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EDICIÓN:
Rosana Satorre Cuerda

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38. Effectiveness of a novel e-learning environment for learning applied clinical biochemistry

Peña-Fernández, Antonio[1]; Peña, María de los Ángeles[2]; Breda, Carlo[1]; Evans, Mark Dennis[1]

[1]Leicester School of Allied Health Sciences, De Montfort University. The Gateway, Leicester LE19BH, UK; [2]Universidad de Alcalá

ABSTRACT

Comprehensive developments were carried out in the virtual environment e-Biology© (http://parasitology.dmu.ac.uk/ebiology/) to help with the on-line delivery of the final year BSc Biomedical Science module of Clinical Biochemistry at De Montfort University (DMU, UK) in 2020/21. To provide a holistic education around human biology, e-Biology© has four interactive modules: i) theoretical; ii) laboratory; iii) microscope; and iv) case studies. The recent developments undertaken to help with the applied teaching of clinical biochemistry includes: two practicals (identifying disease using urinalysis and competitive ELISA for human biomonitoring of nicotine exposure), and specific case studies. 65.2% and 57.8% students (n=46/166) highlighted that they learnt to perform both practicals for clinical biochemistry diagnosis, urinalysis and ELISA, respectively. However, similar percentages were observed about the preference of students regarding the delivery of the practicals, face-to-face (43.5%) vs. on-line (43.4%). Following the completion of the virtual case studies, 82.6% of responders indicated learning of specific tests for diagnosing kidney pathologies. Most responders considered that the overall e-Biology© helped with their study of Clinical Biochemistry, and enhanced their learning and reasoning of applied Clinical Biochemistry. In conclusion, the novel package was an effective resource for the virtual teaching of Clinical Biochemistry due to the COVID-19 pandemic.

KEY WORDS: e-Biology©, clinical biochemistry, virtual learning, clinical reasoning.

1. INTRODUCTION

The coronavirus pandemic 2019 due to SARS-CoV-2 (COVID-19), with more than 164 million cases and over 3 million deaths globally as of May 19th 2021, has significantly disrupted bioscience and medical education. Clinical training programmes in England, including the BSc Biomedical Science (BMS) at De Montfort University (DMU, Leicester, UK), have abandoned or significantly reduced face-to-face laboratory teaching during 2020/21 to meet the social distancing regulations imposed.

Online teaching has numerous advantages versus traditional teaching methods, such as flexibility, and alleviates different challenges that higher education is currently facing, including changes in the student demographics, lifelong learning, increasing the educational offer (including new programmes and courses), or to provide students with immersion in new technology (Concannon et al., 2005; Müller and Wulf, 2020). However, despite online learning becoming the "new normal" in education, there are still important challenges that need to be addressed to deliver a successful education by virtual means, specifically maintaining learner's engagement. Students' engagement can be overcome by setting up an appropriate and effective learning community, for example by using video calls, group activities, etc. through different platforms, such as Microsoft Teams (Microsoft, Redmond, Washington) or Blackboard (Blackboard e-Education platform, Blackboard Inc, Washington, D.C.) (Serrano-Solano et al., 2021).

During summer 2020, an international innovation teaching team led by DMU in collaboration with different European Universities, including the University of Alcalá (Spain), has completed a series of comprehensive developments in our novel virtual teaching and learning environment named e-Biology© (http://parasitology.dmu.ac.uk/ebiology/), to aid with the online delivery of the final year BMS module of Clinical Biochemistry and overcome the constraints imposed by the pandemic regarding face-to-face teaching.

The development of the e-Biology© package was initiated in 2017 as a response to tackle student retention and progression, by providing students with a complete virtual environment to support biology and (bio)chemistry to enable them to make a smooth transition from further education to university studies, as the BMS programme receives students from different routes, including from non-traditional routes such as Business and Technology Education Council (BTEC) qualification. Thus, our teaching team identified that providing some initial support in STEM subjects for our first year students in 2016/17 could have been the factor responsible of the small reduction in the percentage of new students that abandoned their studies after their first year from 2015/16 (10.3%; 24 students) to 2016/17 (6.5%; 13 students) [data described in Peña-Fernández et al. (2017)].

The package developed has four interactive modules, which covers the specifications for AS and A level described by the Assessment and Qualifications Alliance (AQA, 2017) for human biology and the specifications of the first year modules related to human biology and biomedicine [*e.g.* human anatomy and physiology, (bio)chemistry, microbiology]: i) theoretical; ii) laboratory (to learn important biomedical techniques, e.g. medical histology/ tissue staining); iii) microscope (with digitised virtual human tissue slides); and iv) case studies (to facilitate the acquisition of reflective and clinical skills).

The **main aim** of this communication is to validate the e-Biology© package as a potential teaching tool with BMS students and its effectiveness in aiding with the online teaching of Clinical Biochemistry from an applied perspective. Thus, we measured the degree of success of this resource in providing students with the following learning objectives considered for pathologies including those affecting the excretory system:

- Biochemical/physiological processes in kidney disease and their relationship to appropriate laboratory measurements for the diagnosis/patient management.
- Interpretation of clinical biochemical data for the diagnosis of some common pathologies with the use of urine as a non-invasive diagnostic tool.
- The commonly encountered mistakes/difficulties in the use of the chemical pathology laboratory in diagnosis and management of these patients.

2. METHODS

Two Graduate Champions (a DMU scheme for promoting real work experience to recent graduates), a multimedia developer and a graphic designer, were hired in summer 2020 to develop the novel resources on Clinical Biochemistry for the e-Biology© package, following previous successful methods for the development of virtual resources (Peña-Fernández et al., 2020). Briefly, the novel e-learning units for the virtual laboratory and virtual case studies modules were specifically created with Articulate 360 software (Articulate Global, Inc.) in close collaboration with the academic team. Artworks, graphic designs and visual media were created with support from the academics involved in this project and DMU technicians, to develop appropriate and engaging e-learning units, which will facilitate understanding and enhance knowledge transfer/retention, facilitate student engagement, aid students in visualising model-based reasoning and simplify the communication of complex biological concepts. Specifically, we have created:

a) Two practicals on clinical biochemistry (available at: http://parasitology.dmu.ac.uk/ebiology/biologyLaboratory_units.htm): 1) urinalysis, which consists on the performance and interpretation of analysis of human urine using specific dipsticks; 2) competitive ELISA for human biomonitoring of nicotine exposure. Both practicals were performed and recorded by the lab-lead academic, and later embedded in engaging e-learning units in form of short videos with audio and captions, which comprehensively explained the different steps. These e-units were then populated with further background information and different mini-quizzes to facilitate comprehension and engagement.
b) Specific clinical biochemistry case studies (available at: http://parasitology.dmu.ac.uk/ebiology/biologyCaseStudies.htm): mini and major e-learning case studies units were created on different topics, including common pathologies particularly those affecting the liver and kidney. These clinical case studies were created with differing degrees of difficulty to facilitate the acquisition of clinical biochemistry skills by promoting reflection and critical thinking. Briefly, these e-learning units are provided with a complete a medical history of a "virtual patient", with detailed information of clinical biochemistry data. The user needed to diagnose the possible disease by using the data provided, including the use of virtual "clinical samples" available with the functionality of the virtual microscope. To facilitate engagement and clinical reasoning, the user is prompted to navigate through the case study, meanwhile completing different mini-games and exercises regarding the virtual patient, which also involve management and differential diagnoses to aid the patient.

2.1. Context and participants

Final year BMS students (n=166) at DMU used aspects of the e-Biology© for studying Clinical Biochemistry (compulsory module; 15 credits) in 2020/21, specifically the practicals and the applied clinical biochemistry sessions. This module, despite its large lab practical component, was entirely delivered online in 2020/21 this academic course, using the virtual learning environment (Blackboard Collaborate Ultra©), due to the COVID-19 pandemic. The BMS programme at DMU is accredited by the Institute of Biomedical Science (IBMS), and is a popular clinical science programme which offers a myriad of career opportunities, including working in the pathology departments in hospitals, research institutions, biotechnology and pharmaceutical industries, education and other areas. Thus, approximately 600 students are currently enrolled in this programme at DMU.

2.2. Instruments

We used different quantitative approaches to determine the effectiveness of the e-Biology© in facilitating the acquisition of the described clinical biochemistry skills. A validated electronic feedback-questionnaire with Likert scale and open-questions (free-response) was used to collect student impressions and opinion on the different four modules available in the e-Biology© package (we describe here the feedback provided for the most relevant modules, *i.e.* the virtual laboratory and case studies modules). Different authors have described that feedback-questionnaires are an appropriate tool to determine the degree of acceptability and satisfaction of a blended learning approach (Scamell and Hanley, 2018), and can measure the degree of satisfaction of the teaching and learning processes (Peña-Fernández et al., 2015). Ethical approval was provided by the Research Ethics Committee at DMU (Ref. 1850) and written approval from participants was obtained in each electronic questionnaire.

2.3. Process

Students received a pre-recorded video of each lecture (less than 15 min) and completed a full 50 min synchronous lecture, in which they completed different minigames and exercises to practice main lectures' objectives, and were signposted to the different e-learning theoretical units available on the e-Biology© package to specifically revisit anatomy and physiology, which it is essential for the appropriate learning of this topic. During the first term of the course, students completed both clinical biochemistry practicals available in the e-Biology© package, and completed all the different mini-games and exercises available. Finally, students completed a specific virtual workshop in small groups during the second term, in which they completed the mini and major clinical biochemistry case studies available on kidney disease in e-Biology©. This workshop was repeated several times to distribute students into small groups, and were asked to complete the main virtual case study related with kidney disease. Students needed to navigate throughout the entire e-Biology© package and use all the tools/sections (specifically the virtual microscope and laboratory) to resolve the clinical biochemistry case scenario proposed. Results were discussed with the students even though they were prompted with instant feedback when completing the virtual case study, in order to clarify erroneous knowledge or misinformation, by using Blackboard Collaborate. At the end of this session, students were asked to voluntarily provide feedback by completed the validated electronic feedback-questionnaire in Jisc Online Surveys.

3. RESULTS

Forty six out of 166 final year BMS students that studied with these novel resources in Clinical Biochemistry at DMU in 2020/21 provided comprehensive voluntary feedback at the end of the workshop. Most students enjoyed the experience with the e-Biology© (73.9%), specifically the voice-over and subtitles available in the mini-videos and the presence of different formative activities and highly interactive mini-games, which helped them to understand the topics delivered in the module. Students' responses, in percentages, on their impressions on the use of the e-Biology© for the clinical biochemistry practicals are depicted in Table 1, meanwhile Table 2 collects information regarding the virtual case studies. 58.7% (30.4% neither agree nor disagree) participants considered that studying and learning Clinical Biochemistry will help their future career.

Table 1. Responses (%) to the feedback-questionnaire to evaluate the clinical biochemistry virtual practicals.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The two practicals available were easy to understand	0	10.9	15.2	58.7	15.2
The formative assessments and mini-games available enhanced my learning	0	8.9	11.1	51.1	28.9
I have learnt to perform urinalysis for clinical biochemistry diagnosis	2.2	8.7	23.9	58.7	6.5
I have learnt to perform ELISA for clinical biochemistry diagnosis	6.7	13.3	22.2	55.6	2.2
The practical units could substitute the real practicals in the laboratory	15.2	28.3	13	39.1	4.3

Table 2. Responses (%) to the feedback-questionnaire to evaluate the clinical biochemistry case studies.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have gained an appropriate knowledge of specific clinical biochemistry tests for diagnosing kidney diseases	0	10.9	6.5	71.7	10.9
I have learnt some non-invasive techniques for confirming kidney pathology	0	10.9	8.7	69.6	10.9
I have gained an appropriate knowledge of specific clinical biochemistry tests to manage patients with kidney diseases	0	10.9	19.6	58.7	10.9

4. DISCUSSION AND CONCLUSIONS

Participants highlighted an appropriate learning of both practicals (Table 1), specifically 65.2% (23.9% neither agree nor disagree) and 57.8% (22.2% neither agree nor disagree) highlighted that they learnt to perform urinalysis and ELISA for clinical biochemistry diagnosis, respectively. These results agree with those reported in similar experiences, which have reported a greater understanding of how to analyse laboratory results in students using virtual platforms, possible due to the possibility of repeating the lab experiments as necessary, which increases student's understanding and is impractical in a physical laboratory environment due to physical, economic and time constraints (Kolil et al., 2020). Moreover, emerging evidence has suggested that distance learning would not have significant differences when compared to traditional classroom teaching (Ødegaard et al., 2021). However, although students indicating significant acquisition of clinical practical knowledge, 43.5% considered that the virtual practicals could not substitute the physical practicals in the laboratory. This mix result has been also recently reported in similar experiences, for example for the teaching of toxicology practicals at the Universidad Complutense de Madrid (Ramos and Romero, 2021), as well as with junior/senior chemistry majors that completed a virtual online ELISA practical (Simpson and Jakubowski, 2020). Similarly, our students also reported to struggle with the calculus of the ELISA practical, which may highlight a need to strengthen mathematical skills in our DMU students. We consider that the optimal learning environment would be a blended approach, in which students can perform the practicals physically in a lab classroom in combination with the benefits of online instruction to reinforce the scientific theory through technology integration. This approach will reduce the common limitation found in students' ability to manipulate tangible laboratory equipment observed in those that have only use online learning platforms (Hall, 2016), and strengthen their chemical/calculus reasoning. Thus, most responders considered that the overall e-Biology© package helped with their study of Clinical Biochemistry (with only 10.9% students in disagreement).

The clinical biochemistry virtual case studies, which were completed in an innovative workshop to promote students' collaboration and interaction, pivotal for facilitating engagement using virtual resources, seemed to have a higher effect on the learning of students than the practicals. Thus, 82.6% indicated learning of specific tests for diagnosing kidney pathologies, meanwhile 69.6% reported learning of different tests for managing patients with kidney diseases and up to 80.5% learnt non-in-

vasive techniques for differential diagnoses (Table 2). Although the e-Biology© package shown to be a highly successful tool to facilitate students' acquisition of technical skills, the results, although very positive, seemed to suggest that the package was less efficient in facilitating students' acquisition of critical thinking and reflection, key competences to acquire applied clinical reasoning knowledge of clinical biochemistry (Devi et al., 2017). These results are in agreement with previous experiences using virtual clinical case studies undertaken by our research team, which have suggested acquisition of clinical reasoning and applied skills. Thus, third year Agricultural Engineering students at the Universidad de Salamanca learnt specific clinical parasitology skills following completion of the case studies available in our other virtual environment, named e-Parasitology© (73.3% agreed, 3.3% strongly agreed; Peña-Fernández et al., 2021).

Although participants found the e-Biology© a valuable tool for developing applied clinical biochemistry skills, they suggested a combination of both teaching methods as the best approach for their learning, *i.e.* online learning in combination with traditional face-to-face teaching. This request is not surprising due to the substantial laboratory component of the final year BMS modules, including Clinical Biochemistry. A similar request has been reported by Bloomfield and Jones (2013) in graduate first-year pre-registration nursing students. These students also reported similar perceptions as our BMS students at DMU, *i.e.* students found the video clips very useful, meanwhile technical difficulties were reported as the main frustration of using virtual learning environments.

Finally, the incorporation of the e-Biology© package has resulted in an enhancement in students' interest and motivation in studying clinical biochemistry, which is a critical component of future students' academic success in terms of retention, learning and subsequent performance. Thus, most responders indicated an enhancement in their interest in studying clinical biochemistry (7.3% disagreed).

In conclusion, e-Biology© helped with the efficient virtual teaching of clinical biochemistry, which has a significant laboratory practical component, during a challenging year for students. This novel virtual package positively aided final year BMS students in gaining significant knowledge of clinical biochemistry by promoting self-learning, as well as facilitating them to acquire specific clinical and technical skills and reasoning, which are highly valuable for these future clinical science professionals. The virtual laboratory and clinical case study modules combined with the virtual tissue slides available in the virtual microscope, have also shown to facilitate a team-based learning approach, which involves self-work followed by teamwork using different platforms, such as Blackboard Collaborate Ultra. Academics can use the freely available e-Biology© web-based resources (laboratory and microscope) in a myriad of effective practical activities.

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