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Integrating the Curriculum for Respiratory Scientists

Evaluating the Impact of Online Problem-Based Learning Integrating Pulmonary Pathophysiology with Pulmonary Function Testing Interpretation

Alison White * | Griffith University, Australia

Abstract

An online, asynchronous, self-paced problem-based learning (PBL) workbook was introduced into the curriculum for postgraduate Respiratory Science students to complement lecture-based teaching. The PBL activity was horizontally integrated, drawing on concepts from multiple subjects, and aimed to develop critical thinking, understanding of pulmonary pathophysiology, and confidence in interpreting pulmonary function tests (PFTs). These skills are increasingly required by Respiratory Scientists due to a rising prevalence in global lung disease. Delivered after didactic teaching, the workbook engaged students in complex clinical scenarios. Post-activity questionnaires indicated increased engagement, improved conceptual understanding, and greater confidence in PFT analysis. Students also reported feeling better prepared to manage unfamiliar clinical problems. These findings suggest that flexible, non-traditional learning approaches can effectively support diagnostic reasoning and problem-solving skill development and thus support clinical readiness. The

* Corresponding author:
Alison White, Email: alison.white@griffith.edu.au

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model of online learning described in this manuscript shows potential for broader application across allied health education to better prepare graduates for clinical practice.

Keywords: Respiratory Scientist; Pulmonary Function Technologist; Problem-Based Learning; Pulmonary pathophysiology; Pulmonary function testing

Introduction

Problem-Based Learning (PBL), grounded in constructivist theory, places students at the center of their education, promoting active learning through guided exploration of real-life problems (Beachey, 2007; Günter, 2018). This approach fosters critical thinking and encourages learners to build upon existing knowledge, progressing from foundational concepts to clinical application (Beachey, 2007; Boud, 1985). In health education, Case-Based Learning (CBL) is a practical extension of PBL, presenting students with authentic clinical scenarios linked to previously taught content (Günter, 2018; Dulloo & Pathare, 2013; Donkin, et al., 2023). Delivered in various formats, including small groups, online, or asynchronously, CBL challenges students to analyze cases, research concepts, synthesize knowledge and identify knowledge gaps with the aim of elucidating a solution to the clinical case (Sistermans, 2020). This approach prompts students to move beyond mere recall and lays the foundations for growth of academic performance and clinical competency as the knowledge built can be utilized to guide decision making in future clinical cases (Donkin, et al., 2023; Sistermans, 2020). This process of analysis and synthesis which CBL provides, enhances critical thinking and clinical decision-making skills (Sistermans, 2020).

CBL has proven effective in teaching pathophysiology in medicine and nursing; improving student autonomy and integration of theory with practice (Brown, et al., 2012; Grønlien et al., 2021; Zhang et al., 2018; Peng & Wei, 2021). In addition, CBL can cover multiple different subject areas which enables assimilation of concepts across curricula. The concept of an integrated curriculum can be defined as education which crosses subject matter boundaries and academic time periods where concepts from separate subjects are combined over time in the curriculum with the aim to create meaningful associations (Brauer & Ferguson, 2015). The benefits of an integrated curriculum for students is that it supports students to demonstrate how knowledge from various subjects are related to each other beyond memorization of facts (Winarno, et al., 2020).

Respiratory Scientists (RS) are allied health professionals who conduct, interpret, and report Pulmonary Function Tests (PFTs) and in some instances provide therapy support. The role of an RS requires advanced critical thinking to operate equipment, follow protocols, adhere to evidence-based practice and interpret data accurately so as to optimize patient care (Barnes, et al., 2010; Doorely, et al., 2019; Zaccagnini et al., 2024). The educational level of Respiratory Scientists varies globally, ranging from Diploma to Master's level; with variations in role titles including Respiratory Therapists, Technicians, Technologists, Respiratory Physiologists and Clinical Scientists (Shakespeare, et al., 2019; Australian Council for Clinical Physiologists, 2020; Kollet, 2017; Danzy, et al., 2022; Sreedharan, et al., 2022). Respiratory Scientists differ from medical doctors as they do not undertake medical training and are thus unable to prescribe treatments. The COVID-19 pandemic intensified demand for RS, a trend expected to continue to rise due to increasing lung disease prevalence globally (Danzy, et al., 2022; Doorley et al., 2019).

The evolving clinical landscape for RS necessitates educational strategies which cultivate critical thinking and problem-solving skills. The use of PBL supports the development of critical thinking skills, yet evidence of the inclusion of PBL or CBL in the curriculum for RS remains scant in the literature (Ismaiel, Y., et al., 2014; Jones, T.D., et al., 2023). To address the gap in the use of PBL in the curriculum for a group of postgraduate RS in Australia, an asynchronous, self-paced CBL workbook was developed using the online software platform of PebblePad. The workbook was completed by students in their first semester of a two semester program, prior to undertaking clinical work integrated learning (clinical placement or clinical experience). Based on classroom content taught across multiple subjects, the workbook included clinical case histories, diagnostic PFT data, multimedia resources including both audio and image files, and guided questions. The content of the online CBL activity integrated concepts from pulmonary physiology, pulmonary pathophysiology and pulmonary function testing results data. On completion of the online CBL, students were provided with feedback on their answers from faculty members. Students were invited to reflect on their experiences with the CBL activity post-completion of the activity. This paper explores how integrated online CBL activities can extend learning beyond traditional methods of didactic classroom teaching, deepen understanding of respiratory diagnostics test interpretation, and enhance student confidence in approaching complex clinical scenarios.

Methods

Workbook design and rationale

The manner in which PBL is delivered can vary and be tailored to meet the needs of a specific cohort of students. In spite of potential variations, at the core of PBL are three key elements 1.stimulate, 2.consolidate and 3.extend; presenting content as a problem to stimulate learning, providing faculty or group feedback to consolidate learning and group or tutor discussions to extend learning (Ghani, et al., 2021). The online workbook design described in this manuscript is summarised in the table below, in order of how the content appears in the workbook. The progressive nature of the order in which the content was presented in the workbook was curated to reveal information in staged segments such as would occur in a real clinical encounter. The progressive disclosure encourages revision of content, metacognition and active engagement (Vuma, S., & Sa, B., 2015). Aligning with the key principles of PBL design, learning objectives and patient case history stimulate learning; diagnostic testing data and pathophysiology explanations consolidate learning; whilst reflection supports extension of learning. Tudor Car and colleagues in their 2019 systematic review compared online PBL to traditional learning and found that online PBL improved knowledge retention through a greater level of student engagement and interaction with the content in comparison to traditional learning methods (Tudor Car, et al., 2019). Online learning can be passive if open questions which challenge critical thinking are not incorporated. Featuring open PBL questions in online learning promotes critical thinking through the use of an enquiry based approach where students can take ownership of their learning through goal setting and reflection (Saqr, M., & Lopez-Pernas, S., 2023). The aim of the online workbook was to provide an asynchronous realistic patient scenario to support students to apply theoretical knowledge from multiple subjects to a genuine clinical problem in a stepwise manner to provide relevance and motivation for learning.

Workbook design description	**Description of incorporation of PBL principles in the online workbook**
List of learning objectives	Initiate learning by prompting student recall from content presented in previously delivered didactic lectures
Patient case history	To provide contextual background to support the practice of clinical reasoning
PFT data	Authentic case study results from a real-life patient are presented to introduce students to abnormal diagnostic test results
Guided questions on PFT data	The guided questions are designed to prompt students to critical analyse testing results in order to prompt diagnostic reasoning skills
Signs and Symptoms	Multimedia artefacts including auscultation, sputum images and X-ray images are presented in the workbook which enhances the realism of the case. Questions regarding the artefacts, clinical signs and symptoms are presented with the aim to encourage the development of the skill of differential diagnosis
Pathophysiology questions	Complex questions regarding the potential pathophysiology involved in the patient case were presented. This step in the workbook is crucial for promoting active and independent learning, rather than merely recalling or reciting facts. In this section of the workbook, students are required to integrate pathophysiology knowledge to explain the derangements to functional capacity as well as determine the cause of the presenting signs and symptoms (i.e. linkage of the pathophysiology to diagnostic data and clinical manifestations).
Reflection	Due to the asynchronous nature of the online workbook, the element of immediate tutor or group feedback was absent. To support this element of traditional PBL design, students were required to undertake a reflection with guided prompts subsequent to receiving feedback from tutors on their workbook answers. The reflection supports students to identify gaps in their knowledge and encourages students to extend their learning through independent research.

Table 1. Online workbook design principles and rationale.

Research design

This qualitative study was conducted over three separate academic years (2022, 2023, 2024) to three different cohorts of postgraduate Respiratory Science students enrolled in the Graduate Diploma of Clinical Physiology at Griffith University Australia. Participation in the research project was voluntary. All students enrolled in the postgraduate program had previously completed a three-year undergraduate level bachelor's degree in biomedical science or clinical science. Participants were asked to complete a survey on their experiences prompted by a Likert scale questionnaire as well as open-ended (free response) questions. The research described in this paper was approved by Griffith University's Research Ethics Committee (Griffith University ethics reference number: 2022/151).

A total of 30 students were enrolled in the program over the three year period that the research was conducted, and 16 students chose to complete the questionnaire. All survey questions were answered by all respondents, except for 1 survey question in which 1 participant did not answer the question of "The digital case based learning helped me to develop my problem solving skills for this module". The demographics of survey participants were: 70% birth sex female, 30% birth sex male, 100% were domestically enrolled, age ranged between 21 and 35 years of age.

Results

Cross-course integration (the integrated curriculum)

Student perceptions on the effectiveness of the online clinical CBL workbook were captured and are shown in Figure 1. Results of the 5-point Likert scale questions revealed that no student disagreed or strongly disagreed with any of the survey questions.

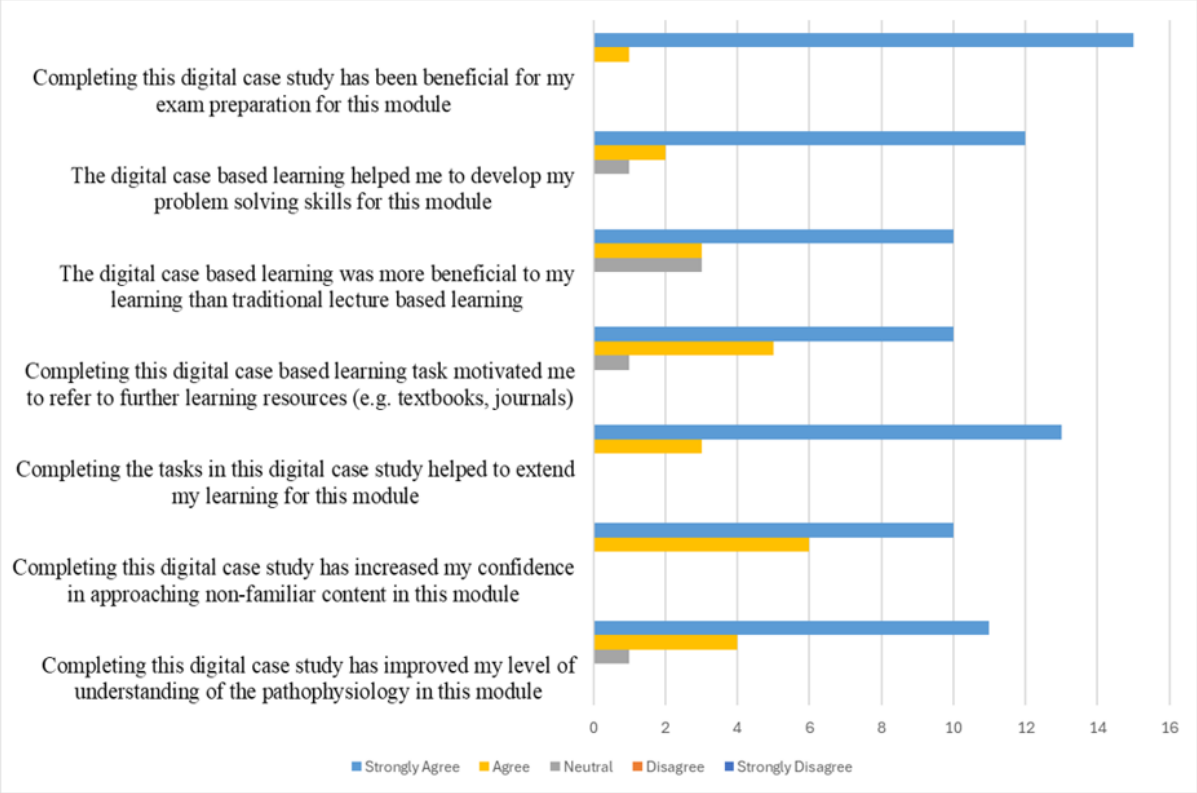

Figure 1. Student perceptions of the effectiveness of the asynchronous online integrated curriculum clinical CBL activities. Legend: Blue = Strongly Agree, Yellow = Agree, Grey = Neutral. There were no responses for Disagree or Strongly Disagree.

Students reported that their level of understanding of the pathophysiology content related to coursework increased after engaging with the online CBL, as 73% of students strongly agreed that their knowledge of respiratory pathophysiology improved due to completing the online CBL. Representative comments to the open, free response question of "What was the most beneficial aspect of completing the digital case study?" include:

> "I found linking the evaluation techniques and pathophysiology content very beneficial. it is a holistic approach to learning, not just reciting facts."

> "I got to implement what I've learnt from two courses and integrate my knowledge. I now see how everything comes together, and it does make me appreciate the details of lung function testing, and how important patient symptoms and trends over the years predict their prognosis."

> "The combination of x-rays, spirometry, symptoms and clinical manifestations and pathophysiology helps to link together all the foundational knowledge and skills gained during separate courses and pull them together to create a solution"

These results reflect that students value the integration of theoretical knowledge (e.g., pathophysiology) with practical evaluation techniques, as it promotes a more comprehensive and meaningful learning experience. Students appreciated the opportunity to synthesize knowledge from multiple subjects which helped them see connections between content module areas. This integration of the curriculum enhanced students' appreciation for the complexity and clinical significance of pulmonary function testing for patient outcomes. These positive results link to the key PBL elements of stimulating and extending learning.

Online PBL and confidence with content

Student RS in the Graduate Diploma of Clinical Physiology are expected to develop advanced and integrated knowledge of the theoretical, practical, professional and critical analysis skills required of a RS in the clinical diagnostic testing environment. Given the level of expectation required of these students in their professional role, supporting the development of the level of confidence was a driving factor in developing the online CBL activities. The online CBL workbook was effective in building levels of student confidence in approaching unknown content, with 62.5% of respondents strongly agreeing and 37.5% of respondents agreeing that their level of confidence with the content and their ability to manage unfamiliar content directly increased as a result of engaging with the online CBL workbook. The degree of impact on developing student confidence is also evidenced from answers to the free-response question:

> "Provided a very good starting point for exam revision and allowed me to gauge my confidence on certain topics as well as apply my knowledge to a simulated real world example of a patient with lung disease. It also encouraged me to go back through my notes to revise topics I had less confidence in."

> "Helps me have a well-rounded education and makes me more confident going into the workplace."

> "I am not confident in respiratory, particular interpreting data, and found that this learning experience has allowed me to improve and further understand respiratory conditions and their associated pathology."

The online case-based learning (CBL) workbook enhanced student confidence in managing unfamiliar clinical content by fostering integrated knowledge and practical application. This approach effectively supported the professional readiness of students, aligning with the advanced expectations of their future roles.

Online CBL vs. lecture based CBL

Over half of the survey respondents (65.5%) strongly agreed that the online CBL was more beneficial to their learning than traditional lecture-based learning. Student comments on the benefit of the online CBL versus traditional in-class learning showed consistency in the themes of that the online activity was more effective in providing a vehicle for them to step through the content at their own pace and allowed them to focus on concepts more thoroughly then the traditional in-class learning permitted them to.

When responding to the open question of "What was the least beneficial aspect of completing the digital case study?" students were overwhelming positive about their experiences and commented that *"nothing was unbeneficial"* and *"There was nothing that wasn't beneficial to me."* The only criticism of the online PBL was reflected in a single students' comment of they did not like the "*inability to immediately check some answers*." A limitation of the model of how the CBL was delivered in the current research project was students were unable to receive immediate feedback on their answers because the CBL was offered online asynchronously to the content delivery. However, there was minimal time for students to wait for feedback as written feedback on students answers was provided within 48 hours of students completing the online CBL workbook. The concern of the inability to receive immediate feedback could be addressed in future offerings of the workbook by having a deadline for submission of the workbook with a subsequent online discussion forum to review answers.

Discussion: Reflections and recommendations

Graduate RS must possess the ability to problem solve in the clinical workplace (Barnes, et al., 2010; Doorely, et al., 2019, Jones, et al., 2023). Possessing high levels of problem solving skills in clinical practice is a key factor in the adaptability of healthcare professionals (van der Merwe, et al., 2023). The ability to approach and solve unfamiliar problems (problem solving ability) can be enhanced in student healthcare professionals through the use of CBL in integrating multiple subject areas (Ummat & Kochhar, 2021; Vedi, 2021; Gasim, et al., 2024). The link between utilizing CBL to elevate learning skills in clinical practice was demonstrated in a study of undergraduate medical students by Tiwale and colleagues (2019) who found that 76% of research participants strongly agreed that by participating in CBL, they felt that their ability to apply knowledge in their clinical practice will improve. Although the education and curriculum of RS varies from medical students, similar results were captured in the current study with 85% of participants strongly agreeing that CBL improved

their problem solving ability and 62.5% strongly agreeing that their ability to approach and adapt to unfamiliar content improved as a result of engaging with CBL. The current study has demonstrated that the incorporation of CBL for student RS allows students to recognize the importance of pathophysiology concepts, how they drive changes in pulmonary function, which in-turn, expands clinical reasoning capability and correct diagnosis of pulmonary function testing results.

Brown and colleagues (2012) reported that health sciences students preferred CBL to didactic lectures and that CBL promoted a greater ability to identify concepts and integrate basic science knowledge. Studies of nursing students have reported that when traditional didactic teaching of bioscience concepts (including anatomy, physiology and interpretation of physiological data) are combined with digital learning opportunities, knowledge acquisition and integration are enhanced (Grønlien, et al., 2021). The current study aligns with the findings of multiple studies that by utilizing online CBL, student RS can expand and integrate their knowledge of pulmonary pathophysiology with PFT analysis and interpretation (Kollef, 2017; Dulloo & Pathare, 2013; Brown, et al., 2012; Grønlien, et al., 2021). The outcome of the current study is that students felt that their knowledge of respiratory pathophysiology and their ability to interpret PFT results with reference to derangements in lung function increased as a result of the online CBL.

Kollef and colleagues (2017) in their study of RS in Missouri, USA reported the need for RS to have an in-depth knowledge of pulmonary pathophysiology and PFT due to the crucial role that RS play in the care and management of patients with respiratory diseases. The American Thoracic Society (ATS)/European Respiratory Society (ERS) in their 2022 Technical Standards on Interpretive Strategies for Routine Lung Function Tests, emphasize that for appropriate functional classification of impairments to lung function to occur, knowledge of disease processes needs to be considered and integrated when classifying test results (Stanojevic, et al., 2022). The consolidation and integration of pulmonary pathophysiology knowledge with PFT interpretation can be achieved through the use of CBL. The results of the current study clearly demonstrate the benefits of an integrated curriculum CBL.

Lastly, the confidence of student RS to face uncertainties in clinical practice can be supported by exposing students to real-life situations through the application of online CBL. Student RS in the current study who participated in online CBL reported a clear increase in their confidence and this finding is consistent with the literature. Traditional learning methods of didactic lectures or even classroom PBL can result in students learning more passively and not exerting initiative to drive their learning (Liu, et al., 2024). Lecture based

teaching can result in an inefficient transfer of knowledge and provides minimal opportunities to apply knowledge which is disparate from the professional needs of health professionals in the clinical workplace (Liu, et al., 2024). Online learning through CBL enables students to progress at their own speed and plan their studies to achieve optimal outcomes (Donkin, et al., 2023; Grønlien, et al., 2021; Wang, et al., 2022). Students who engage with online CBL can undergo a change in mindset from needing to be prompted to learn to wanting to learn in order to obtain solutions to problems (Wang, et al., 2022). This shift in mindset increases student confidence (Wang, et al., 2022).

Limitations

The author acknowledges the limitations of the current study. Firstly, all students (30) enrolled in the program completed the online workbook, however, just over half of the students choose to participate in the research project survey. This could be contributed to survey fatigue as the students undertook several university wide surveys at the same time as the research survey was deployed. It should be noted that those students who chose not to respond to the survey still demonstrated improvements in learning through the accuracy of their answers in the workbook and their positive comments and engagement with tutor feedback.

The small sample size could restrict the findings of this study being applied on a larger scale or generalizing the findings; however, the results of this project are encouraging and affirm the benefits of integrating concepts across the curriculum in the format of an online CBL for the professional development of allied health professionals.

Conclusion

This study highlights the role of an integrated curriculum approach to Case-Based Learning (CBL) in enhancing the clinical problem-solving abilities, knowledge integration, and confidence of student respiratory scientists (RS). CBL fosters adaptability by encouraging students to apply theoretical knowledge to real-life clinical scenarios, particularly in interpreting pulmonary function tests (PFTs) and understanding the underlying respiratory pathophysiology which results in the PFT results. The findings align with existing literature, demonstrating that CBL not only improves knowledge acquisition but also promotes active learning and a shift in student mindset toward self-directed learning. Online CBL, in particular, offers flexibility and supports deeper engagement with complex clinical content. Despite the limitation of a small sample size, the results affirm the value of integrating CBL

into health science curricula to better prepare students for the demands of clinical practice.

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