and to learn more in depth about their own profession and others. In doing so, students can recognise the professional skills of others, thus fostering interprofessional respect. This is vital for our

future graduates as healthcare will be patient-centred and will often involve several practitioners. It can build the student's sense of belonging to a profession and can help them to better understand their role in the healthcare industry.

The increasing development and accessibility of digital technology has certainly changed the education environment and transformed student learning (Røe et al., 2022). Students have been entering the tertiary sector with an advanced set of educational technological skills for many years, while social media and globally accessible information has revolutionised the way students learn, study and interact with instructors and peers (Siemens et al., 2015). The impact of the COVID-19 pandemic and lockdowns has inevitably led to students engaging in more online activities and digital learning, while lecture attendance rates were already declining pre-pandemic (Kelly, 2012; Mokhtari, 2021; Moore et al., 2008). In addition, the changing student profile with regards to life stage, social and cultural diversity demands that our courses be more accessible, interactive in delivery and connected to real-world case studies that involve critical thinking, problem-solving, collaboration and evaluation. In this study, we implemented innovative and sustainable teaching strategies to enhance student engagement and maximise learning outcomes. In order to equip our students with work-ready problem-solving skills in professions which often involve the application of interdisciplinary knowledge and digital literacies, we adopted an engaging interdisciplinary, reflective and practice-based approach in our pathology courses via the delivery of interactive e-learning modules and on-campus workshops, supporting a blended learning approach.

Pathology courses are undertaken by multi-cohort students studying various academic disciplines (e.g., anatomy, radiology, pathology), before specialising in one professional discipline (e.g., laboratory medicine, medical radiations, BM, Chinese medicine, chiropractic, osteopathy). By the end of their studies, the students' professional discipline influences what is known and valued, while the relevance of the academic disciplines is unclear due to lack of engagement, reflection and application in a practice-based context (Davies & Devlin, 2007). Furthermore, our students are not given the opportunity to learn about each other's professional disciplines or to see how these professions will impact their future work practice.

The specific aim of the e-learning modules was to increase student engagement (via authentic teaching and assessment activities), provide students with a holistic view of how the different professions could work together to problem-solve (via interdisciplinary learning) and reinforce the significance of the academic disciplines before specialisation (via reflection of prior curricula). The interdisciplinary nature of the learning outcomes and content of the modules were also designed to foster communication, collaboration and respect between the biomedical, AH and CM student cohorts, with the additional aim of contributing to a sense of community and belonging as future healthcare workers. This would enhance the student's preparation for work in the healthcare industry. As such, our instructionally designed e-learning modules are based on patient case studies that are interoperable in many programmes, integrate the academic and professional disciplines thereby promoting interdisciplinary learning and facilitate reflection and application of their theoretical knowledge in a practice-based context.

Interdisciplinary learning is an approach that integrates two or more subject areas to enhance the understanding of each area (Cone et al., 1998; Corbacho et al., 2021). It is evident that students appreciate interdisciplinary models (Ghisla et al., 2010) and have a positive attitude towards interdisciplinary learning and teaching (Gero, 2017). It also helps in understanding and valuing differences in each other's professional discipline and perspective (DMani, 2011). For example, students with conventional medicine and CM backgrounds need to be exposed to each other's therapies to improve communication between such professions and the quality of patient care (Frawley et al., 2017; Stub et al., 2017). It is also evident that interdisciplinary learning benefits students by enhancing their critical thinking (Bellaera, 2021; Buchbinder et al., 2005; Nowacek, 2005) and problem-solving skills (Lattuca et al., 2004), which are important graduate attributes (Hill et al., 2016).

Furthermore, interdisciplinary learning empowers learners with the realisation of the complexities and multi-team approach involved in problem-solving in the workplace (Rich, 2009). It is a complex, context-

dependent and deep learning experience that needs to stimulate engagement of interdisciplinary learners to reflect on their practice, discuss alternative perspectives, open their minds to different outlooks, integrate and construct knowledge from various disciplines and make meaningful links and informed work-related decisions (Berasategi et at., 2020; Rich, 2009). It is also a vital element in providing students with work-ready skills such as effective problem-solving and communication capabilities, and universities and training institutions have a key responsibility in devising course curriculum where these learning outcomes can be achieved. Healthcare professionals with conventional medicine and CM expertise share the common goal of improving the quality of patient care. As such, there is a need for students studying BM, AH and CM programmes to understand the importance of the roles of professionals across the various disciplines and to be fully informed of the essential collaborative problem-based learning strategies that take place in daily healthcare practice. Students need to be independent learners and critical thinkers who are open to new challenges and concepts and to adopt collaborative and holistic problem-solving approaches to constantly improve workplace practices.

In addition to interdisciplinary learning, our e-learning modules promote reflection by revisiting anatomy, radiology and pathology courseware, thus enabling deep rather than surface learning. Reflection is vital in any form of learning as it enhances meaning and the students' insight, by linking the current learning experience to previous learning experiences (Costa & Kallick, 2008). It therefore allows students to act upon and process information more effectively and with confidence and to apply what they have learned to a current context. Reflection also promotes learning by transferring information to long-term memory and into work practice (Burns & Sinfield, 2004). It allows students to achieve their intended learning objectives and facilitatse their success in the workforce following graduation. As healthcare professionals, reflection highlights the best practice to optimise clinical performance, enhance professional values and stimulate life-long learning (Sim & Radloff, 2008; Winkel et al., 2017).

Our decision to develop and deliver our patient-based case studies via an interactive online mode was supported by evidence that online delivery versus face-to-face delivery does not disadvantage students with regards to learning outcomes and grade-based performance (Cavanaugh & Jacquemin, 2015). Furthermore, an online mode decreases the teaching and technical demands of week-to-week teaching, and it is also evident that in the case of teaching clinical skills, this approach is no less effective than the traditional means (McCutcheon et al., 2015). There is also strong evidence that instructionally designed online modules are more flexible in addressing the divergent range of learning styles in students and have proved to be 30% more engaging than face-to-face delivery (Dziuban et al., 2004; Maley et al., 2008). In combination with the convenience of online delivery and engagement with digital technology, the student's satisfaction of this learning environment is enhanced with direct feedback and interaction with the instructor and their peers. A sense of a community of learning gives them the opportunity to ask questions and provide them additional support via online discussions with their instructor as their primary point of contact and with their peers through group activities and assessments (Berry, 2019; Cole et al., 2014).

Our patient-based e-learning modules have integrated prior courseware (anatomy, radiology, pathology) and the work practice of biomedical scientists, AH professionals and CM practitioners, thus allowing students to reflect on previous learning experiences and to enhance their interdisciplinary learning before they enter the workforce. As the current generation of learners live in a technology-driven environment and prefer to interact through digital means, our modules are enriched with videos, audios, images, animations and interactive questions which accommodate different learning styles and enhance student-centred teaching. They also permit students to learn at their own pace and to revisit these resources throughout the semester for review and re-enforcement purposes, thus aligning with the principles and processes of reflection and self-directed learning. As well as offering a dynamic, flexible, accessible and collaborative environment beneficial to both students and educators, our modules enable instantaneous and formative feedback. The inclusion of interactive questions that are required to be answered correctly in order to progress allow students to reflect and make active choices throughout the learning process.

Overall, this learning environment facilitates the achievement of student learning outcomes and enables graduates to operate more effectively in their chosen professions in an increasingly digitally driven future. It also contributes to overall improved communication and collaboration between such professions, and therefore to improved quality of patient care (Borrego & Newswander, 2010; Dunston et al., 2013; Ivanitskaya et al., 2002; Pennington, 2008; Thoma et al., 2019).

In this study, we investigated the impact of our patient-based e-learning modules on the students' experience of interdisciplinary learning, reflection and e-learning.

Methods

This research study was approved by the RMIT College of Human Ethics Advisory Network and was funded by a RMIT Scheme for Teaching & Learning Research Grant.

Module development and delivery

Five instructionally designed patient-based e-learning modules were developed for pathology students in collaboration with Synotive Technologies to introduce interdisciplinary learning, promote reflection, increase student engagement and maximise learning outcomes. Each module was developed in the form of a sharable content object reference model and was implemented and offered via the learning management system at RMIT University. Features of each module consisted of avatars of teaching staff presenting various stages clinical cases; integration of pathology, anatomy and radiology content with linear progression and voice over; interactive presentation of differential diagnosis, laboratory medicine and medical radiations results, conventional and CM treatments; integrated video podcasts, audio podcasts, digital images, animated text and graphics; and learning checkpoints. Each module required an average completion time of 40 minutes.

The modules were designed as multidisciplinary problem-solving exercises, employing various tools to promote student engagement, reflection and interdisciplinary learning. Patient symptoms and signs were presented via an audio and graphics tool, after which students would navigate through learning checkpoints of prior curricula and diagnostic procedures via video, audio, graphics, multiple-choice questions and/or animation tools. Learning checkpoints included choice of possible diseases, interdisciplinary investigations required to rule in and rule out conditions, analysis of test results, choice of definitive diagnosis, interdisciplinary treatments and management of patients. Different interface functions were incorporated such as play-back features, the ability to pause to stop and reflect before moving forward and the completion of all scaffolded components to facilitate linear progression of learning. The online flexible delivery accommodated students with equitable learning plans, work commitments or caring responsibilities, allowing them to participate at their own pace when it suited their circumstances. Figure 1 shows the instructional design template used for all case studies, whilst examples of the interactive e-learning modules can be accessed through https://rmit.instructure.com/courses/112764/pages.

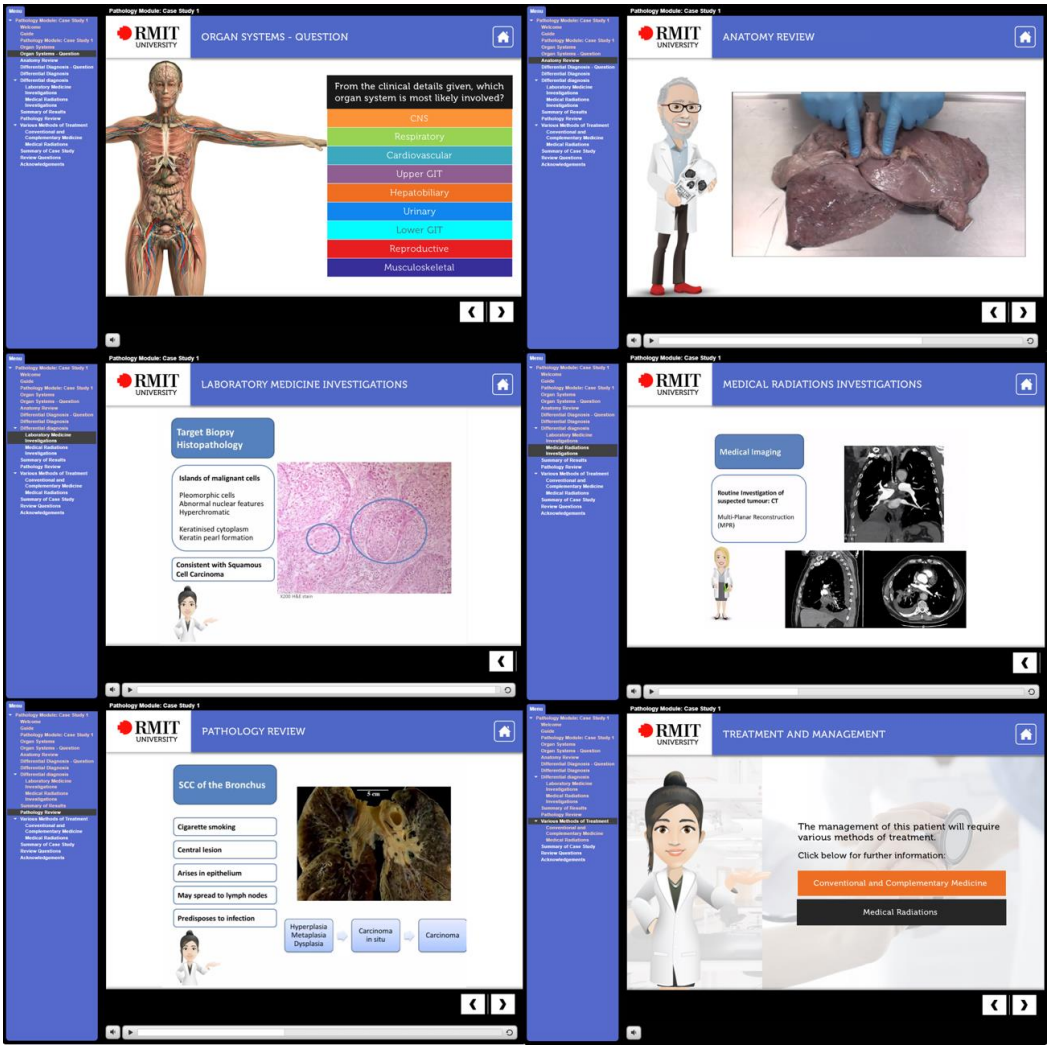

Figure 1. Instructional design template used to deliver an interactive e-learning module showcasing interdisciplinary learning and reflection of prior curricula (anatomy, medical radiations, pathology) via a patient-based case study. Interdisciplinary learning is also showcased through laboratory medicine and medical radiations investigations, as well as conventional and CM treatments.

Participants

Students undertaking pathology units at RMIT University were invited via email and during two workshop classes to participate in this research study by a research assistant, independent of us authors. Student groups were divided into three discipline clusters: AH, consisting of laboratory medicine and medical radiations students; CM, consisting of chiropractic, osteopathy and Chinese medicine students); and BM, consisting of BM students). Participation was purely voluntary, and students remained anonymous. No exclusion criteria were applied to this study. Out of a total cohort of 465 students, 253 participated in the study.

Data collection

This research project was designed to evaluate the student's experience of the five patient-based online modules by completing two hard-copy survey questionnaires and participating in two focus group sessions. The two survey questionnaires were administered by the research assistant at pre-intervention stage in the last 10 minutes of a scheduled pathology workshop class and at post-intervention stage in the last 10 minutes of a scheduled pathology workshop class. We were not present during the invitation and administration of the surveys.

The first survey (Survey 1) investigated the students' perception of e-learning, reflection and interdisciplinary learning prior to delivery of the interdisciplinary case-based modules. The second survey (Survey 2) investigated the students' overall experience of the five e-learning modules. It evaluated the online delivery, as well as student engagement with the interdisciplinary case design and the opportunity to apply prior learning or reflection to each of the presented cases. Both surveys consisted of Likert scale and open-ended questions, from which themes and coded responses were developed (Tables 1 and 2).

Table 1
Themes and coded responses for Survey 1

Themes for the Likert scale questions	Open-ended question: What are the advantages of e-learning?	Open-ended question: What are the disadvantages of e-learning?	Open-ended question: What would make e-learning a better experience for you?
1. E-learning 2. Reflection 3. Interdisciplinary learning	1. Flexibility 2. Accessibility 3. Learning styles 4. Reinforcement	1. No direct support 2. Requires self-motivation 3. Easily distracted 4. Technical difficulties 5. Not engaging 6. No limitations	1. Videos or visual aids 2. Interactive assessment 3. Blended delivery 4. Feedback 5. Discussion forums 6. More interaction/interactive 7. Online support (technical, links to online resources) 8. More direction

Table 2
Themes and coded responses for Survey 2

Themes for the Likert scale questions	Open-ended question: Overall, have the online modules been a good learning experience for you?	Open-ended question: With regards to the online modules, can you offer some suggestions for improvement?
1. E-learning 2. Reflection 3. Interdisciplinary learning	1. Yes 2. No	1. No improvement 2. Clarity on due dates 3. Assign assessment weighting 4. Extended module availability 5. More clinical focus 6. More modules 7. Increase difficulty 8. More questions 9. Downloadable videos

Two focus group discussions were also organised and conducted by the research assistant at pre-intervention and post-intervention stages to evaluate perceptions and experiences with regards to e-learning, reflection and interdisciplinary learning. Focus group discussions were audio-recorded and transcribed. All comments made were strictly confidential. Five students participated in the focus groups at both pre- and post-intervention stages.

Students could choose to participate in one or both surveys and/or focus group discussions. Following administration of Survey 1, each participating student was assigned an identifying code in a sequential order. That is, the first student who submitted the completed survey was assigned "S1", second student was assigned "S2" and so on. The same code was also given to the same student in the second survey questionnaire if they chose to participate. This code was used to compare survey results across both questionnaires and comment on any associations between overall student preconceptions of e-learning versus the student experience in completing the online modules. We did not have access to the student

names, identification number and identifying codes on the survey questionnaires as this information was stored securely by the research assistant. All data was collated and coded by the research assistant, independent of us. As such, there were no potential biases or limitations in the study.

It is important to note that some questions in Survey 2 differed from Survey 1; hence, the two surveys were also analysed independently.

In summary, 138 students completed Survey 1 (BM = 9; AH = 49; CM = 80), of whom 78 students also completed Survey 2 (BM = 5; AH = 14; CM = 59). In addition to the 78 students, 115 students (BM = 5; AH = 19; CM = 91) completed Survey 2 only. There was no significant difference in the analysis between the programmes of study; hence, this data is not included.

Data analysis

All descriptive statistics, thematic and cluster-based analyses were conducted using SPSS version 24.0. Firstly, the differences in the prior e-learning experience of students across the three discipline clusters (BM, AH and CM) were established as percentages.

Secondly, question items in both Survey 1 and Survey 2 that reflected a common theme were grouped together. Under each theme, the coded responses to the items were summed for each participant in the survey, and the resulting total score was expressed as a percentage of the maximum score possible across all the items within a theme. These theme scores were assessed for any significant differences across the three discipline clusters via the one-way analysis of variance (ANOVA) test. A percentage greater than 50% indicates an agreement with the items reflecting each theme.

Thirdly, each question under a theme required one of the following response categories: *strongly disagree*, *disagree*, *unsure*, *agree*, *strongly agree*. Each of these categories were coded 1, 2, 3, 4, 5, respectively. Thus, if a theme had two items, the maximum score would be 10 if the respondent chose to *strongly agree* with both items or a minimum score of 2 if a respondent chose to *strongly disagree* with both items. Each respondent obtained a theme score that was expressed as a percentage of the maximum score possible. For instance, if a respondent chose to *agree* to one item and *disagree* to the second item of a theme composed of two items, then the total score would be 4 + 2 = 6. If expressed as a percentage of the maximum possible score, this would be 6/10 x 100 = 60%. High percentages would indicate strong agreement with the items under each theme. These theme score percentages were obtained for each respondent per theme. They were summarised using means and standard deviations under each of the discipline clusters. One-way ANOVA via the *F* statistic test was then used to determine any significant differences ($p < 0.05$) in theme scores across the discipline clusters for both Surveys 1 and 2.

Fourthly, we compared the responses to similar items from Survey 1 and Survey 2 across the whole cohort of responses irrespective of discipline. This was assessed for significant differences via the Wilcoxon signed-rank test using the benchmark, $p < 0.05$, via a *z* statistic from a normal distribution. This statistical test assessed whether there were significant changes in responses between Survey 1 and Survey 2 on similar questions by ranking responses, which then yield a *Z* value to which is attached a probability value from the normal distribution. The *p* value is an indicator of whether a significant difference in response occurred over the two surveys on the same question using a threshold value of 0.05. Any value at or below this threshold value indicated that there was a significant change in the responses between the two surveys.

Results

Thematic score analysis of Surveys 1 and 2 data

A thematic analysis of Survey 1 (prior to delivery of e-learning modules) and Survey 2 (post-delivery of e-learning modules) results was performed. The responses to the questions by the students in both surveys

reflected important themes: e-learning, reflection and interdisciplinary learning. The mean theme scores for all participants and discipline clusters indicate a positive view and experience of the items reflecting each theme as percentages generated from Surveys 1 and 2 were above 50% (Tables 3 and 5). There were also no significant differences in mean theme scores across the discipline clusters, BM, AH and CM (all *p* values > 0.05; Tables 4 and 6) in both surveys.

Table 3
Theme score descriptive analysis of Survey 1 data

Theme	Overall theme score summary across all participants	Overall theme score summary by discipline clusters		
		BM	AH	CM
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
E-learning	76.5 (15.0) (*n* =138)	80.6 (19.9) (*n* = 9)	73.3 (15.1) (*n* = 49)	77.9 (14.2) (*n* = 80)
Reflection	75.9 (12.8) (*n* =138)	76.7 (18.0) (*n* = 9)	75.9 (12.6) (*n* = 49)	75.9 (12.5) (*n* = 80)
Interdisciplinary learning	78.4 (11.2) (*n* =138)	85.6 (11.3) (*n* = 9)	79.2 (10.6) (*n* = 49)	77.1 (11.4) (*n* = 80)

Table 4
One-way ANOVA assessment of theme score differences across discipline clusters in Survey 1

Theme	*F* statistic	*p* value
E-learning	1.85	0.161
Reflection	0.02	0.985
Interdisciplinary learning	2.52	0.084

Table 5
Theme score descriptive analysis of Survey 2 data

Theme	Overall theme score summary across all participants	Overall theme score summary by discipline clusters		
		BM	AH	CM
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
E-learning	85.9 (11.4) (*n* = 193)	88.5 (12.7) (*n* = 10)	84.1 (10.8) (*n* = 33)	86.2 (11.4) (*n* = 150)
Reflection	81.4 (13.9) (*n* = 191)	80.0 (16.3) (*n* = 10)	77.8 (16.6) (*n* = 32)	82.3 (13.1) (*n* = 149)
Interdisciplinary learning	81.9 (13.6) (*n* = 191)	86.0 (13.1) (*n* = 10)	81.9 (12.8) (*n* = 32)	81.6 (13.9) (*n* = 149)

Table 6
One-way ANOVA assessment of theme score differences across discipline clusters in Survey 2

Theme	*F* statistic	*p* value
E-learning	0.72	0.489
Reflection	1.42	0.249
Interdisciplinary learning	0.49	0.615

Assessment of prior e-learning experience of students from the BM, AH and CM disciplines

A vast majority of students from the three disciplines, BM, AH and CM, reported an e-learning experience prior to the COVID-19 pandemic (78%, 80% and 81%, respectively). Of the online learners across the disciplines, 58%–78% had a positive previous experience and 89%–91% felt that they had engaged with their prior e-learning modules (Figure 2).

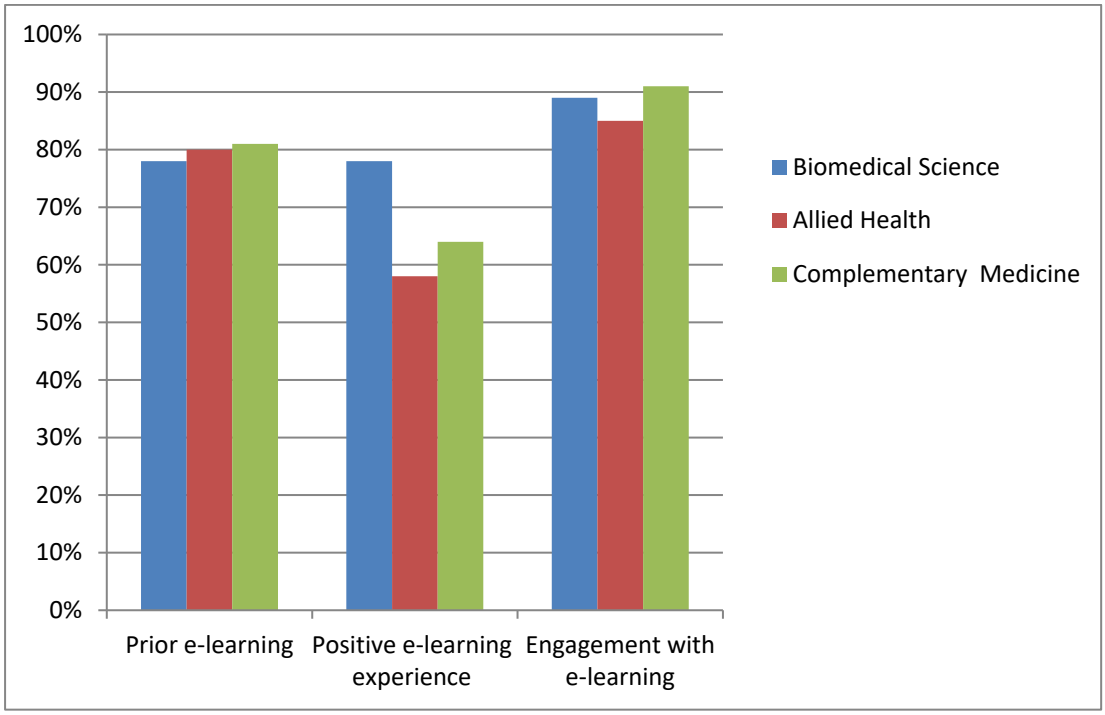

Figure 2. Survey 1 results based on the prior e-learning experience of students from the BM, AH and CM disciplines. Of those who had a prior e-learning experience, their perception (positive vs negative) and engagement (engaged vs did not engage) in their online experience are indicated as percentages.

Evaluation of qualitative data obtained from Surveys 1 and 2

The main advantages of the students' e-learning experience compared to face-to-face only classes centred on the themes of flexibility, accessibility, learning style and reinforcement of course material. Both the BM and AH disciplines reported that reinforcement of course material through e-learning was a key advantage, while the AH discipline also reported accessibility as being an important factor (Figure 3). The CM discipline indicated that e-learning would provide them with flexibility on being able to learn at their own pace and would offer an alternative mode of learning (Figure 3).

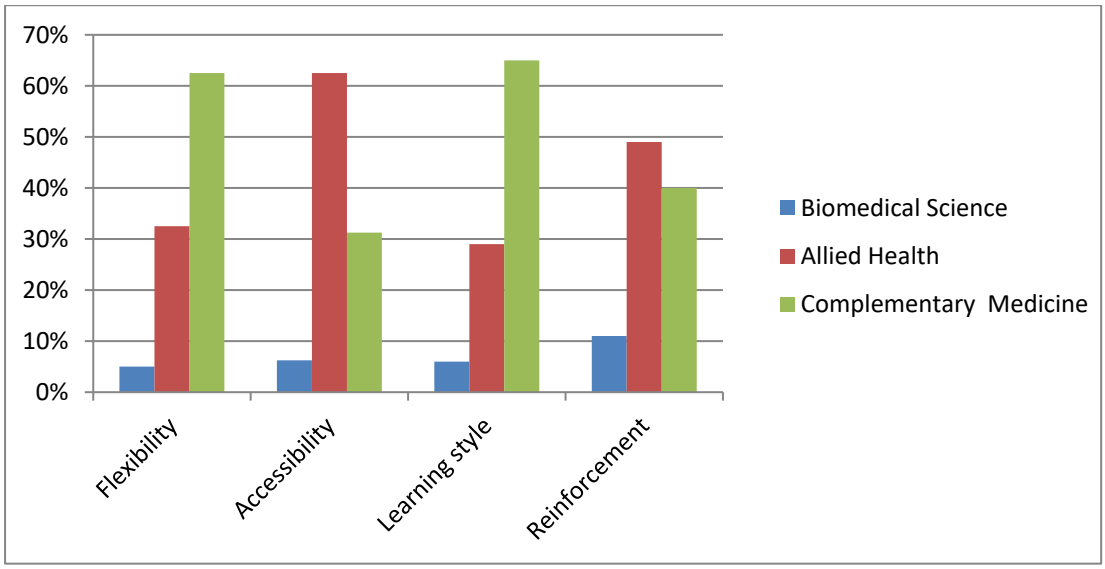

Figure 3. The major advantages of e-learning as perceived by students from the three discipline clusters (Survey 1).

Whilst 8%–15% of the students across the three discipline clusters felt that e-learning had no limitations, the challenging factors that were reported consisted of lack of direct support, requirement of self-motivation, being easily distracted, technical issues and a lack of engagement (Figure 4). Out of these, the majority of students across all disciplines hoped to receive more direct or "live" support during their current e-learning experience (Figure 4).

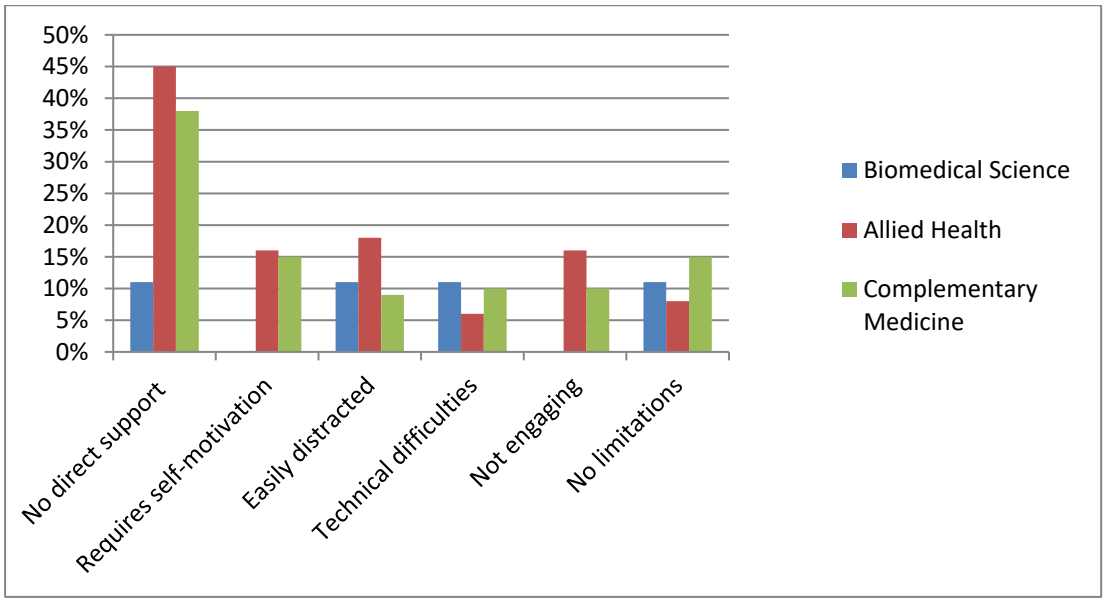

Figure 4. Areas of concern regarding e-learning as perceived by students from the three discipline clusters (Survey 1)

The BM student cohort reported that 33% of them would like the integration of interactive assessment and quizzes into e-learning, whilst 11% said that technical support and links to online resources embedded within the modules would enhance the e-learning experience (Figure 5). Of the AH cohort, 14% preferred a blended delivery of course material and discussion forums to be included in e-learning whilst the minority said that videos or visual aids, interactive assessments or quizzes, feedback, online support and clear direction or organisation could perhaps improve the student engagement in e-learning. Of the CM cohort, 16% and 11% felt that inclusion of videos or visual aids, and interactive assessments or quizzes in e-learning can promote a better learning experience, respectively. The rest of this discipline preferred blended delivery and would like more feedback, discussion forums or chats, online support and better direction or organisation. Of the three disciplines (BM, AH, CM), 33%, 14% and 25% respectively, were unsure or gave no response to areas where an e-learning experience could be improved.

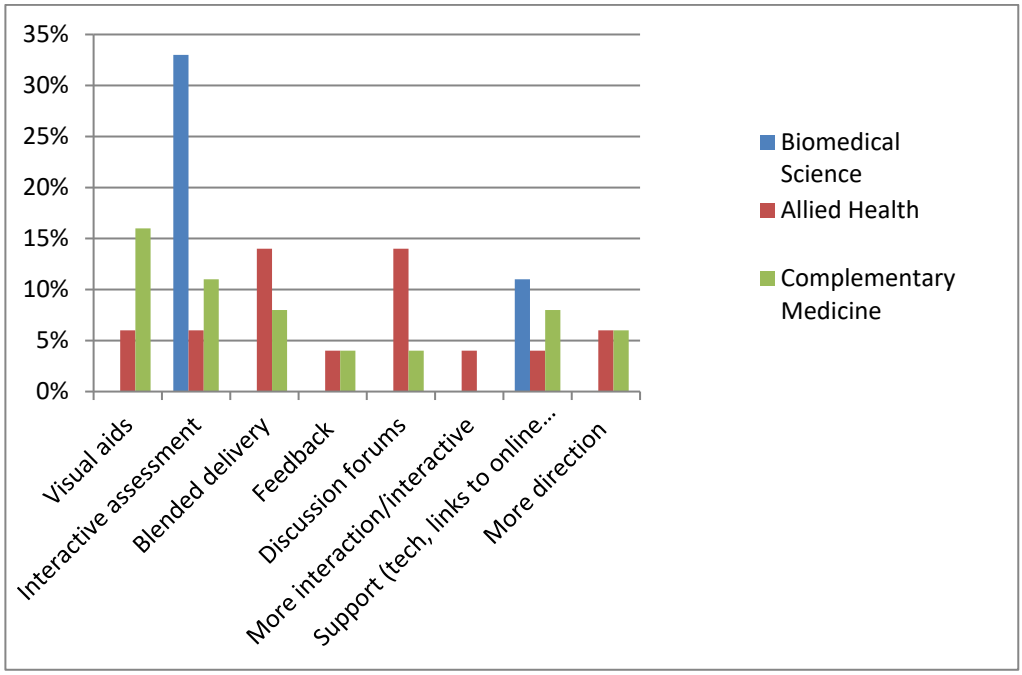

Figure 5. Factors perceived by students that would improve the e-learning experience (Survey 1)

Following delivery of the e-learning modules and in response to an open-end question of Survey 2, 98.7%–100% of students across all disciplines (BM, AH, CM) agreed that the e-learning modules introduced in the pathology course was a positive learning experience. This is also evident in Figure 6, which shows that the patient-based e-learning modules were well received. Many students across the three disciplines stated that the modules did not require any improvement or gave no response. Others mentioned areas of improvement, such as clarity on due dates; inclusion of assessment weighting for the quizzes; extended availability of the modules; and inclusion of additional resources such as more clinical content, questions, downloadable videos and more modules overall. The BM cohort mainly suggested more patient-based interactive modules with extended availability. The AH and CM cohorts suggested that more questions could be integrated into the modules.

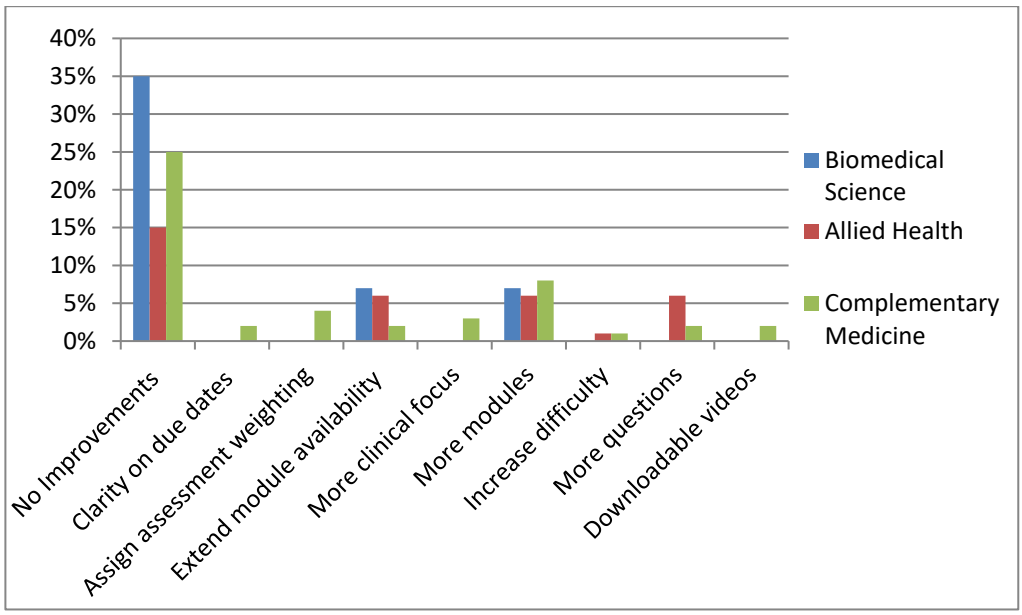

Figure 6. Student feedback on delivery and suggested improvements of the e-learning modules in the pathology course (Survey 2)

Finally, question items of a similar nature from Surveys 1 and 2 were identified to assess whether a change in response had occurred between the two surveys for students across all disciplines (Table 7).

Table 7
Comparison of question items addressed in Surveys 1 and 2

Survey 1	Survey 2
Q4: I like the accessibility and flexibility of online delivery of material.	Q5: I liked the accessibility and flexibility of online learning materials.
Q7: Reflection in a course encourages me to actively engage with the course.	Q8: Reflection in this course encouraged me to engage with the course.
Q10: I believe that online modules that incorporate reflection and interdisciplinary learning will be a good way to deepen my understanding of the material presented.	Q13: I believe that online modules that incorporate reflection and interdisciplinary learning are a good way to deepen my understanding of the material presented.
Q9: Interdisciplinary learning in a course encourages me to actively engage with the course.	Q10: Interdisciplinary learning in this course encouraged me to engage with the course.

In the comparative analysis of responses to corresponding questions in Surveys 1 and 2, the aspects of online delivery of material with regards to accessibility and flexibility, active engagement with course through reflection and interdisciplinary learning were not statistically significant pre- or post-intervention. However, the delivery of the e-learning modules in this course induced a statistically significant change in students' perception on how the modules deepened their understanding of course materials via reflection and interdisciplinary learning (*Z* value = -3.04; *p* = 0.002; Table 8).

Table 8
Statistical analysis of responses to corresponding questions from Surveys 1 and 2

Response comparison	*Z* value	*p* value
Q4 versus Q5	-1.55	0.121
Q7 versus Q 8	-1.61	0.108
Q10 versus Q13	-3.04	0.002
Q9 versus Q10	-1.20	0.230

Another aspect of this study included the focus group (*n* = 5) and workshop discussions (*n* = 253). The group discussions conducted at pre-intervention stage (prior to delivery of modules) revealed that all participants had prior experience with e-learning in the form of online instruction and/or quizzes, videos, tutorials and discussion forums. Students did not have a clear understanding of reflection or interdisciplinary learning, and until that point, had not considered the perspective of a different disciplinary cohort other than their own whilst undertaking studies comprising multiple cohorts. However, they did believe that some knowledge of the other cohorts' future professions would be beneficial to them.

Following delivery of the e-learning modules, all students reported through group discussions that they actively engaged with their pathology studies because of the modules, and that they found them useful to reflect on current and previous (anatomy, radiology, pathology) courseware for review and re-enforcement purposes. Participants from all three disciplines reported that they developed an awareness of the role and perspective of the other disciplines, especially the AH and BM cohorts of the CM discipline, appreciating that each other's future profession plays an important role in patient healthcare and well-being.

Discussion

This study investigated the impact of five patient-based e-learning modules on the experience of pathology students belonging to one of three discipline clusters: AH, CM and BM. A survey questionnaire

and a focus group discussion were conducted at both pre- and post-intervention stages to analyse the students' experience of three themes: e-learning, reflection and interdisciplinary learning.

The thematic analysis of Survey 1 showed that students from all discipline clusters had a positive preconception of all 3 themes prior to intervention (Table 3), and there was no significant difference between the clusters (Table 4). This can be attributed to the fact that prior to the study of pathology, all student groups from the three discipline clusters had engaged in some degree of e-learning and reflection and had undertaken courses with students from other disciplines sometime during their tertiary studies. As shown in Figure 2, the majority of students surveyed reported a good experience following engagement with prior e-learning modules. As a vast majority of current students have advanced educational technology skills and daily interaction with social media that dictate and facilitate their academic and everyday learning, there is an expectation of a digital presence within courses and a perception that e-learning will be beneficial in accelerating the acquisition and understanding of new and, possibly, global knowledge (Siemens et al., 2015). In addition, all student groups within each cluster had work-integrated learning or clinical experience as part of their programme, and e-learning with reflection was perceived to supplement their face-to-face learning. This is also supported by Sim and Radloff (2008), who showed that reflection through online learning provided good practice for optimising clinical performance. Thus, the students' prior online exposure and engagement, their clinical placement needs, as well as courses undertaken with multiple cohorts may have contributed to their positive attitudes at pre-intervention stage with all three themes.

From the evaluation of qualitative data obtained from Survey 1, key advantages and disadvantages of online learning were identified. Students from all three discipline clusters perceived a key advantage of e-learning was flexibility (Figure 3), which supports the needs and demands of current students for courses to have a digital presence and be more flexible, accessible and interactive in delivery (Siemens et al., 2015). As the students also participated in clinical placements at various stages of their programme, some of which were off-campus, flexible delivery was perceived as an important factor in enabling them to study, reflect and consolidate their learning in their own time and at their own pace, thus catering for the divergent range of students' learning styles.

The main disadvantage of e-learning by the discipline clusters was perceived as no direct support or interaction (Figure 4). Students wanted more interaction with teaching staff and the opportunity to ask questions and clarify concepts. They wanted answers provided in real time as opposed to sending emails or messages via the learning management system with potentially delayed response times. This is a common complaint regarding online delivery, as students feel anxious, lack in confidence or may not have the opportunity to ask questions simultaneously (Kemp & Grieve, 2014). We responded by linking the e-modules to our active-learning workshop activities. The workshops fostered reflection of the modules (e.g., case study analysis, review of results, and patient treatment and management) and conceptualisation (e.g., flow charts and decision trees to assist problem-solving). They also fostered collaboration between teaching staff and students, enabling staff to check learning and provide feedback in real time. As such, this blended learning environment with scheduled live workshops was linked to online activities and an online discussion forum, creating an environment that provided students with the necessary support and opportunity to maximise their learning outcomes (Cole et al., 2014; Fu et al., 2017; Kemp & Grieve, 2014). Interestingly, 8%–15% of students across the three discipline clusters reported that e-learning had no disadvantages, and this correlates with the results in Figure 2, as the majority of students reported they had a positive prior e-learning experience.

Next, students from the three discipline clusters listed similar factors that they perceived would help enhance their e-learning experience but each of the cohorts selected different factors as their top choice. As shown in Figure 5, the BM cohort predominantly reported that the integration of interactive assessment and quizzes would improve their experience, the AH cohort identified both blended delivery and discussion forums, whilst the CM cohort predominantly reported the inclusion of videos and visual aids. Visual aids and interactive assessments can be incorporated to improve future iterations of the modules by use of gamification and virtual simulation approaches. It has been reported that gamified

virtual environments provide benefits in medical and science, technology, engineering and mathematics education via enhancing student engagement (Krishnamurthy et al., 2022; Wang et al., 2022). Employing a visual storytelling approach and including the background of patients, other interesting "characters" and/or plot twists could improve student engagement while enhancing comprehension, reflection and retention of content via learning checkpoints. Creating a virtual reality simulated learning environment can also improve the clinical training of students (Sapkaroski et al., 2022; Yang et al., 2023). It can foster an emotional connection between students and the content (i.e., patients and their disease), and influence students' attention, empathy and communication skills (Sapkaroski et al., 2022; Yang et al., 2023), thus making them more receptive to learning and assessments.

The differences and similarities between discipline clusters with regards to suggested improvements could be attributed to the different programme structures and therefore a different e-learning exposure experienced by the clusters. Different exposures range from entire courses being delivered online, to integration of online modules, quizzes, tutorials and discussion forums within courses that are delivered primarily through the face-to-face mode, or simply course material, videos, audios and presentations that are delivered via the learning management system.

At post-intervention stage, the thematic analysis of Survey 2 showed once again, that students from all the discipline clusters had a positive experience with the three themes (Table 5), and there was no significant difference between the clusters (Table 6).

Responses to question items relating to similar investigations aspects in Surveys 1 and 2 were also compared. As shown in Tables 7 and 8, a statistically significant change was evident in students' perception of this question item pre- (Question 10) and post-intervention (Question 13). The finding suggests that the online modules have induced a deeper understanding of the course content via reflection and interdisciplinary learning; and potentially stimulated a better comprehension and reinforcement of these learning approaches and their applications in the student learner. The focus group discussions also supported this as the students increased their awareness and began to actively recognise and engage in interdisciplinary learning and reflection of courseware during delivery of the modules. Whilst not considering the perspective of other disciplines at pre-intervention, these students expressed their appreciation of an interdisciplinary approach as being critical in their chosen profession and how it can be integrated into online learning. Following delivery of the e-modules, these perceptions translated to improved course experience data from 81% to 91%. This emphasises the power of interactive, instructionally designed case study-based e-learning modules that are relevant and connected to the students' future professions.

Moreover, the convenience of flexible online delivery and by promoting reflection of prior courseware with interactive tools, this approach also enables deep rather than surface learning (Burns & Sinfield, 2004; Costa & Kallick, 2008; Czerkawski, 2014; Sim & Radloff, 2008). Thus, students are more likely to achieve the intended learning objectives and be successful in the workplace. Other studies with a similar approach have also reported good learning outcomes (Cavanaugh & Jacquemin, 2015; Maley et al., 2008; McCutcheon et al., 2015; Mills et al., 2014). Mills et al. reported that medical residents as part of their ongoing education engaged in online learning in the form of pathology or cytopathology tutorials. All residents (n = 20) reported that the easy accessibility and opportunities for self-assessment were very important variables contributing to the use of the resource, and that it would make them more likely to benefit from face-to-face lectures and/or slide sessions. Maley et al. showed that online learning satisfied a broader range of learning styles in pathology students and that those who made maximal use of online formative assessments had better summative outcomes.

Recent literature has reported the development of online modules to enhance student engagement and retention of knowledge in various medical disciplines including pathology and immunology (Schoenherr et al., 2022; Tomasi et al., 2021). Although these modules do integrate online resources such as videos and quizzes, they are focused on the learning of a single discipline. Therefore, the online modules presented in our study are unique as they provide students with a holistic digital learning experience by

engaging with interdisciplinary content and reflecting on how their intended profession fits within a multi-disciplinary healthcare setting. Our modules were not only tailored and instructionally designed to suit all discipline clusters but to suit all individual student groups within each cluster. They were connected to authentic practice involving critical thinking, problem-solving and interdisciplinary learning through clinical investigations, diagnostic methods, treatments and patient management. Engagement was fostered by the flexible delivery and reflection of prior courseware as the students navigated through checkpoints to determine a final diagnosis. In addition, students were engaged through a video assessment task that showcased their future profession, employing creative media resources such as a digital poster, short movie, slow animation, role-play or infographic. The significance of collaboration between the different professions in the care of a patient was reinforced as they learnt more in depth about their own future profession and the professional skills of others. From the evaluation of data obtained in Survey 2 and also evident in Figure 6, the majority of students from each discipline cluster reported that the modules provided a positive learning experience and that no improvements were required.

Finally, whilst our online modules integrated the academic and professional disciplines, and were interoperable in many programmes, their scalability was also optimised to include other health disciplines such as pharmacy and nursing in future iterations. As such, our case study exemplars will facilitate a new cohort of students to reflect and apply their theoretical knowledge in a practice-based context and will also support other interdisciplinary teaching staff to deliver integrated, engaging and relevant content to their students. In addition, as some of the students reported, e-learning has its limitations with regards to direct student support and interaction. Therefore, the linked face-to-face workshops have built upon and complemented the e-learning modules and provided an opportunity for students to apply and demonstrate their problem-solving ability. This blended learning approach has also supplemented the students' interdisciplinary learning and reflection of courseware in an engaging face-to-face environment and has encouraged active learning to improve the student experience. It has allowed the desired learning outcomes and the effectiveness of e-learning to be measurable via face-to-face assessment methods. This study will inform future developments of our pathology courses and e-learning modules. An interdisciplinary, holistic, collaborative approach to learning will continue to be employed to enhance clinical training though a variety of teaching methods. Additional strategies of engagement will include gamification and a virtual reality simulated learning environment to stimulate and maintain students' interest which will enhance their comprehension, communication skills and applications to clinical practice.

Conclusion

Overall, this study highlighted the importance of interdisciplinary learning as a holistic learning experience, as the e-modules focused on a multidisciplinary and team-based approach in solving healthcare issues surrounding diagnosis, prognosis, and treatment and management of patients. The online modules have deepened the clinical focus of the curriculum of the pathology courses and have engaged our students in reflective practice by considering how multidisciplinary roles and their future careers align with the desired outcomes of healthcare. Importantly, we have created authentic digital experiences that harness the capabilities of our students to meet the demands of a dynamic and evolving digital future; particularly when the completion of online training or competency modules is common practice in professional development across the different careers. Whilst reflection of courseware and flexible delivery were also key factors in the students' satisfaction, a blended delivery with face-to-face contact, feedback, activities linked to the online modules and interaction with fellow multi-cohort students also contributed to a positive learning experience, accommodating the various learning styles of a wider spectrum of diverse learners. Such an approach has provided a holistic understanding and transformed the learning experience. It has increased the awareness of students regarding each other's future healthcare professions and has made an impact on their future work practice by fostering communication and collaboration with each other and fostering the desired outcome of improved quality of patient care (Borrego & Newswander, 2010; Dunston et al., 2013; Ivanitskaya et al., 2002; Pennington, 2008).

Author contributions

Roula P. Kyriacou: Conceptualisation, Investigation, Data curation; Formal analysis; Writing – original draft, Writing – review and editing; **Cliff Da Costa:** Data curation, Formal analysis; Writing – review and editing; **Fiona Maxey:** Writing – review and editing; **Tom Molyneux:** Writing – review and editing; **Renee Mineo:** Writing – review and editing; **Jeremy Keens:** Writing – review and editing; **Faith A. A. Kwa:** Data curation; Formal analysis; Writing – original draft, Writing – review and editing.

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