

Research

Student perspectives and usage of adaptive learning technology in the university physiology course, and the association with question design

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Abstract

To improve the online learning experience, adaptive learning technologies are being used to personalise learning content to suit individual learning needs, with learning analytics being integrated to collect data about the student usage behaviour on the platform. Research indicates that the adaptive learning platforms promote a supportive learning environment, but in order to examine the impact of specific aspects of the platform on student learning, more detailed research is needed regarding the students' perspective of using the platform, and the learning analytics data related to the platform. The participants were students who were enrolled in the physiology courses at the University of Queensland, Brisbane, Australia. Students accessed the Smart Sparrow adaptive learning platform, or modules, typically during the practical (laboratory) class. The student feedback and learning analytics data were then collected and analysed with respect to Action Potentials and Vestibular Function modules in 2019. The results for the Vestibular Function module showed that students commonly mentioned *visual features* and *questions and activities* as helpful for learning. On the contrary, students commonly reported that learning was hindered by the *need to answer questions to proceed to the next slide*, and the *module not being able to recognise correct responses* for short answer questions. In addition, there was a noticeable decline in the percentage of students attempting questions as it approached the latter part of both modules. These study findings will support instructors when designing or reassessing their online learning platforms, and by suggesting ways to enhance the student learning experience.

Keywords Adaptive learning · Learning analytics · Student feedback · Educational technology · Online learning · Physiology

1 Introduction

Adaptive learning technologies are increasingly being adopted by educational institutions globally to deliver course content [4]. The EDUCAUSE Horizon Report 2020 have also listed adaptive learning as one of six emerging technologies and practices for higher education [4]. They are perceived as a way to improve student learning outcomes by chief academic officers [12], higher education administrators and experts [19], and their adoption is expected to increase [12]. One major feature contributing to the widespread use of adaptive learning technology is the ability to personalise learning based on individual learning needs and backgrounds. This is achieved through the collection of real-time data

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and the use of artificial intelligence, as well as automated and instructor interventions, which could then provide a more valuable learning experience [5, 11].

Instructors and educational institutions also benefit from adaptive learning technologies. The built-in analytics features allows data to be collected to determine factors that contribute to student success and improve learning [18] through recognising knowledge deficits and misconceptions [27]. The learning analytics feature within the adaptive learning technology also supports instructors to identify students at-risk, which is valuable in targeting assistance to those who need it most [14, 20, 28]. In addition, data may be potentially used to improve course and adaptive learning platform design [28] by identifying course content that is causing students issues.

Previous research has demonstrated the positive impact of adaptive learning technology on students' learning of course content [1, 30]. Adaptive learning technologies have been shown to improve learning efficiency, student confidence towards learning, retention of students, academic performance, and student engagement towards learning [5, 30, 35]. In addition, [1] has found that higher scores on learning activities in adaptive learning modules translated to higher overall scores in a course.

While current research demonstrate that the adaptive learning platforms promote a supportive learning environment, more detailed research is needed regarding student perspectives of the adaptive learning platform. Other studies have collected data on the students' experiences and perspectives regarding the adaptive learning technology [17, 29, 32], but they involved a small number of study participants ($n = 15$, $n = 17$ and $n = 20$, respectively for the cited studies). Further research is needed based on a large number of participants so that a broad range of feedback can be collected and analysed. This is essential in order to better determine whether existing platforms are satisfactory and meet the student learning needs. There is also limited research examining learning analytics data in adaptive learning platforms involving physiology content. Pursuing this research is essential as this may assist in identifying specific physiology topics within the adaptive learning platform that students have difficulty with. This could then support instructors to modify existing teaching methods and platform content to address learning difficulties in physiology and potentially other disciplines.

Thus, the primary aim of this study will involve examining student feedback regarding aspects of the adaptive learning platform that supported or hindered learning, and investigating the learning analytics data to examine the module attempts, question attempts within modules, and student progression through the modules, in order to assess the existing adaptive learning platform within this study. This finding could provide guidance to instructors when designing various online learning platforms for a smoother user experience and greater student engagement with the platform, leading to enhanced student learning experience and maximising the potential of online learning platforms.

2 Methods

2.1 Course context and participants

Participants were students enrolled in the courses including Physiology I (Semester 1, 2019) and Physiology II (Semester 2, 2019) which were offered by the School of Biomedical Sciences (SBMS) at The University of Queensland (UQ), Brisbane, Australia. Students who undertook these courses (approximately 250/semester) were typically in their second year of the Bachelor of Physiotherapy (Honours) or Bachelor of Speech Pathology (Honours), or in the Master of Speech Pathology Studies. Most students who completed Physiology I also completed Physiology II in the same year. Physiology I offered in 2019 consisted of three hours of lectures per week, and eight 3-h practical (laboratory) classes in a semester including six face-to-face classes and two classes with online practical modules. Physiology II was composed of three hours of lectures per week, and six 3-h practical classes in a semester with four face-to-face classes and two classes using online practical modules.

As part of the course assessment, meta-learning tasks were offered online through Blackboard™ (Blackboard Inc., Washington, D.C., U.S.) with four meta-learning tasks in Physiology I and three in Physiology II. They were worth 12% of the course assessment and the final grade for Physiology I and 9% for Physiology II, and were offered at two to four weeks intervals in most cases, with a five week interval in one occasion. Meta-learning tasks included six open-ended questions on course content, metacognition of learning and self-regulated learning strategies. Students had one week to complete each task. Meta-learning tasks have been designed and implemented in many of the biomedical science courses at UQ. The aim of the tasks was to prompt students to be aware of their knowledge and learning processes [10]. Incorporating meta-learning tasks has been found to have positive impacts on the learning process [10].

2.2 Ethical considerations

Only students who gave informed consent to use their data for educational research purposes participated in this study. To determine whether the consenting cohort was academically representative of the entire course cohort consisting of both consenting and non-consenting students, an unpaired t-test on two-sample assuming unequal variances was conducted on Microsoft® Excel® (Redmond, Washington, U.S.). The grades were from Physiology I in semester 1, 2019. The results showed that the average grade of the consenting students was $79.7 \pm 0.91\%$ and the entire cohort was $78.3 \pm 0.77\%$, with a t-test indicating that the performance was not significantly different between these two groups ($p = 0.2207$), hence the performance of the consenting students is representative of the entire cohort.

The student data was protected in accordance with the *Information Privacy Act 2009 (Qld)* and Research Data Management policy at The University of Queensland. Effort was employed to protect the student data, including the de-identification of student identification numbers (Student ID) which was conducted in a way that could not be identified by the third parties. Institutional Human Research Ethics Approval was obtained from The University of Queensland to undertake this study (Approval number: 2018001055).

2.3 Adaptive learning modules

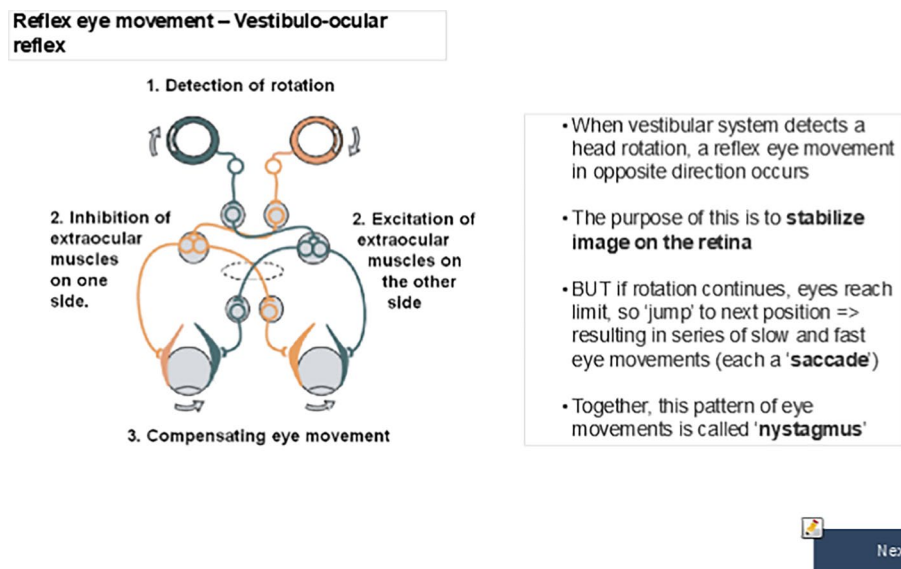
The adaptive learning modules “Action Potentials” and “Vestibular Function” were offered in Physiology I and Physiology II respectively. Both modules were created by the staff from SBMS specifically for these courses and were delivered by the adaptive learning platform Smart Sparrow® (Smart Sparrow Pty Ltd, Sydney, NSW, Australia). Students gained access to the modules online through Blackboard from 1 to 3 days prior to the lectures for these topics. They were free to choose their timing to undertake them, but the majority typically completed them in-class during scheduled practical classes.

Adaptive learning modules were voluntary learning tasks where students were free to choose whether to attempt and complete the modules. Each module consisted of learning content related to a specific physiology topic, and included content related to practical activities, visual representations, and formative questions to test the student’s understanding. Action Potentials module covered areas on action potentials, Nernst equation, resting membrane potentials and refractory periods, whereas the Vestibular Function module covered details on the structure and function of the vestibular system, hair cells, rotational movement and nystagmus. Multiple choice and short answer questions were included in both modules at various intervals throughout the module. Screenshots from the modules are presented in Figs. 1 and 2 as examples.

Fig. 1 The screenshot of slide within the Action Potentials module which includes a short answer question

The screenshot displays a slide titled "Refractory periods Q1". On the left, there is a graph of a compound action potential. The x-axis is labeled "Time (ms)" and has markers at 0, 5, and 10. A stimulus is indicated by an upward arrow at 0 ms. The graph shows a single action potential peak followed by a period of no response (refractory period) until approximately 10 ms, where a second stimulus is indicated by another upward arrow. To the right of the graph is a text box containing the following text: "This compound action potential was recorded when a stimulus was delivered to a nerve trunk. A second stimulus of the same size was delivered 10 ms later (at arrow). What response do you expect from the nerve? Explain why you expected this result." Below the text box is a text input field labeled "Enter Answer:". At the bottom right of the slide, there is a "Next" button.

Fig. 2 A screenshot of a slide within the Vestibular Function module



2.4 Qualitative data collection and analysis: student feedback on modules

At the completion of Physiology I in semester 1, 2019 a short survey was administered online through Blackboard, where two questions were asked regarding the students' experience using the Action Potentials module (Table 1).

In semester 2, 2019, questions were asked to students regarding their learning experience with the Vestibular Function module in Physiology II which were offered in that semester. As there were opportunities to incorporate these questions both at the end of the module and in the meta-learning assessment task for the course, task-specific questions were created (Table 1). Also, as the latter contributes towards the final grade, more students were likely to provide feedback on the modules.

To collect student feedback on modules, students were asked three open-ended survey questions in the final section of Vestibular Function module regarding their experiences using the module (Table 1). Then approximately two weeks after the lecture on vestibular function, and 1–2 weeks after students had the chance to work on the Vestibular Function module in their scheduled class, meta-learning task 3 was administered. This included two questions asking for their feedback on the Vestibular Function module (Table 1). Student responses from the survey questions included in the final section of the module and the meta-learning task were then collected.

Table 1 Questions within surveys and meta-learning tasks regarding their learning experiences with the modules

Physiology I (Semester 1, 2019)

Survey at the end of Physiology I course

1. What were the positive aspects of Action Potential Module for your learning in this course?
2. What were the negative aspects of Action Potential Module for your learning in this course, and are there any areas for improvement?

Physiology II (Semester 2, 2019)

Survey within Vestibular Function module

1. Was the feedback provided in this module helpful? If so, in what ways?
2. Did you have any difficulties while working through this module? If so, what were they?
3. Can you suggest any improvements that would enhance the learning experience of this module?

Meta-learning task 3

1. You recently completed an online module on Vestibular Function. What aspects of this module were useful in supporting your learning? How were those aspects helpful?
2. What aspects of the online module on Vestibular Function hindered your learning? How did these make learning more difficult, and what will you do to overcome these difficulties?

The responses from the surveys and meta-learning tasks for semester 1, 2019 and semester 2, 2019 were collected and de-identified. These open-ended responses were qualitatively analysed using the NVivo® software (QSR International Pty Ltd, Melbourne, Australia), where the features within the Action Potentials module and Vestibular Function module which assisted or hindered student learning were identified.

Qualitative analysis of meta-learning task responses involved two steps, thematic analysis followed by qualitative content analysis. Thematic analysis is a method of identifying, analysing, organising, describing and reporting themes in the data [25]. A theme represents an important aspect of the research question, and they demonstrate a pattern or meaning on a recurrent topic within the data [3, 25]. Themes were identified using an inductive approach where the data was coded without pre-existing theoretical framework or the researcher's preconceptions, so themes were closely linked with the data [3]. Before reporting themes in the data from thematic analysis, a qualitative content analysis was conducted which was performed at a latent level for this study, where the hidden meaning of the textual data was determined, and the themes were quantified by counting the number of respondents included in each theme [2]. This approach of quantifying qualitative data allowed the representation of magnitude of themes more clearly [2].

Once the themes have been identified and the data were grouped into the relevant themes on NVivo in relation to helpful and hindering aspects of the modules, the data were exported to Excel. Then the percentages of students who mentioned each feature as helpful for learning were calculated with respect to the Action Potentials module, out of the total number of students who responded to the meta-learning task question related to the helpful aspects of that module. This was repeated for the aspects which hindered student learning in relation to the same module. This whole process was repeated for the Vestibular Function module.

2.5 Quantitative data collection and analysis

The learning analytics data was imported from the Smart Sparrow platform into Excel, where the data was first checked to ensure that all consisted of relevant and accurate data. Individual students within the data were assigned a number. The learning analytics data that was collected and analysed include the number of module attempts and number of question attempts within modules.

2.5.1 Module attempts

The module attempts were analysed in Excel using the learning analytics data by identifying the number of module attempts by each student for the Action Potentials module. The number of students who attempted the module once, twice or three times or more were determined, and their percentages were calculated out of all students who attempted the module. Then the percentage of students who attempted the module was calculated out of all consenting students for the specific semester in which that module was offered. This procedure was repeated for the Vestibular Function module.

2.5.2 Number of question attempts within Action Potentials module

The number of attempts for each question within the Action Potentials module were also investigated to identify the features associated with the question and module which may affect the number of question attempts. This could then assist in identifying features that support or hinder learning, which could improve question design within adaptive learning platforms.

Firstly, the number of students which corresponded to each specific number of question attempts were determined, from one to five or more attempts, with respect to the first module question at the students' first attempt in the Action Potentials module. This was repeated for the other questions within the same module. Then the percentages for each specific number of attempts associated with the question within module were calculated, by dividing the number of students corresponding to the specific number of attempts by the total number of students who were categorised into each specific number of attempts with respect to the specific question. This was repeated for other questions within the module. The question attempts were analysed based on the students' first attempt at the module, as this represented how students progressed through the module without prior knowledge of its content and structure. This allowed better understanding on the alignment between module content and questions, and could identify any issues to reform and improve in relation to the questions and module content.

2.5.3 Student progression through the module

The data analysed from previous section on module question attempts were used to investigate the changes in the percentage of students who attempted each question as they progressed through the modules. This was important in order to identify which parts of the question or module are creating issues, if any, and to examine how much content within the module that students covered or completed.

A question attempt includes both students who have entered a correct answer and those who attempted but were unable to answer correctly. To progress through to the next slide and question within the module, the student needed to answer the question correctly. As questions were inserted between other contents in the different parts of the module, this provides an indication of the amount of content that the student has covered. A decrease in the percentage of students from one question to the next could indicate that the student left the module after being unable to answer the previous question correctly, the student have left at some point in the module between the previous question and the next question, or that the student viewed the next question but did not attempt it.

To analyse the student progression through the module, the first step was to calculate the total number of students who have attempted the first question at least once for the Action Potentials module. The percentage of students attempting the rest of the questions in the specific module were then calculated by dividing the total number of students who attempted each question by the total number of students who attempted the first question within the module. This process was repeated for the Vestibular Function module.

3 Results

3.1 Participants

Students ($n = 177$) from Physiology I in semester 1, 2019 consented to participate in this study. This represents 66% of the cohort and includes 106 Bachelor of Physiotherapy students, 60 Bachelor of Speech Pathology students and 11 Master of Speech Pathology Studies students. Of these students, 162 also completed Physiology II in semester 2, 2019, including 104 students from Bachelor of Physiotherapy and 58 students from Bachelor of Speech Pathology. Based on consenting students from Physiology I, 70% of students were female and 12% were international students.

3.2 Student feedback on modules

The student responses from surveys indicated that few students responded to the surveys associated with the modules on Action Potentials ($n = 7$) and Vestibular Function ($n = 22\sim 23$). The low number of responses is likely due to the survey attempts not contributing towards the final course grade. In relation to the Action Potentials module, the most positive aspect that students mentioned with respect to their learning was that the module was enjoyable and interesting, whereas the negative aspect that students mentioned the most was that the module content were not helpful, useful nor relevant for learning the topic covered in the module. In relation to the Vestibular Function module, students commonly agreed that the feedback explanations and hints provided by the module were helpful, and students often indicated that they did not have any difficulty while working through the module.

With regards to the student responses to meta-learning task, the module features that were commonly mentioned by students which supported or hindered learning are presented in Tables 2 and 3, respectively, which includes module features that were mentioned by more than 10% of students.

Values are shown as a percentage of all respondents ($n = 155$) to the relevant meta-learning task. The percentage for *Visual Features (General)* also includes the percentage representing *Videos*. Students could mention more than one aspect of the module.

Table 2 Vestibular Function module features that students commonly mentioned which supported their learning

Module features	Students (%)	Description	Example of student responses
Visual features (general)	59.4	Visuals in module such as videos, diagrams, graphs, pictures, images and tables were helpful	"The visual presentation of the information with the diagrams and text made it easier for me to learn as I respond well to visual learning stimuli."
Videos	42.6	Videos included in the module were helpful	"I found the videos quite helpful in summarising and explaining how the vestibular system all works."
Questions and activities (general)	31.6	Questions and practical activities in module were helpful	"I liked how there was questions throughout the tutorial to reinforce what I have learnt."

Values are shown as a percentage of all respondents (n=155) to the relevant meta-learning task. The percentage for Visual Features (General) also includes the percentage representing Videos. Students could mention more than one aspect of the module

Table 3 Vestibular Function module features that students commonly mentioned which hindered learning

Module features	Students (%)	Description	Example of student responses
Need to answer questions to proceed	16.8	Questions had to be answered correctly to proceed to the next slide	"Although the quizzes were good, it has also hindered my learning as I wasn't able to move on to the next section until I've gotten the answer right."
Module cannot recognise correct responses well	14.2	Module platform could not recognise responses well so they could not mark responses accurately	"Some of the answers that we had to input had to be worded in a specific way. So even though we had been putting in essentially a correct answer, it wouldn't accept it until we asked the tutor what they were asking for because it needed to be worded 100% correctly."

Values are shown as a percentage of all respondents (n = 155) to the relevant meta-learning task. Students could mention more than one aspect of the module

Table 4 Percentage of students who have attempted the module and the number of module attempts

	Action potentials (n = 177)	Vestibular function (n = 162)
Students who attempted module	50.8	71.6
Number of attempts		
One attempt	86.7	87.9
Two attempts	7.8	8.6
Three attempts or more	5.6	3.4

Values for students who attempted the module are shown as a percentage of all consenting students (n), and values for the number of attempts are shown as a percentage of all students who attempted. Modules are listed from left to right in the order that they took place

3.3 Module attempts

The results showed that not all students attempted the modules, with only about 50% of students attempting the Action Potentials module and 71% of students attempting the Vestibular Function module (Table 4). In relation to the number of module attempts, most students only attempted the modules once (Table 4).

3.4 Question attempts within Action Potentials module

In terms of the question attempts in Action Potentials module, the results revealed that students attempted the short answer questions a greater number of times than the multiple choice questions (Table 5). Note that the number of question attempts represent either the number of times that students attempted to correctly answer and move onto the next slide, or the number of times that students attempted before they left the module without entering the correct answer.

3.5 Student progression through the module

The results revealed that there was a gradual decrease in the percentage of students who have attempted the questions as students progressed through both modules (Table 6). This was more prominent when they involved the short answer questions, such as in the Vestibular Function module between questions 1 and 2, and questions 2 and 3 (Table 6). The data also show that for the Vestibular Function module, nearly half of students who attempted the first question did not reach and attempt the final question (46.2%) (Table 6).

4 Discussion

The aim of this study was to investigate elements within adaptive learning modules that either support learning or that create issues for students based on the learning analytics and student feedback data.

4.1 The aspects within the Vestibular Function module that supported student learning

In relation to the Vestibular Function module, students most commonly reported visual features as helpful for their learning (Table 2). In computer-based online learning, incorporating visual features such as illustrations, diagrams and videos, in addition to the text or words are beneficial for learning rather than the words alone [22]. Visual features could make the learning content more engaging [36] and easier to understand, and could also help maintain the students' attention and focus towards the learning material [16]. A study by [16] have showed that the majority of students had a positive perception towards learning material involving multimedia, which includes text and visual features, and students have preferred this learning method over the traditional method.

Table 5 Number of attempts on the individual questions within the Action Potentials module

Number of attempts	1. Intra-cellular recording 1 (multiple choice) (n = 126)	2. Nernst equation (multiple choice) (n = 122)	3. Intra-cellular recording 2 (multiple choice) (n = 118)	4. Conduction velocity (short answer) (n = 113)	5. Refractory periods 1 (short answer) (n = 105)	6. Refractory periods 2 (short answer) (n = 97)	7. Compound action potential (short answer) (n = 97)
1	83.3	37.7	81.4	21.2	39	50.5	38.1
2	15.1	15.6	13.6	45.1	10.5	39.2	16.5
3	1.6	44.3	3.4	22.1	8.6	7.2	8.2
4	0	2.5	0.8	3.5	3.8	2.1	10.3
5 or more	0	0	0.8	8	38.1	1	26.8

The values are shown as a percentage of all students (n) who attempted the *specific* question in their first attempt of the module. Questions are listed from left to right in the order that was included in the modules, with the question type in brackets

Table 6 Percentage of students progressing through to subsequent questions within the module

Question number	Action Potentials (n = 126) (%)	Vestibular Function (n = 106) (%)
1	100 [MC]	100 [MC]
2	96.8 [MC]	82.1 [SA]
3	93.7 [MC]	63.2 [SA]
4	89.7 [SA]	62.3 [SA]
5	83.3 [SA]	59.4 [SA]
6	77.0 [SA]	55.7 [MC]
7	77.0 [SA]	53.8 [MC]
8	–	53.8 [MC]

The values represent the percentage of students who attempted each question in their first attempt. The percentages are out of total number of students (n) attempting Question 1, so all values for the first question within modules are 100%. Letters next to the percentages indicate the question type. Modules are listed from left to right in the order that they took place. Dashes indicate that there were no further questions included in the module

MC multiple choice question, SA short answer question

The specific visual feature that students frequently mentioned that supported learning was the videos (Table 2). This could be because the topics on vestibular function involve more visual representation such as the anatomy associated with the vestibular function. Many other institutions have also incorporated videos to deliver practical components of the course online [26] and in diversified online learning formats such as MOOCs (Massive Open Online Courses) [24].

Videos are beneficial as they have the potential to enhance the understanding and remembering of the learning content compared to the text format, and improve the academic performance [8]. Videos also allow students to control their learning by adjusting the speed of video clips and using the pause function to suit the individual learning pace, which could promote students' learning and understanding of the content [8]. Students may have also preferred videos as people learn better in an online learning setting when words are spoken rather than printed on screen, according to the modality principle for managing essential processing in online learning [22]. The finding from [36] also indicated that students largely expressed a positive attitude towards the online review videos covering gross anatomy, with students stating that the videos were an enjoyable way to study and a helpful resource for learning.

Another module feature that students commonly reported as helpful for their learning was questions and activities (Table 2). Students in other studies also had positive perceptions about working with questions, with students in dental courses perceiving online assessments and quizzes positively [13], and students having a positive experience with the opportunity to answer extra questions related to the learning material [15]. In addition, students expressed their enjoyment in finding the answers and explanations for the questions that they answered wrongly [21].

Questions that were included in the module are a part of formative assessment which enables students to receive feedback on their learning progress by identifying areas that students understand or are experiencing difficulties and requires more study, without the requirement for grading, thus assisting in the student learning process [6]. Identifying areas that students have not yet understood is essential as part of the formative assessment in the course so that they can be resolved before the end of the course [6].

Formative assessments have been shown to enhance self-motivation [9], and improve performance in the summative assessments as demonstrated by [15] where students who answered the voluntary multiple-choice questions performed better on the written examination associated with those questions. Furthermore, the use of online assessments such as tests and quizzes have been associated with better academic performance in healthcare-related courses [7], which could indicate that the quizzes related to the online learning content support student learning [8].

4.2 The aspects within the Vestibular Function module that hindered student learning

In contrast, the Vestibular Function module features that were commonly mentioned by students as hindrance to their learning was the need to answer questions to proceed to the next slide, and the module not being able to recognise the correct responses well with respect to the short answer questions (Table 3). This is likely because the Vestibular Function consisted of short answer questions. Short answer questions can be challenging as students have to enter their answer in their own words, and their answers need to be recognised as correct by the online learning system to proceed to the

next slide. In addition, the question design may have been inadequate in terms of not describing the question clearly and creating confusion. Furthermore, the feedback may not have been helpful in guiding students towards the correct response and not providing enough hints. The difficulty with questions may have been further contributed by not being able to go back to previous slides to check for specific information to answer the question.

4.3 Factors affecting module attempts

In relation to the percentage of students who have attempted the Action Potentials and Vestibular Function modules, not all students have attempted the modules (Table 4). But it is important to note that this result is probably affected by how the data was collected. These modules were typically completed in the practical class where students worked through them in groups of two or three, and only one of the students within each group entered their student number on the computer to log in and access the module. When calculating the percentage of students who attempted, the learning analytics data was used which only included these student numbers that were entered into the computer, so the actual percentage of students who attempted the module would have been much higher if the student numbers of all students within each group were included. Thus, the percentage of students who attempted the module is probably an under-representation of the actual percentage who attempted it. The findings also show that most students only attempted the modules once (Table 4). This is likely due to the delivery mode of the course being face-to-face. Consequently, students may have thought that it was sufficient to only attempt the modules in class and that it was unnecessary to attempt again later outside of class time.

4.4 Factors affecting the question attempts within the Action Potentials module

In relation to the Action Potentials module, the short answer questions seem to be associated with a greater number of question attempts compared to multiple choice questions (Table 5). Similar finding was also observed by [23]. This result is probably due to the difference in the question design, where multiple choice questions are easier to answer correctly because multiple possible responses are provided with one of them being correct. Short answer questions are more difficult as students need to work out and enter their responses in their own words. Hence students have to continue making question attempts until their responses match with the one that are registered by the online learning system.

In terms of the individual questions within the Action Potentials module, there seems to be a greater number of attempts for Question 2 compared to other multiple choice questions within the module, with 44.3% of students making three attempts (Table 5). This may be due to this question being a mathematical question, with mathematics being considered to be a difficult discipline [34]. In addition, students were possibly not prepared to apply the mathematics skills needed in the physiology discipline, as students did not expect mathematics to be involved in the physiology course [33]. Also this was a multiple choice question with three possible responses to choose from, so students may have reached the correct response at third attempt after selecting two other possible responses which were incorrect. Another finding that should be noted is regarding Question 5 on Refractory Periods 1, which had the highest percentage of students attempting five or more times (Table 5). This could be due to only one word that was being recognised by the system as the correct response, which resulted in student responses being marked as incorrect even if they were describing the similar idea as the word that was recognised by the system.

4.5 Student progression within the modules

In terms of the student progression through the module, a decline was seen in the percentage of students attempting the questions that followed the first question with respect to the Action Potentials module and Vestibular Function module (Table 6). This may be a result of students being expected to complete the modules in class. Students may have become distracted by the surrounding environment and the presence of other students in class, so this may have affected the students' progress through the module. Another possible reason for the decline could be that students were less engaged with the module content [31], or that students may have had difficulty with the module and content.

The result that should be noted specifically is the greater decline observed for question attempts as students progressed through the Vestibular Function module in contrast to the Action Potentials module (Table 6). This is potentially due to the inclusion of short answer questions in the early part of the Vestibular Function module from Question 2 to Question 5 (Table 6), which are considered to be more difficult to answer correctly to progress to the next slide than

the multiple choice questions. Students possibly felt discouraged to continue further so they may have left in the early stages of the module (Table 6).

With regards to the Vestibular Function module, there was a decrease in the percentage of students who attempted the question from Question 1 to Question 2 (Table 6). This could be due to the diagram associated with Question 1 which was not clearly represented and was difficult to understand in some areas. This may have discouraged students from progressing further in the module. Another reason could be due to how Question 2 was written. The concepts related to this question were covered in the previous slide, but the terminology used in the question was not mentioned in the previous slide so this made the question confusing, difficult and unclear on the type of response that was required. Consequently, this opened up the question to a broad range of answers. This difficulty was further deepened by this question being a short answer question, so students may possibly have only viewed the question and decided to not attempt it and leave the module.

In terms of the Action Potentials module, there was a decrease in the percentage of students who attempted the question from Question 4 to Question 5 (Table 6). This is likely due to issues with Question 4 where the important details needed in order to answer the question correctly were missing in the question, and the mathematical equation was not presented well, with the division being shown as a slash rather than the horizontal line, which created a slight confusion. As a result, students may have been discouraged from progressing further in the module due to not being able to answer Question 4 correctly, and this question being a mathematical question which could pose difficulties among physiology students [33, 34].

There was also a decrease in the proportion of students who made question attempts from Question 5 to Question 6 within the Action Potentials module (Table 6). This is potentially because Question 5 was a short answer question where there were issues with the system's ability to recognise correct responses, with responses being marked as incorrect even if they represented the same meaning as the correct response. Hence students may have been unable to answer the question correctly so they were unable to proceed further in the module. In addition, Question 5 and the diagram associated with this question were slightly unclear so this may have also contributed to the difficulty answering this question correctly and progressing to the subsequent questions.

4.6 Limitations and future research

One of the limitations of this research was that students worked on the module in groups with only one of the students in a group registering their module use with their student account. Hence the percentage of students who have attempted the module as presented in Table 4 is probably not accurate. Thus future research should collect data on the module usage for each student to better understand the module usage.

This study would have been more complete if there was more student feedback data in relation to the Action Potentials module. The student feedback data for this module was limited, as there were only a small number of responses to the Action Potentials module survey. More data would have been collected if the questions regarding students' feedback of the module were included within the meta-learning task. But this was not possible as the meta-learning tasks were all completed for the semester associated with this module when the data collection for this study was about to begin. More student feedback data from the Action Potentials module would have provided an insight into the differences in feedback between modules covering different course topics.

The student feedback and learning analytics data collected for the modules were all based on the Smart Sparrow platform and the content was all related to the physiology course so this could be another limitation. The findings may differ from this study if a different online learning platform is used or if the modules included content from another discipline. Thus subsequent research should explore the student feedback and learning analytics data based on a different platform and different discipline to examine any variability in findings.

5 Conclusion

The study findings have revealed aspects related to the module that supported or hindered learning from the students' perspective. This data could support instructors in designing the adaptive learning platforms and potentially other online learning platforms that delivers a supportive learning experience that adapts to the students' learning needs. Instructors currently using the online learning platform as part of their courses could incorporate or maintain the aspects that students found helpful and useful based on this study. Instructors could also refer to the aspects that hindered learning and

identify areas within their existing online learning platform that could be contributing to students' learning hindrance, and how to resolve issues and make improvements with the platform to enhance the learning experience. The learning analytics data also revealed that further improvements need to be made when designing short answer questions and the ability for the platform to recognise correct responses to the short answer questions. With online learning forming a core part of university courses, the study outcomes could support instructors to assess their current teaching methods and whether they are maximising the potential of online learning platforms.

Author contributions HA, PI and KC contributed to the research design and methodology development. KC was involved in the collection of data. HA was involved in writing the meta-learning task questions and the analysis of data. HA, PI and KC drafted, revised and edited the manuscript. All authors read and approved the final manuscript.

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Data availability The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate All methods in this study were carried out in accordance with relevant guidelines and regulations.

Competing interests The authors declare no competing interests.

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