

# Remediation of Muddy Concepts in Chemical Pathology Enhances Medical Students' Summative Performance

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## Abstract

*A pilot three-week Chemical Pathology (CP) remediation online programme targeted muddy concepts to support medical students preparing for supplementary examination. Online teaching tools incorporated discussion groups, short-narrated lectures, and quizzes. Student online programme engagement, and formative and summative performance (categorised by Bloom's Taxonomy's cognitive domain) were analysed by descriptive statistics. Results showed all students accessed online content and engaged with formative assessments. Test items examined factual and conceptual knowledge in CP, Clinical Sciences and Basic Sciences. Students' pre-remediation formative assessment scores showed better performance on multiple-choice test questions which examined lower cognitive domains than short-answer questions embedded in case vignettes. Scores on the post-remediation summative performance identified higher total mean scores and pass rates across most CP topics; however, students still obtained lower scores on case vignettes items. Online remediation helps students engage effectively and improves overall pass rates but challenges their higher-order thinking in CP examined by clinical vignettes.*

**Keywords:** Chemical pathology; remediation; online teaching; Bloom's Taxonomy.

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## 1. Introduction

Chemical Pathology (CP) is a medical specialisation in laboratory medicine that focuses on understanding diseases and supporting patient care by analysis of abnormal biochemical parameters in the body related to metabolism, organ function and hormone balance (Marshall

and Bangert, 2012). Undergraduate medical students are required to utilise higher-order cognitive thinking to evaluate biochemical disease patterns derived from laboratory tests and consider them in the context of relevant clinical patient data. Therefore, students are required to integrate pre-clinical Basic Science and Clinical Science knowledge in patient disease conditions. The primary aim of this module is for students to make a correct biochemical diagnosis and assist with patient care decisions by evaluating clinical vignettes. Some students struggle integrating CP, and clinical and fundamental science knowledge dimensions and applying high-order cognitive processing to make sense of CP in a clinical context.

Remediation in education aims to support struggling students to achieve acceptable professional competency (Kalet et al, 2017). This non-punitive support is organized as a discrete, time-bound and standard-focussed programme (Ellaway, 2018). The remediation programme encompasses four key steps: identifying the need for remediation, setting targeted learning outcomes, implementing structured training with monitoring, and assessing progress toward pre-defined goals (Ellaway, 2018; Kalet et al., 2017).

This study aimed to develop and evaluate a targeted online remediation programme in CP for underperforming second-year medical students enrolled at the Faculty of Health Sciences, University of Cape Town (UCT), South Africa.

## **2. Methodology**

### **2.1 Remedial programme design and implementation**

A remedial online programme was developed for second-year UCT medical students undertaking supplementary examinations in CP (n=12). The programme aimed to clarify muddy concepts and support examination preparation during student vacation (Figure 1). The muddy concept themes, summarised in Figure 1, were identified by evaluation of students' feedback and performance data, and a student questionnaire. The online learning material was delivered by a learning management system (LMS) and consisted of lectures, videos, case studies, and quizzes. The teaching material emphasised threshold concepts and the integration of Clinical and Basic Science knowledge; aligned with the identified muddy conceptual themes. Participation was voluntary, with all students providing written consent. The study received institutional ethical approval (HREC reference: 983/2024).

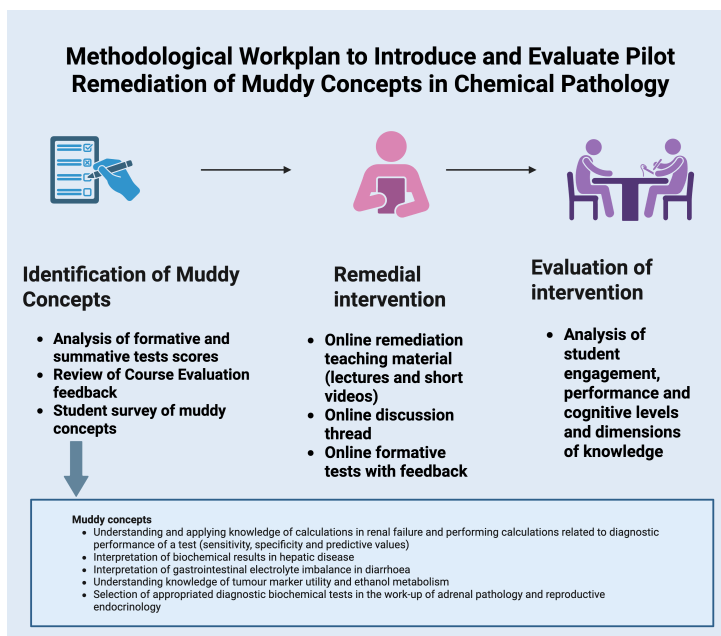
### **2.2 Data collection of student engagement and performance**

Student engagement with learning material and activities was measured by monitoring their online attendance and engagement with online resources (lectures and narrated PowerPoints, discussion threads and formative quizzes). Student formative and summative scores for multiple-choice (MCQ) and short-answer questions (SAQs) - which were embedded in case

vignettes, and student pass rates (with a pass score cutoff  $\geq$  50%) were evaluated post-remediation.

### 2.3 Data analysis

Quantitative data were extracted from the LMS for analysis of engagement metrics. All assessments were classified for knowledge dimensions and cognitive processes using Bloom's Revised Taxonomy of educational objectives (Anderson et al., 2001). Within the Knowledge dimension, each assessment item was analysed and categorised as either factual or conceptual knowledge, and further grouped according to its content as relating to Chemical Pathology, Biological Science, or Clinical Science. The six cognitive domains (L1-L6) classified test items across the various CP themes assessed. All quantitative data were analysed by descriptive statistics and assessment scores expressed as mean percentage  $\pm$  standard deviation (SD) using MS Excel (Microsoft 365 MSO, Microsoft Corporation, Version 2501, USA).



*Figure 1. Development, implementation and evaluation of the pilot remediation programme (image created in BioRender.com)*

### 3. Results

#### 3.1. Student access and engagement with the online remediation programme

All students engaged with the online programme (100%,  $n=12$ ), evidenced by LMS access metrics which showed online course access for the duration of the course enrolment. The proportional distribution of student access to the three online tools was content access (58%), forum discussion threads (14%) and online quizzes (28%).

#### 3.2. Student performance on formative assessments

Students' performance (Table 1) showed that many students failed the CP assessments obtaining  $<50\%$  pass score. The students obtained scores of  $58\%\pm 10$  and  $41\%\pm 22$  on the two MCQ assessments which evaluated five CP themes and  $33\%\pm 13$  on SAQs embedded in case vignettes. In assessment one, students consistently obtained lower scores on identical CP themes tested using SAQs compared with MCQs.

**Table 1: Formative assessments examined in Chemical Pathology topics using MCQs and SAQs.**

	MCQ FORMATIVE ASSESSMENT					
	US	GIT	HS	TOTAL SCORE	MRS	FRS
MEAN (%)	42	65	54	58	33	48
SD (%)	21	14	14	10	22	25
PASS RATE (%)	33	100	100	92	42	75
PASS (n)	4	12	12	11	5	9
SAQ FORMATIVE ASSESSMENT						
	US	GIT	HS	TOTAL SCORE		
MEAN (%)	39	27	36	33		
SD (%)	20	13	24	13		
PASS RATE (%)	33	17	17	8		
PASS (n)	4	2	2	1		

Abbreviations: US, Urinary System; GIT, gastrointestinal system; HS, hepatic system; MRS, male reproductive system; FRS, female reproductive system.

#### 3.3. Comparison of student performance in summative assessment post-remediation

A comparison of student pass category and student total mean scores on summative assessments showed improvement in post-remediation across most CP themes (Table 2). The total scores obtained in post-remediation for MCQs was  $67\%\pm 9$  compared with pre-remediation,  $55\%\pm 17$ . The students' performance improved overall on SAQs (post-remediation total score of  $48\%\pm 11$  compared with pre-remediation,  $32\%\pm 13$ ). The pass rate for SAQs was 42% ( $n=5$ ) compared to the MCQ pass rate of 67% ( $n=8$ ).

**Table 2. Comparison of summative test scores pre-remediation versus post-remediation**

	HS		GIT		MRS		SUMMATIVE SAQ US		CVS		TOX		TOTAL SCORE	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)
PASS RATE (%)	50	100	58	67	58	42	8	42	17	42	8	17	17	42
PASS (n)	6	12	7	8	7	5	1	5	2	5	1	2	2	5
	HS		MRS		RS		SUMMATIVE MCQ FRS		TOTAL SCORE					
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)	MEAN (%)	SD (%)
PASS RATE (%)	75	100	35	32	75	92	33	46	55	67				
PASS (n)	9	12	2	1	9	11	1	4	3	8				

Abbreviations: PRE, pre-remediation; POST, post-remediation; Total Score, total score based on the average performance of all CP themes.

### 3.4. Knowledge dimensions assessed in summative assessment post-remediation

All three areas of Biological Sciences, Clinical Sciences and core CP were examined by summative test items, SAQs and MCQs (Figure 2). The summative SAQs, which were embedded in clinical case scenarios, contained a greater proportion of Clinical Science and Biological Science content compared to the formative assessment. This identifies that the summative assessment placed a stronger emphasis on applying foundational knowledge to real-world clinical contexts and aligned with the learning outcomes of the CP course, and broadly with professional practice competency requirement of a medical intern after graduating from undergraduate medicine.

Abbreviations: FRS, female reproductive system; MRS, male reproductive system; RS, respiratory system; HS, hepatic system; TOX, toxicology; CVS, cardiovascular system, GIT, gastrointestinal system, CS, Clinical Science; BS, Biological Science; CP, Chemical Pathology.

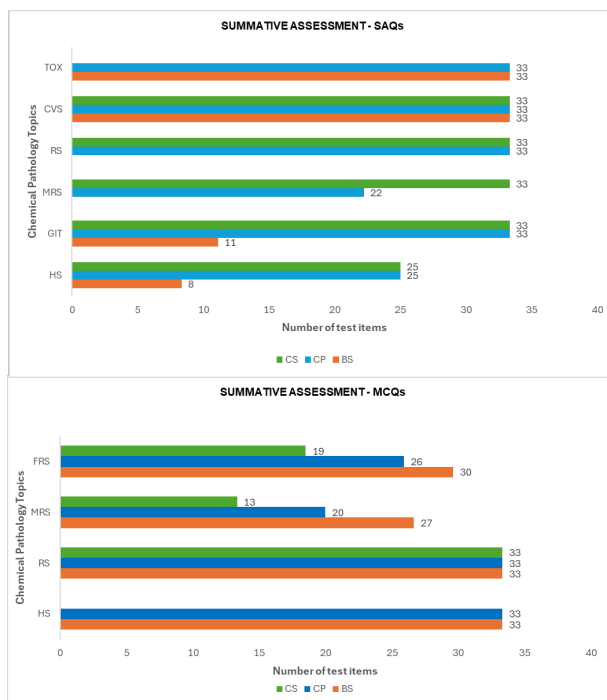


Figure 2. Knowledge dimensions assessed during the post-remediation summative assessment.

### 3.5. Categorisation of cognitive domains assessed in summative assessment post-remediation

The summative assessments showed evaluation of higher cognitive thinking (L4 and L5) by SAQs in case studies in comparison to MCQ testing (L1 and L2). There was variation noted in the distribution of cognitive levels tested between CP themes (Table 3).

Table 3. Assessment of cognitive domains on SAQ and MCQ items for summative assessments.

SUMMATIVE SAQs							SUMMATIVE MCQs						
	L1	L2	L3	L4	L5	L6		L1	L2	L3	L4	L5	L6
HS	0	0	0	45	55	0	HS	0	0	100	0	0	0
GIT	0	0	0	25	75	0	RS	100	0	0	0	0	0
MRS	40	20	40	0	0	0	MRS	60	0	20	20	0	0
RS	0	37	63	0	0	0	FRS	22	11	67	0	0	0
CVS	0	100	0	0	0	0							
TOX	0	100	0	0	0	0							

Abbreviations: L1, Remember; L2 Understand; L3, Apply; L4, Analyze; L5, Evaluate; and L6, Create; HS, hepatic system; GIT, gastrointestinal system; MRS, male reproductive system; RS, respiratory system; CVS, cardiovascular system; TOX, toxicology.

#### **4. Discussion**

This study investigated the benefit of a three-week online remediation program targeting challenging concepts in CP by evaluating student engagement and summative assessment performance. The findings indicate active student engagement and an overall improvement in the pass rate following remediation. The study also highlights that delivering remediation through an online LMS is both feasible and accessible, particularly for supporting students remotely as they prepare for supplementary exams during vacation periods. This study also identified that the opportunity to engage in online discussions with peers and lecturers was underutilised. This limited interaction may have hindered students from fully addressing evolving conceptual difficulties, particularly in understanding case-based CP concepts presented in clinical vignettes.

Ellaway et al. (2018) conceptualise medical education performance as core subsystems (success and failure) with remediation bridging these subsystems. Remediation in medical education has shown positive education effect in assessment outcomes. For example, tailored remedial support of underperforming medical students at the pre-clinical phase for a Biochemistry course demonstrated improved performance scores post-remediation (Hedge et al., 2024). Further, Joshi et al (2021) observed in medical students studying Osteopathy that remediation by utilising formative quizzes and assignments encouraged positive learning strategies and assessment outcomes. The findings of these studies are consistent with both the improved outcome scores and pass rate observed after the remediation intervention of the current study.

In this study, students were able to access and engage with all materials. The study also highlights that the online LMS delivery method is feasible and accessible as a route for administering remediation to students remotely, preparing for supplementary exams during the vacation period. The utility of developing online discussion with peers and lecturers was underutilized in the study; and this may have contributed to students not optimally redressing evolving areas of conceptual difficulty in case-based CP concepts examined in case vignettes.

We observed that students struggled on constructive test items in case vignettes. This highlights challenges that medical students experience in the pre-clinical phase of integrating the three factual and conceptual knowledge dimensions tested in CP coupled with deploying high cognitive thinking of Analysis and Evaluation cognitive domains (Bloom, 1956, Anderson et al, 2001) to answer CP assessments.

Undergraduate medical students who fail high-stakes exams often use ineffective study methods for both clinical and written tests and struggle to cope productively with failure (Patel et al., 2015). For example, studies report that underperforming medical students struggle to integrate large volumes of medical material, experience poor time and stress management, and have inefficient test-taking skills (Guerrasio, 2014).

Therefore, a structured programme of remediation to target deficiencies in content knowledge and high-order cognitive domains may be beneficial. A focus on analysing and evaluating clinical vignettes in CP can potentially improve underperforming students' ability to solve problems and make medical sense of relevant pathophysiology linked to laboratory test data. Remediation thereby has the potential to increase the students' pass rates.

Self-regulation theory (SRT) describes the cyclical process by which learners control their academic and clinical performance through key mechanisms such as goal-directed behaviour, the use of specific learning strategies, and the ongoing adaptation of these strategies to optimise learning and performance outcomes (Sandars et al., 2011). Research has shown that undergraduate medical students who struggle academically often have difficulties with self-regulation. Although the findings of this study do not explore academic and non-academic factors contributing to the sub-optimal student performance, it is likely that managing cognitive demands of clinical case vignettes challenged student performance. These findings suggest that remedial programmes for students studying CP should focus on strengthening student goal-setting and learning behaviours to support answering CP-based evaluation of case studies. By adopting an SRT informed approach, educators can better appreciate the variation in learners' self-efficacy and adaptive behaviours, and thus design more effective and individualised remediation strategies (Durning et al., 2011).

## **5. Conclusion**

The development of a targeted remedial programme in CP requires identification of core conceptual problems that undergraduate medical students experience during their studies of CP. Targeted remediation can support students to effectively improve their performance and develop self-efficacy to answer authentic CP questions in clinical cases. A structured remedial approach which considers time-bound outcomes and feasible delivery via an LMS can consider use of discussion forums, short-narrated lectures and formative assessments to engage students. An emphasis on higher cognitive domains in clinical case-based scenarios needs to emphasise

Analysis and Synthesis domains as CP integrates core factual and conceptual knowledge dimensions, coupled with Biological and Clinical Science knowledge. Future studies need to investigate online versus in-person delivery modes, the impact of item selection on performance and mastery of threshold concepts, and non-academic factors that influence participation and performance in remediation interventions framed by self-regulation theory.

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