

# Did the Rapid Transition to Online Learning in Response to COVID-19 Impact Students' Cognitive Load and Performance in Veterinary Anatomy?

Karina Jones ■ Dan J. Miller ■ Prisca Noble

## ABSTRACT

COVID-19 safety required rapid transitions to online learning across education. This posed unique challenges for veterinary anatomy, which is a practical subject. This study compares the cognitive load and academic performance of first- and second-year veterinary students studying anatomy in 2019 (pre-COVID-19) and 2020 (post-COVID-19 teaching adjustments). Importantly, the core teaching content remained identical for both courses in 2019 and 2020 apart from teaching method (in-person vs. online), allowing us to isolate the effects of teaching method on cognitive load and academic performance. Cognitive load was measured among first- ( $n_{2019} = 105$ ,  $n_{2020} = 49$ ) and second-year students ( $n_{2019} = 85$ ,  $n_{2020} = 42$ ) at the end of each teaching semester, using a validated instrument. The instrument measures intrinsic load (IL, study material complexity), extraneous load (EL, presentation of material), and germane load (GL, self-perceived learning). *t*-Tests compared the 2019 and 2020 cohorts with respect to both cognitive load and academic performance. The results indicated that 2019 and 2020 cohorts did not differ on IL or EL in either the first- or second-year subject. However, among both first- and second-year students, the 2020 cohort reported significantly less GL compared to the 2019 cohort. Additionally, the first-year 2020 cohort performed at a significantly lower level than the first-year 2019 cohort. No significant difference in performances was reported between second-year cohorts. Therefore, despite being less inclined to perceive that online course activities enhanced their understanding of anatomy, second-year students with previous experience of learning anatomy in an in-person tertiary environment adjusted better than first-year students with limited experience.

**Key words:** veterinary education, cognitive load, veterinary anatomy, covid disruption, COVID19

## INTRODUCTION

Cognitive load can be defined as a multidimensional construct representing both the mental load and mental effort imposed on the learner's cognitive system to perform a particular task.<sup>1</sup> Cognitive load theory (CLT),<sup>2-8</sup> assumes that effective learning occurs if instructional conditions are aligned with human cognitive architecture. CLT is based on a view of cognition that involves a limited capacity and duration working memory, interacting with an unlimited capacity long-term memory.<sup>9-11</sup>

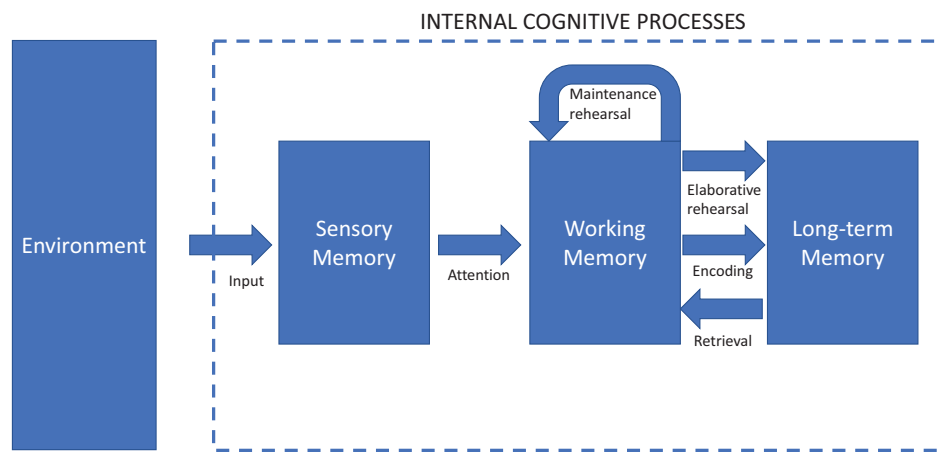
Following an information processing model (Figure 1), new information must be processed through working memory for learning to occur. Instructional strategies which promote successful processing in working memory will enhance learning and understanding. Building up knowledge, information will be processed in working memory then stored in long-term memory in the form of schemas.<sup>6,12</sup> Schemas provide a mechanism for knowledge organization and storage in long-term memory, reducing working memory load. In complement, automation is a process that bypasses working memory and updates existing schemas after sufficient practice.<sup>6,13,14</sup> Automation plays an important role for schema construction and helps to release working memory capacity for the processing of additional information. Finally, CLT assumes that working

memory is more efficient when dealing with familiar concepts already stored in long-term memory.

The efficiency of processing information in working memory is the primary focus of CLT.<sup>6</sup> The load placed on working memory is affected by the intrinsic complexity of the instructional materials (intrinsic cognitive load), the organization and presentation of the information (extraneous load), and the strategy used to create and automate schemas (germane cognitive load). Thus, cognitive load theory differentiates between three types of cognitive load: intrinsic, extraneous, and germane.<sup>8</sup> The sum of intrinsic, extraneous, and germane loads is equal to the total cognitive load. When the cognitive load associated with a task exceeds the learner's working memory capacity, performance, and learning is impaired.<sup>8</sup> Accordingly, the design and implementation of activities and representations should maximize germane load while minimizing extraneous load.<sup>16,17</sup>

In medical education, the cognitive load on students is extremely high because of the advanced concepts and the workload.<sup>18</sup> Veterinary anatomy is a discipline of the veterinary medicine degree that studies the morphology of domestic species. It is typically taught during the early years of the degree. It has a substantial focus on hands-on activities,

© American Association of Veterinary Medical Colleges (AAVMC), 2023. For their own personal use, users may read, download, print, search, or link to the full text. Manuscripts published in the *Journal of Veterinary Medical Education* are copyrighted to the American Association of Veterinary Medical Colleges. Requests for permission to reproduce this article should be made to the University of Toronto Press using the Permission Request Form: <https://www.utpjournals.press/about/permissions> or by email: [journal.permissions@utpress.utoronto.ca](mailto:journal.permissions@utpress.utoronto.ca).



**Figure 1:** Information processing model. Modified from Atkinson and Shiffrin.<sup>15</sup>

including considerable dissection classes connecting surgical theory and practice.<sup>19–21</sup> Veterinary anatomy is perceived as a content-heavy discipline<sup>22</sup> delivered to students at a time in their academic studies associated with increased stress and anxiety, and when the demand on their working memory resources increases dramatically. Under the lens of cognitive load theory, the challenges posed to students learning veterinary anatomy can be better appreciated, highlighting the need for approaches that reduce cognitive load without minimizing the learning outcomes for students.

Veterinary anatomy was historically taught via a classical teaching approach, teaching the discipline without the inclusion of any other related disciplines. An integrated teaching approach appears to have started around the 1880s, with the School of Veterinary Medicine in Bern combining anatomy, histology and embryology.<sup>23</sup> Today, integrated teaching occurs over the world,<sup>24</sup> and both classical and integrated teaching coexist in veterinary anatomy. In parallel, the expansion of multimedia significantly diversified anatomy education programs by combining traditional classroom methods with online educational digital media, that is readily available to students at all times. This combination of methods is often referred to as blended learning.<sup>25–27</sup> This pedagogy strategy aims to address the high cognitive load associated with studying anatomy. In the present study, we define blended learning as a combination of classroom methods with online digital medias but also with differentiated learning methods (e.g., flipped classroom, problem-based-learning [PBL]).

At James Cook University (JCU), the Bachelor of Veterinary Sciences (BVSc) is a 5-year surgical degree. Anatomy is delivered during the first 2 years of the BVSc. It follows a blended and integrated approach that was benchmarked in 2017. Prior to 2020, teaching of veterinary anatomy at JCU was diversified into face-to-face lectures, team-based dissection practicals, flipped classrooms, and PBL. All of the teaching documents (notes, video-recorded lectures, video-recorded practicals) were online, and some formative quizzes were both online (embedded quiz videos) and in-person. In response to the emergence of the COVID-19 pandemic in 2020, JCU veterinary sciences had to rapidly transition their teaching programs to a full-time online learning and assessment program. Although blended learning activities were still embedded throughout the subject, students had to adapt quickly to a markedly different educational experience with a much greater focus on

online learning. Because of the need for flexibility in these circumstances, the impact of the changes on education quality of content and delivery and the staff and the students' experiences was not known.

The aim of this study was to determine whether there was an impact on student learning with the rapid transition to online learning during COVID-19.

This was achieved by comparing the blended-learning (2019, pre-COVID-19) and online (2020, COVID-19 emergency teaching) cohorts in terms of cognitive load required for anatomy learning and the resulting academic performance of these students.

## MATERIALS AND METHODS

### Veterinary Anatomy Curriculum

At JCU, comparative veterinary anatomy is taught during two consecutive semesters in first-year Semester 2 (between end-of-July and mid-December) and second-year Semester 1 (between end-of-February and mid-July). Each semester has a total of 13-weeks teaching, a 1-week mid-semester break, a 1-week study period, a 2-weeks final exam period, and 1-week supplementary exam period.

Table 1 presents the anatomy program of first-year semester 2 and second-year semester 1 subjects. It highlights their corresponding teaching delivery modes (Lecture, Practical, Flipped Class, or PBL) and the major teaching changes in 2020 due to the rapid transition to online learning during COVID-19. It must be noted that COVID-19 pandemic emergency was declared in March 2020. Therefore, the first 3-weeks of teaching in second-year semester 1 were the same in 2020 as in 2019. As COVID-19 pandemic emergency lockdown was declared, anatomy staff was urged to immediately reconsider their teaching mode delivery. Indeed, the mid-semester break was brought forward by 1 week for faculty members to set up their new teaching plans. Note that prior to the pandemic, the JCU anatomy team had already developed numerous digital tools that were used for teaching. As such, our main focus was seeking the most optimal teaching delivery method, rather than the digital media production itself. Live streaming was preferred to pre-recorded video because it allowed students to have real-time conversations with the teaching team during the session. Therefore, while students were locked down at home, anatomy staff opted for a fully online live streaming

**Table 1:** Veterinary anatomy curriculum across year-1 semester 2 and year-2 semester 1 subjects at JCU and changes applied in 2020 due to the rapid transition to online learning during COVID-19

Student year level (semester)	Anatomy teaching blocks	2019 teaching	2020 teaching (changes in comparison to 2019 teaching are in bold).
<b>First year (semester 2)</b>	<b>Locomotor</b>	(5) L live in person (theatre). (9) FC live in person (theatre) using pre-recorded video followed by Question/Answer session. (4) L live in person (theatre) drawing and quizzing on white board. (31) P live in person (laboratory) with (9) pre-recorded video available. (3) PBL live in person (theatre).	(5) L <b>live online and videorecorded</b> . (9) FC <b>live online</b> using pre-recorded video followed by Question/Answer session. (4) L <b>live online</b> drawing and quizzing on black board collaborate. (23) P <b>live online and videorecorded</b> with (9) pre-recorded video available. (8) P live in person (laboratory) (3) PBL <b>live online</b> .
	<b>Nervous</b>	(5) L live in person (theatre) (pre-recorded video available). (6) P live in person (laboratory). (3) PBL live in person (theatre).	(5) L <b>live online</b> (pre-recorded video available). (6) P <b>live online and videorecorded (pre-recorded video available)</b> . (3) PBL <b>live online</b> .
	<b>Revisions</b>	(3) P live in person (laboratory).	(2) P <b>live online</b> .
<b>Second year (semester 1)</b>	<b>Respiratory</b>	(2) L live in person (theatre) (pre-recorded video available). (9) P live in person (laboratory) (pre-recorded video available). (1) PBL live in person (theatre).	(2) L live in person (theatre) (pre-recorded video available). (9) P live in person (laboratory) (pre-recorded video available). (1) PBL <b>live online</b> .
	<b>Circulatory</b>	(5) L live in person (theatre) (pre-recorded video available). (6) P live in person (laboratory) (pre-recorded video available). (1) PBL live in person (theatre).	(5) L <b>live online</b> (pre-recorded video available). (6) P <b>live online and videorecorded (pre-recorded video available)</b> . (1) PBL <b>live online</b> .
	<b>Digestive</b>	(4) L live in person (theatre) (pre-recorded video available). (6) P live in person (laboratory) (pre-recorded video available). (6) P live in person (laboratory). (1) PBL live in person (theatre).	(4) L <b>live online</b> (pre-recorded video available). (6) P <b>live online and videorecorded</b> (pre-recorded video available). (6) P <b>Live online and videorecorded (pre-recorded video available)</b> . (1) PBL <b>live online</b> .
	<b>Urogenital</b>	(4) L live in person (theatre) (pre-recorded video available). (6) P live in person (laboratory). (1) PBL live in person (theatre).	(4) L <b>live online</b> (pre-recorded video available). (6) P <b>live online and videorecorded (pre-recorded video available)</b> . (1) PBL live online.
	<b>Revisions</b>	(3) P live in person (laboratory)	(2) P <b>live online</b>

The number in bracket (number) is for teaching hours; P is for Practical; L is for Lecture; FC for Flipped Class; PBL is for Problem-Based-Learning. Changes in the curriculum between 2019 (blended teaching) and 2020 (COVID emergency teaching) are in bold.

of the program. Anatomy staff were granted “essential faculty member” status and were therefore authorized to access the locked down veterinary sciences campus to live stream all the practicals following the original timetable. Lectures, Flipped Classes, and PBL were also live streamed from the anatomy staff at home or office. In 2020 semester 2, lockdown conditions were somewhat relaxed and as such, first-year students were able to attend 8 hours of practicals on campus spread throughout the 13-weeks teaching period. The other 23 hours practicals, all the Lectures, Flipped Classes, and PBL were still online.

Note that the anatomy staff teaching first and second year classes in 2019 and 2020 remained the same and were very

knowledgeable about digital educational technologies. Thus, it was assumed that there was no differentiated teaching quality due to instructor changes during the study.

### Study Design

This study utilized a modified version of the 10-item Cognitive Load Inventory (CLI-10),<sup>28</sup> which is a validated psychometric tool that measures cognitive load. Items on this scale were modified to be specific to the learning of anatomy. This modified version of the scale has been psychometrically validated for use with preclinical veterinary students.<sup>29</sup> Like the CLI-10, this modified scale (Table 2) has 3, 3, and 4 items measuring Intrinsic Load (IL), Extraneous Load (EL), and Germane Load

**Table 2:** Template of Modified CLI-10 by Miller.<sup>29</sup> It has 3, 3, and 4 items measuring Intrinsic Load (IL), Extraneous Load (EL), and Germane Load (GL).

	Not at all the case										Completely the case
	0	1	2	3	4	5	6	7	8	9	10
1. The topics covered in this block were very complex	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. I perceived the clinical applications of the content in this block as very complex.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. This block covered anatomical concepts and definitions that I perceived as very complex.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. The instructions and/or explanations in this block were very unclear.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. The instructions and/or explanations were, in terms of learning, very ineffective.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. The instructions and/or explanations were full of unclear language	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. This block really enhanced my understanding of the relevance of the material to clinical veterinary practice.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. This block really enhanced my knowledge and understanding of _____ functional anatomy.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. This block really enhanced my understanding of the topics covered.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. This block really enhanced my understanding of anatomical concepts and definitions.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The following questions refer to the \_\_\_\_\_ **learning block** you completed as part of the subject \_\_\_\_\_ (this includes all lectures, practicals, and assessment covered in this block). Please respond to each of the questions on the provided scale—where 0 means not at all the case and 10 means completely the case—by colouring in the circle associated to the most appropriate response.

(GL). All items are on the 11-point Likert-type format. IL is the Cognitive load imposed as a result of the natural complexity of the material being studied. More complex material results in a higher IL. EL is the cognitive load resulting from the way material is organized and presented. Suboptimal instruction results in greater EL. Finally, GL is the cognitive resources the learner has to apply to the material in order to create and automate schemas. Some authors<sup>30</sup> refer to this as a measure of “self-perceived learning.” Lower self-perceived understanding results in lower GL (Figure 2). Participants were also presented with a series of demographic questions, including participant age, gender, university entry score, home state and/or country, first-in-family status (whether they were the first in their immediate family to attend university), and primary language spoken at home.

The CLI-10 tool was administered in this study to query veterinary students about their understanding and perceptions of the difficulty of their course material on the teaching blocks across the IL, EL, and GL subscales. That is, first-year students were presented with the modified CLI-10 twice, once in relation to the locomotor content and once for the nervous anatomy content. Second-year students were presented with the modified CLI-10 four times, once for the respiratory content, circulatory content, digestive content, and urogenital content.

In addition to the cognitive load investigation, final exam performance data for the first- and second-year student cohorts was also investigated in 2019 (before COVID-19) and 2020 (during COVID-19 teaching adjustments). The final theory exam

was chosen as, unlike other forms of final assessment in the course (Table 3), these exams were similar, both being online and equivalent in content. This data was obtained, with consent by participants, through the Academic Service of the College of Public Health, Medical and Veterinary Sciences. This study was approved by the James Cook University Human Research Ethics Committee (H7558).

### Participant Recruitment

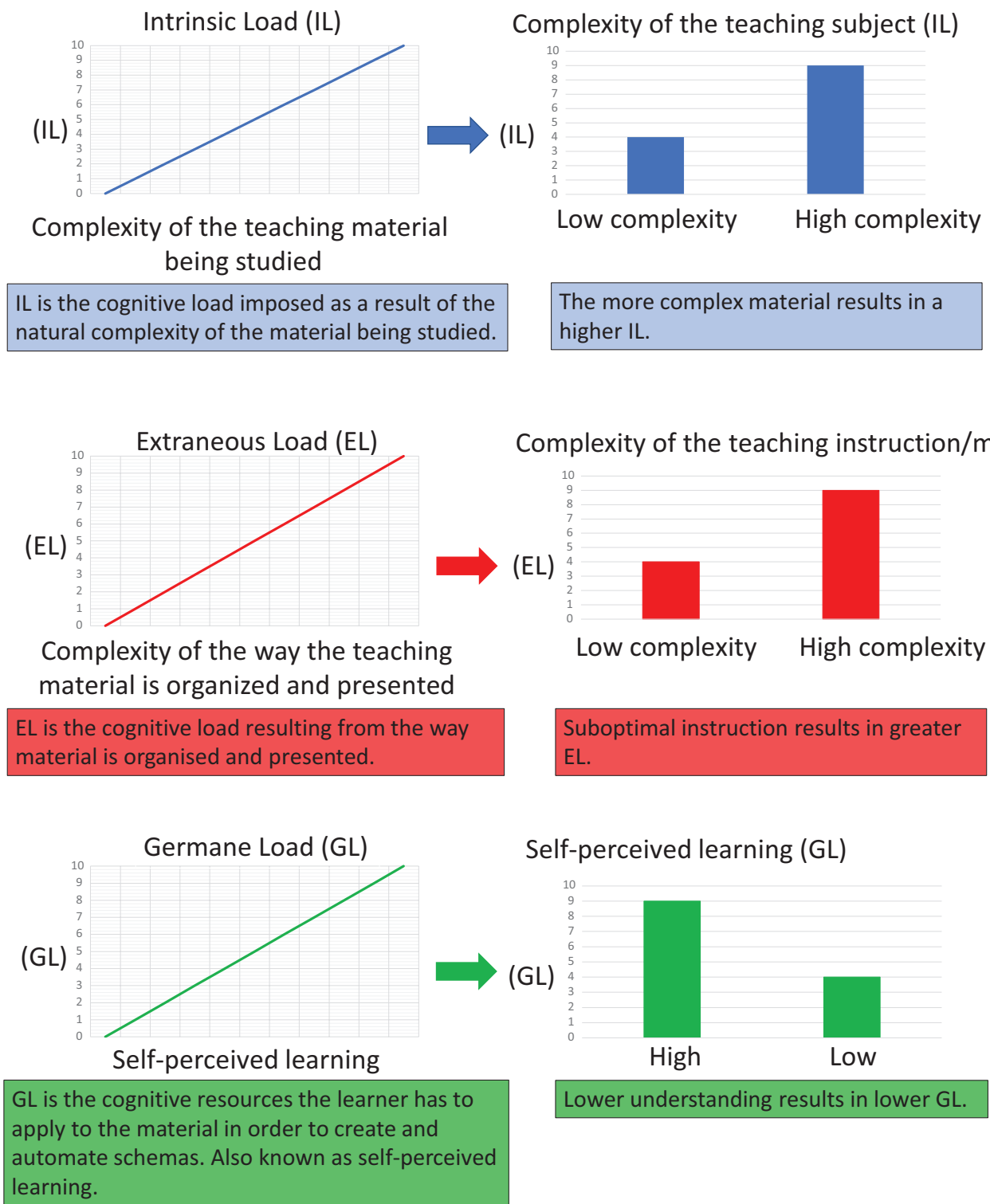
At the end of each teaching semester, during the last practical, students were invited to take a survey on each teaching block that they have studied during the corresponding semester. One week prior to delivering the CLI-10, students were provided details of the study through an announcement during one of their scheduled classes, accompanied by a participant information sheet. Students were assured that participation was voluntary and there would be no adverse academic repercussions for non-participation. It was also emphasized that only staff not associated with their teaching and assessment would be involved in the data collection processes, and that the data would be deidentified prior to analysis and reporting.

All enrolled veterinary anatomy students in both 2019 and 2020 were invited to participate ( $N = 448$ ; see Table 4).

### Analysis

This study has investigated two research questions (RQ).

RQ1: Did veterinary anatomy students’ experience greater cognitive load during online delivery compared to standard delivery (blended learning)?



**Figure 2:** Illustration of the cognitive load components: intrinsic Load (IL), extraneous Load (EL), and Germane Load (GL)

**Table 3:** End-of-semester examination modes of the first year-semester 2 and second year-semester 1 subjects during 2019 and 2020. Changes between 2019 (blended teaching) and 2020 (COVID emergency teaching) are in bold.

Student year level (semester)	End-of-semester Examinations	2019 exam modes	2020 exam modes (changes in comparison to 2019)
<b>First year (Semester 2)</b>	Final theory exam	Written online on campus using a lockdown browser	Written online remote using a lockdown browser
	Practical	Dissection and oral on specimen on campus	<b>Written online on specimen pictures</b>
<b>Second year (Semester 1)</b>	Final theory exam	Written online on campus using a lockdown browser	Written online remote using a lockdown browser
	Practical	Oral on specimen on campus	<b>Written online on specimen pictures</b>

**Table 4:** Total number of students enrolled in veterinary anatomy during 2019 and 2020

Number of students enrolled	First-year (Semester 2)	Second-year (Semester 1)
<b>Blended-learning cohort (2019)</b>	138	100
<b>Online cohort (2020)</b>	90	120

RQ2: Did veterinary anatomy students exhibit poorer performance during online delivery compared to standard delivery (blended learning)?

Both RQ1 and RQ2 were assessed using the de-identified data. *t*-tests were used to address both RQ1 and RQ2. These tests compared the blended-learning (2019, pre-COVID-19) and online (2020, COVID-19 emergency teaching) blended learning cohorts in terms of cognitive load and performances respectively. Finally, the student cohort's demographics were compared using *t*-tests and chi-square tests.

## RESULTS

### Response Rate

In 2019, participation in the study was high, with 76% of first-year blended learning cohort and 85% of second-year blended learning cohort opting to participate.

In 2020, participation in the study decreased noticeably, with only 54% of first-year online learning cohort and 34% of second-year online learning cohorts opting to participate. (See Table 5).

### Demographics

The first-year cohorts did not differ from each other with respect to age,  $t(150) = -0.55, p = .586, d = -.10$ , university entrance score,  $t(119) = -0.68, p = .497, d = -.13$ , gender,  $\chi^2$

**Table 5:** Response rate of invited participants, broken down by degree of blended learning and student year level

	Response rate of first-year students	Response rate of second-year students
<b>Blended-learning cohort (2019)</b>	76% ( $n = 105$ )	85% ( $n = 85$ )
<b>Online cohort (2020)</b>	54% ( $n = 49$ )	35% ( $n = 42$ )

( $1, N = 151$ ) = 0.25,  $p = .618, \phi = .04$  (non-binary participants were excluded from this analysis due to the very small number of non-binary individuals in this sample), or being first in family to attend university,  $\chi^2 (1, N = 154) = 1.66, p = .197, \phi = .10$ . Only one student in either cohort reported being an international student, and thus the cohorts were not formally compared in terms of this variable. Similar to the first-year students, the second-year cohorts were not found to differ from each other with respect to age,  $t(125) = 0.85, p = .398, d = 0.16$ , university entrance score,  $t(93) = 0.61, p = .541, d = .13$ , gender,  $\chi^2 (1, N = 126) = 1.35, p = .245, \phi = .10$ , or first-in-family status,  $\chi^2 (1, N = 127) = 0.01, p = .922, \phi < .01$ . Again, only a small number of students reported being international students ( $n = 2$ ). These results are presented in Table 6.

### Cognitive Load

Independent samples *t*-tests were used to compare the blended-learning and online cohorts in terms of the cognitive load associated with each area covered (locomotor and nervous anatomy for first-year teaching blocks; respiratory, circulatory, digestive, and urogenital anatomy for second-year teaching blocks). These results are presented in Table 7. Cohen's *d* values are presented as effect size measures (for reference it is suggested<sup>31</sup> that *d* values of 0.20, 0.50, and 0.80 can be considered to represent small, medium, and large differences, respectively).

**Table 6:** Comparison of the demographics by the 2019 and 2020 first-year students. Data from the 2019 and 2020 second-year cohorts are also displayed. No significant differences were found.

Student year level	Age	University entrance score	Gender	First in family to attend university
<b>First-year</b>	$t(150) = -0.55$ $p = .586$ $d = -.10$	$t(119) = -0.68$ $p = .497$ $d = -.13$	$\chi^2 (1, N = 151) = 0.25$ $p = .618$ $\phi = .04$	$\chi^2 (1, N = 154) = 1.66$ $p = .197$ $\phi = .10$
<b>Second-year</b>	$t(125) = 0.85$ $p = .398$ $d = 0.16$	$t(93) = 0.61$ $p = .541$ $d = .13$	$\chi^2 (1, N = 126) = 1.35$ $\pi = .245$ $\phi = .10$	$\chi^2 (1, N = 127) = 0.01$ $\pi = .922$ $\phi < .01$

**Table 7:** Comparison of the cognitive load experienced by the blended-learning ( $n = 105$ ) and online ( $n = 49$ ) cohorts of first-year teaching blocks across the anatomy taught. Data from second-year cohorts are also displayed for the blended-learning ( $n = 85$ ) and online ( $n = 42$ ) across the anatomy taught to this year level. Significant differences for all cohorts are in bold.

Student year level	Anatomy Teaching blocks	Cognitive Load Type	M (SD)		t	p	Cohen's d
			Blended learning (2019)	Online (2020)			
<b>First-year</b>	Locomotor	IL	6.45 (1.77)	6.95 (1.37)	-1.72	.088	-0.30
		EL	5.16 (2.46)	5.71 (2.32)	-1.32	.190	-0.23
		<b>GL</b>	<b>7.45 (1.75)</b>	<b>6.73 (1.84)</b>	<b>2.31</b>	<b>.022</b>	<b>0.40</b>
	Nervous	IL	7.51 (1.90)	7.41 (1.44)	0.32	.748	0.06
		EL	5.62 (2.36)	5.69 (2.38)	0.16	.877	0.03
		<b>GL</b>	<b>6.93 (2.03)</b>	<b>6.24 (1.71)</b>	<b>2.07</b>	<b>.040</b>	<b>0.36</b>
<b>Second-year</b>	Respiratory	IL	5.92 (1.86)	5.34 (1.59)	1.72	.089	0.32
		EL	3.21 (2.34)	3.41 (2.24)	-0.47	.639	-0.09
		<b>GL</b>	<b>7.94 (1.38)</b>	<b>7.07 (1.86)</b>	<b>2.70*</b>	<b>.009</b>	<b>0.56</b>
	Circulatory	IL	6.15 (1.86)	5.96 (1.87)	0.54	.589	0.10
		EL	3.34 (2.62)	3.76 (2.45)	-0.86	.390	-0.16
		<b>GL</b>	<b>7.95 (1.30)</b>	<b>6.83 (2.13)</b>	<b>3.12*</b>	<b>.003</b>	<b>0.70</b>
	Digestive	IL	5.82 (2.16)	5.74 (1.95)	0.20	.844	0.04
		EL	2.98 (2.71)	3.86 (2.69)	-1.68	.095	-0.33
		<b>GL</b>	<b>8.20 (1.53)</b>	<b>7.05 (1.91)</b>	<b>3.59</b>	<b>&lt; .001</b>	<b>0.69</b>
	Urogenital	IL	6.28 (2.04)	5.49 (2.17)	1.96	.052	0.38
		EL	3.74 (2.89)	3.19 (2.38)	1.13*	.263	0.20
		GL	7.58 (1.74)	7.10 (1.84)	1.40	.165	0.27

\*Welch's t-test used to account for violations of the assumption of homogeneity of variance.

The results in Table 7 indicate that, relative to the blended-learning (2019) first-year cohort, the online (2020) first-year cohort reported significantly less GL for both teaching blocks covered (locomotor and nervous anatomy). Both of these differences were medium in magnitude. With respect to the second-year cohorts, the online learning students reported significantly less GL for three of the four teaching blocks (respiratory, circulatory, and digestive anatomy) compared to the blended-learning cohort. These differences were medium to large in magnitude.

### Academic Performance

The first-year blended-learning cohort performed significantly better on the final exam ( $M = 69.46$ ,  $SD = 14.67$ ) than the online first-year students ( $M = 50.45$ ,  $SD = 17.92$ ),  $t(145) = 6.92$ ,  $p < .001$ . This was a large difference ( $d = 1.22$ ). In contrast, the

blended-learning second-year cohort performed similarly on the final exam ( $M = 65.26$ ,  $SD = 16.21$ ) to the online second-year cohort ( $M = 69.82$ ,  $SD = 14.56$ ),  $t(124) = -1.53$ ,  $p = .129$ ,  $d = -0.29$ . See Table 8.

## DISCUSSION

### Students' Self-Perceived Learning and Performances

GL was significantly lower during 2020. This pattern of results would suggest that students who experienced emergency online instruction (in response to COVID-19) were significantly less likely to feel that the course activities enhanced their understanding of anatomy. Beyond the cognitive load impacts, our results also show that the first-year students who experienced online teaching performed significantly lower than those that were not learning exclusively online. We also report

**Table 8:** Comparison of the performances obtained by the blended-learning ( $n = 105$ ) and online ( $n = 49$ ) cohorts of first-year subject. Data from second-year cohorts are also displayed for the blended-learning ( $n = 85$ ) and online ( $n = 42$ ). Significant differences for all cohorts are in bold.

Student year level	M (SD) Blended-learning (2019)	M (SD) Online (2020)	t	p	Cohen's d
<b>First-year</b>	69.46 (14.67)	50.45 (17.92)	$t(145) = 6.92$	<b>&lt;.001</b>	1.22
<b>Second-year</b>	65.26 (16.21)	69.82 (14.56)	$t(124) = -1.527$	.129	-0.29

no significant difference in performances between the blended-learning and online second-year students. This indicates that more experienced students with previous experience of learning anatomy in the in-person tertiary environment adjusted better during the online learning than first-year students with limited in-person university experience (despite both year levels perceiving themselves to have learnt less during COVID-19 adjustments). A huge range of challenges associated with online learning may have contributed to these results, and these factors must be overcome if high-quality online teaching of veterinary anatomy is to continue in the peri-pandemic world.

The reduced academic performance of the first-year students who experienced online learning is consistent with other studies on online anatomy teaching. A 2020 survey<sup>32</sup> administered to 1392 veterinary students from 92 countries during the COVID-19 pandemic reported that the majority of veterinary student respondents (96.7%) perceived that their academic performance had been negatively affected by online learning. Almost half (47.5%) of participants were greatly affected, 19.9% were considerably affected, 23.3% were moderately affected, and 6% were slightly affected. A US pilot study<sup>33</sup> on the influence of the shift from face-to-face to online anatomy delivery supports such findings. Data from summative, in-person exams from 2005 to 2020 were analyzed by comparing students' performance on the same questions administered across multiple years. That study found that 2020 students performed significantly worse in all anatomy regions than previous years ( $p < 0.00001$ ), due to the shift to online anatomy delivery. This is similar to the pattern reported in the present study, wherein the academic performance of first-year students who experienced the rapid transition to online learning was considerably lower than those of the previous year.

Also consistent with other studies, our results suggest that previous tertiary experience of veterinary anatomy may ease the transition to an online learning environment. The lack of significant difference in performances between the blended-learning and online second-year students reported here indicates that the more experienced students with previous experience of learning anatomy in the in-person tertiary environment adjusted better during the online learning adjustment than first-year students with no university experience (despite students' perceptions of their own learning being to the contrary). Indeed, a 2022 survey,<sup>34</sup> which analyzed students' perspectives and attitudes regarding the sudden shift of veterinary anatomy teaching mode during the COVID-19 pandemic, found that second-year students reported a significantly higher rate of understanding than first-year students. These second-year students also showed a higher rate of satisfaction with the provided learning materials, significantly higher comfortability rate regarding technological skills, and significantly higher rate of interest in studying anatomy online. From these findings the authors explained that senior students who were more familiar with anatomical and medical terminologies coped better with the change to online in comparison to first-year students. Moreover, these senior students also had prior experience on campus and with cadavers that allowed them to develop a baseline understanding that first-year students had not yet gained. Finally senior students were already familiar with the teaching staff and their peers as an established network support. Extending beyond veterinary species, similar drops in academic performance of COVID-19 affected cohorts were

reported in human anatomy students in Taiwan.<sup>35</sup> Another study,<sup>36</sup> surveying 1068 undergraduate medical and nursing students analyzing their satisfaction level regarding distant preclinical and clinical teaching amidst COVID-19 across India, showed similar results with first-year students significantly dissatisfied compared with other senior students. All these considerations may explain why the performances of the second-year students in our study did not drop after a major shift to online learning.

Although the rapid transition to online learning was a necessary adjustment to the pandemic, there were benefits and drawbacks to doing so. According to the Australian TEQSA (Tertiary Education Quality and Standards Agency) report on student experience of online learning in Australia higher education report across 118 tertiary education providers during COVID-19 pandemic,<sup>37</sup> there were some advantages of online learning. This included flexibility of classes, capacity for students to manage their own time better than in face-to-face environments, and opportunity to self-study. However, there were also several challenges that may have contributed to the results reported in the present study. These include lack of engagement and interaction, subject matter issues, access to services, assessment type and arrangements, IT problems, student welfare, and wellbeing.

### “Hands on” Experience

The results of this study may be further explained by the practical nature of anatomy which makes it more difficult to deliver completely online. Half of anatomy teaching corresponds to dissection classes. Very specifically, veterinary anatomy aims to develop skills such as dissection instrument handling and dissection approaches. It also deals with the appreciation of the size, orientation, and texture of anatomical structures. All these face-to-face, hands-on teaching activities are difficult to substitute by live streaming. The Australian TEQSA report<sup>37</sup> highlighted that there was significant reporting of issues associated with online learning for particular disciplines. The main areas where it was considered that the breadth of exposure to particular professional skills and practice was inferior in comparison to face-to-face class included science practicals, which require laboratory spaces that are not easy to simulate in a virtual environment. Moreover, a 2020 study<sup>32</sup> reported the mean evaluation score as being lower for practical components of online veterinary education in comparison to overall; on a 10-point Likert scale survey, online veterinary education in general was scored higher ( $5.1 \pm 2.4$ ) while practical components scored lower (only  $3.6 \pm 2.6$ ). Participant's responses to the common problems with online learning of veterinary sciences highlighted a “lack of online information about certain subjects, such as veterinary anatomy” and that it was “hard to teach the practical lessons of clinical subjects in online basis.” Finally, a 2022 study<sup>38</sup> that surveyed 961 veterinary students across 87 countries and 6 continents during the COVID-19 pandemic found that 52.76% of students believed that online learning of anatomy was acceptable for theory, but only about 8.74% of students believe that online learning of anatomy was suitable for practical parts. Together, these reports highlight that student perceive that a complete online delivery of anatomy negatively impacts their ability to understand the practical aspects of anatomy. This sentiment is consistent with our results, wherein the online learning cohort were significantly less likely to feel that the course activities enhanced their understanding of anatomy.

## Quality of Assessment

In response to the pandemic, the nature of the assessment tasks were often altered from those used in on-campus learning to remote examinations.<sup>37</sup> Other interventions, including shortening examinations and adjustments to the grading scheme to record only pass/fail results, took place. Because assessment is so closely related to the attainment of prescribed learning outcomes, some of the adjustments made have the potential to impact on the quality assurance for both the course and its subjects. Moreover, although electronic proctoring was utilized to ensure academic integrity, with less face-to-face contact with students, threats to academic integrity and contract cheating became a concern.<sup>39</sup>

Such issues are also true of the assessment in the JCU Veterinary Anatomy subjects. Prior to the pandemic, final veterinary anatomy assessments were diversified into on-campus online final exams, on-campus practical oral exams, and on-campus dissection exams. This set up allowed teaching staff to assess different forms of knowledge and competency. During the COVID-19 pandemic, the lockdown conditions forced most of the assessments remote online (Table 2). Interestingly, despite the increased concerns surrounding exam integrity, student performance on the final theory exam was weaker in 2020 for first-year cohort and not significantly different for second-year cohort. This may be a further reflection of reduced knowledge transfer through the online medium, reduced assessment quality, or both. The transition to online assessment certainly impacted the information that could be extracted from the exam results. Additionally, since competency is intimately linked to practical skills, it is a sound assumption that online practical teaching and corresponding assessments may not be equivalent to the former on-campus versions (dissection exam, oral exam). Thus, it may lead to a quality devaluation of both training and assessment.

## Non-Verbal Cues

While in-person class discussion requires conversational turn-taking where eye movements play a central role and hand gestures can support explanation,<sup>40,41</sup> these signals are often lost in videoconferencing. This can make virtual learning more difficult than residential learning.<sup>42</sup> The lack of real life, social, face-to-face interactions during online learning may be a factor in decreased germane cognitive load and reduced academic performance observed in our results. Moreover, online learning may have been even more intense and harder to adapt to for students with a visual or hearing impairment. It is estimated that 7% of the general population is stereo-blind, which is the inability to perceive depth and distance.<sup>43</sup> In Australia among the 15–50-year-old age group, about 5% are described with a hearing loss and 3% with hearing disability.<sup>44</sup> The inability to handle the specimens, or process auditory information by viewing the face of the teaching academic, may have further restricted the learning of such students. While we did not specifically investigate students with visual and hearing impairments, future studies on the impact of online learning would benefit from considering this as a factor.

## On-Campus Academic Resources

Participants in TEQSA report<sup>37</sup> reported that they were unable to access the library on their campus due to the lockdown conditions in the various states. The issue here was less about access to library materials, but more the two major benefits provided by libraries: being a quiet place to study away from the increasingly congested home environment during lockdown;

and libraries now being key places of student social interaction where work is also discussed. This is also true of the main library at JCU, in addition to the JCU veterinary museum and JCU veterinary study room. All are very popular places for both social interactions and study. The lockdowns prevented students from accessing required textbooks (not available online) from the library, as well as articulated skeletons and anatomical models from the JCU veterinary anatomy museum. This may have impacted the ability of the students to study, consolidate their knowledge, and discuss concepts with their peers.

## Student Welfare and Wellbeing

University students from various disciplines and countries have consistently reported increased stress and anxiety as a result of the COVID-19 pandemic and associated public health measures.<sup>45–52</sup> The transition to online learning, and associated perceived reduction in quality of learning and teaching has also been linked with increased anxiety.<sup>53,54</sup> This is also true of veterinary science students<sup>55,56</sup> and should be considered when interpreting the results of the present study. At JCU, the majority of our undergraduate veterinary students are domestic (originating from all the states and territories of Australia). A small portion of the student body are comprised of international students. Because of the closure of the interstate borders, students from other Australian states and overseas were not able to visit their family for more than a year. This would have undoubtedly had negative impacts on the mental health of these students. Moreover, many JCU students have a part-time job to pay their study and accommodation. Cifuentes-Faura et al.<sup>57</sup> reported student employment reductions due to COVID-19, and associated stress, in Spain, Oman, Nigeria, and Cambodia. As lockdown conditions were extensive in Australia, stress and anxiety may have been more severe in the students who depended on their part-time job for income.

## Limitations

CL components (IL, EL, and GL) were thought to have varied solely due to the pedagogical changes in the mode of instruction delivery (blended learning on campus versus online at home). However, given the period of global health crisis during which the 2020 data were collected (online cohorts), it is reasonable to assume that 2020 CL components (IL, EL, GL) could have been influenced by additional extraneous factors. The inability to isolate instructional changes from underlying life stressors (such as changes to the student environment) should be considered a limitation. A second limitation was the difference in response rates between the blended learning cohorts and online cohorts. Indeed, the reduced sample size of the online cohorts should be kept in mind as smaller samples are associated with reduced statistical power. The cognitive load results showed that the blended-learning and online cohorts did not significantly differ with respect to IL or EL. However, it is possible that emergency changes in the mode of teaching delivery and learning environment could have had a small effect on EL which was not detectable due to power limitations.

## CONCLUSIONS

The impact on student learning with the rapid transition to online learning during COVID-19 was analyzed through their cognitive load required for anatomy learning, and their performances. Our cognitive load results showed that the 2019 and 2020 cohorts did not significantly differ with respect to IL or EL. However, GL was significantly lower in the 2020 cohorts.

First-year students in 2020 performed significantly lower than the 2019 first-year students. No significant difference in performances was reported among the 2019 and 2020 second-year students. These results highlight that following the shift from a face-to-face to an online anatomy delivery the academic performance of experienced students were less impacted than those who had not previously had face-to-face instruction of anatomy and university.

These findings should be taken into consideration when major program changes are implemented into veterinary anatomy teaching. Practical activities cannot be replaced by online teaching without affecting the cognitive load of the students. Finally, particular attention should be given to the first-year veterinary students. Comparing to more senior students, first-year students benefit more from on-campus and face-to-face anatomy teaching than corresponding online classes.

Future studies should benefit from increasing their sample size to improve the power of their test and be able to detect even small differences in the IL, EL, and GL. Also, it would be relevant to measure students' stress and anxiety, so that the effects of these extraneous variables can be statistically analyzed alongside CL measurements.

## ACKNOWLEDGMENT

The authors wish to thank Sue Medlen, Melissa Crawford and Vanessa Harris for their assistance with data collation, Kerry Johns for her assistance with data deidentification, Associate Professor Suzy Munns for her guidance through the construction of this research project, and Tristan Simpson for his editorial comments. We are also grateful to the participants for sharing their time and perspectives with us.

## CONTRIBUTIONS

All authors contributed to the design and implementation of the research. DM contributed to the statistical analysis of the research and KJ and PN contributed to the interpretation of the results. KJ and PN drafted the manuscript. All authors edited and approved the final version of the manuscript.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## REFERENCES


- Paas FGWC, van Merriënboer JGG. Variability of worked examples and transfer of geometrical problem-solving skills: a cognitive-load approach. *J Educ Psychol*. 1994;86(1):122–33. <https://doi.org/10.1037/0022-0663.86.1.122>
- Sweller J. The role of evolutionary psychology in our understanding of human cognition: consequences for cognitive load theory and instructional procedures. *Educ Psychol Rev*. 2022;34(4):2229–2241.
- Sweller J. Cognitive load theory, learning difficulty, and instructional design. *Learn Instr*. 1994;4(4):295–312. [https://doi.org/10.1016/0959-4752\(94\)90003-5](https://doi.org/10.1016/0959-4752(94)90003-5)
- Sweller J. Cognitive load during problem solving: effects on learning. *Cogn Sci*. 1988;12(2):257–285. [https://doi.org/10.1207/s15516709cog1202\\_4](https://doi.org/10.1207/s15516709cog1202_4)
- Sweller J, Chandler P. Evidence for cognitive load theory. *Cogn Instr*. 1991;8(4):351–62. Available from: <https://www.jstor.org/stable/3233599>
- Sweller J, van Merriënboer JGG, Paas FGWC. Cognitive architecture and instructional design. *Educ Psychol Rev*. 1998;10(3):251–6. <https://doi.org/10.1023/a:1022193728205>
- Sweller J, van Merriënboer JGG, Paas F. Cognitive architecture and instructional design: 20 years later. *Educ Psychol Rev*. 2019;31(2):261–92. <https://doi.org/10.1007/s10648-019-09465-5>
- Paas F, Tuovinen JE, Tabbers H, van Gerven PWM. Cognitive load measurement as a means to advance cognitive load theory. *Educ Psychol*. 2003;38(1):63–71. [https://doi.org/10.1207/S15326985EP3801\\_8](https://doi.org/10.1207/S15326985EP3801_8)
- Miller GA. The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychol Rev*. 1956;63(2):81–97. <https://doi.org/10.1037/h0043158>
- Sweller J. Working Memory, Long-term Memory, and Instructional Design. *J Appl Res Mem Cogn*. 2016;5(4):360–7. <https://doi.org/10.1016/j.jarmac.2015.12.002>
- Peterson L, Peterson MJ. Short-term retention of individual verbal items. *J Exp Psychol*. 1959;58(3):193–8. <https://doi.org/10.1037/h0049234>. PMID: 14432252
- Chi MTH. Expertise in problem solving. Hillsdale, IN: Advances in the psychology of human intelligence; 1982 p7-75. Available from: chrome-extension://efaidnbmnfnkibaipiihnkbnlpiiilzpjjoc/efindmkaj/[https://education.asu.edu/sites/default/files/lcl/chiglaserrees\\_0.pdf](https://education.asu.edu/sites/default/files/lcl/chiglaserrees_0.pdf)
- Shiffrin RM, Schneider W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychol Rev*. 1977;84(2):127–90. <https://doi.org/10.1037/0033-295X.84.2.127>
- Schneider W, Shiffrin RM. Controlled and automatic human information processing: I. Detection, search, and attention. *Psychol Rev*. 1977;84(1):1–66. <https://doi.org/10.1037/0033-295X.84.1.1>
- Atkinson RC, Shiffrin RM. Human memory: a proposed system and its control processes. *Psychol Learn Motiv*. 1968;2(C):89–195. [https://doi.org/10.1016/S0079-7421\(08\)60422-3](https://doi.org/10.1016/S0079-7421(08)60422-3)
- van Merriënboerand JGG, Sweller J. Cognitive load theory in health professional education: design principles and strategies. *Med Educ*. 2010;44(1):85–93. <https://doi.org/10.1111/j.1365-2923.2009.03498.x>. PMID: 20078759
- Sweller J, Chandler P. Why some material is difficult to learn. *Cogn Instr*. 1994;12(3):185–233. [https://doi.org/10.1207/s1532690xcii1203\\_1](https://doi.org/10.1207/s1532690xcii1203_1)
- Young JQ, van Merriënboer J, Durning S, ten Cate O. Cognitive load theory: implications for medical education: AMEE Guide No. 86. *Med Teach*. 2014;36(5):371–84. <https://doi.org/10.3109/0142159X.2014.889290>. PMID: 24593808
- Korf HW, Wicht H, Snipes RL, et al. The dissection course - necessary and indispensable for teaching anatomy to medical students. *Ann Anat*. 2008;190(1):16–22. <https://doi.org/10.1016/j.aanat.2007.10.001>. PMID: 18342138
- Johnson JH. Importance of dissection in learning anatomy: personal dissection versus peer teaching. *Clin Anat*. 2002;15(1):38–44. <https://doi.org/10.1002/ca.1090>. PMID: 11835543
- Gummery E, Cobb KA, Mossop LH, Cobb MA. Student perceptions of veterinary anatomy practical classes: a longitudinal study. *J Vet Med Educ*. 2018;45(2):163–76. <https://doi.org/10.3138/jvme.0816-132r1>. PMID: 29767571
- Laakkonen J, Nevgi A. Relationships between learning strategies, stress, and study success among first-year veterinary students during an educational transition phase. *J Vet Med Educ*. 2014;41(3):284–93. <https://doi.org/10.3138/jvme.0214-016R1>. PMID: 24981421
- Vollmerhaus B, Roos H, Knospe C, Reese S. Max Flesch (1852–1943): Veterinär-anatom, Arzt und NS-Opfer. *Schweiz Arch Tierheilkd [Internet]*. 2008;150(1):23–28. Available from: <http://sat.gstsvs.ch/de/pubmed/?doi=10.1024/0036-7281.150.1.23>

- 24 Warren AL, Donnon T. Optimizing biomedical science learning in a veterinary curriculum: a review. *J Vet Med Educ.* 2013;40(3):210–22. <https://doi.org/10.3138/jvme.0812-070R>. PMID: 23975068
- 25 Osguthorpe R, Graham C. Blended learning environments: definitions and directions. *Q Rev Distance Educ.* 2003;4(3):227–233.
- 26 Graham CR. Blended learning systems: definition, current trends, and future directions. In Bonk, C. J. and Graham, C. R., eds. *Handbook of blended learning: Global Perspectives, local designs.* San Francisco. IN: Pfeiffer Publishing, 2006:3-21.
- 27 Khalil MK, Abdel Meguid EM, Elkhider IA. Teaching of anatomical sciences: a blended learning approach. *Clin Anat.* 2018;31(3):323–9. <https://doi.org/10.1002/ca.23052>. PMID: 29352730
- 28 Leppink J, Paas F, van der Vleuten CPM, van Gog T, van Merriënboer JGG. Development of an instrument for measuring different types of cognitive load. *Behav Res Methods.* 2013;45(4):1058–72. <https://doi.org/10.3758/s13428-013-0334-1>. PMID: 23572251
- 29 Miller DJ, Noble P, Medlen S, Jones K, Munns SL. Brief research report: psychometric properties of a cognitive load measure when assessing the load associated with a course. *J Exp Educ.* 2023;91(2):401–10. <https://doi.org/10.1080/00220973.2021.1947763>
- 30 Leppink J, van den Heuvel A. The evolution of cognitive load theory and its application to medical education. *Perspect Med Educ.* 2015;4(3):119–27. <https://doi.org/10.1007/s40037-015-0192-x>. PMID: 26016429
- 31 Cohen J. A power primer. *Psychol Bull.* 1992;112(1):155–9. <https://doi.org/10.1037//0033-2909.112.1.155>. PMID: 19565683
- 32 Mahdy MAA. The impact of COVID-19 pandemic on the academic performance of veterinary medical students. *Front Vet Sci.* 2020;7:1–8. <https://www.frontiersin.org/article/10.3389/fvets.2020.594261/full>
- 33 Nongnuch Inpanbutr, Rebecca Garabed, Jay Hsiao, Shayna Mohr. Impact of learning veterinary anatomy 100% online during the COVID-19 pandemic: preliminary analysis. In: *Anatomia, histologia, embryologia.* Sinowatz F, ed. John Wiley & Sons, Ltd; 2022. p31. <https://onlinelibrary.wiley.com/doi/epdf/10.1111/ahc.12759>
- 34 Mahdy MAA, Sayed RKA. Evaluation of the online learning of veterinary anatomy education during the Covid-19 pandemic lockdown in Egypt: Students' perceptions. *Anat Sci Educ.* 2022;15(1):67–82. <https://doi.org/10.1002/ase.2149>. PMID: 34714602
- 35 Chang M, Liao M, Lue J, Yeh C. The impact of asynchronous online anatomy teaching and smaller learning groups in the anatomy laboratory on medical students' performance during the Covid-19 pandemic. *Anat Sci Educ.* 2022;15(3):476–492. <https://doi.org/10.1002/ase.2179>. PMID: 35291048
- 36 Dutta S, Ambwani S, Lal H, et al. The satisfaction level of undergraduate medical and nursing students regarding distant preclinical and clinical teaching amidst COVID-19 across India. *Adv Med Educ Pract.* 2021;12:113–22. <https://doi.org/10.2147/AMEP.S290142>. PMID: 33564272
- 37 Martin L. November 2020 Tertiary Education Quality and Standards Agency. Foundations for good practice: the student experience of online learning in Australian higher education during the COVID-19 pandemic. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/<https://www.teqsa.gov.au/sites/default/files/student-experience-of-online-learning-in-australian-he-during-covid-19.pdf>
- 38 Mahdy MAA, Ewaida ZM. Evaluation of the emergency remote learning of veterinary anatomy during the COVID-19 pandemic: global students' perspectives. *Front Educ (Lausanne).* 2022;6:1–12. Available from: <https://www.frontiersin.org/articles/10.3389/feduc.2021.728365/full>
- 39 Newton PM, Essex K. How common is cheating in online exams and did it increase during the COVID-19 pandemic? A systematic review. *J Acad Ethics.* 2023. <https://doi.org/10.1007/s10805-023-09485-5>
- 40 Dzemidzic Kristiansen S, Burner T, Johnsen BH. Face-to-face promotive interaction leading to successful cooperative learning: a review study. *Cogent Educ.* 2019;6(1):1–19. <https://doi.org/10.1080/2331186X.2019.1674067>
- 41 Hessels RS. How does gaze to faces support face-to-face interaction? A review and perspective. *Psychon Bull Rev.* 2020;27(5):856–81. Available from: <https://link.springer.com/10.3758/s13423-020-01715-w>
- 42 Salamuddin A. comparative analysis of students' perceptions in modular distance learning approach versus face-to-face learning approach of mindo State Unive. Sulu. Open Access Indonesia. *J Soc Sci.* 2021;4(2):395–407
- 43 Chopin A, Bavelier D, Levi DM. The prevalence and diagnosis of "stereoblindness": A best evidence synthesis. *J Vis.* 2019;19(10):262b. Available from: <https://jov.arvojournals.org/article.aspx?articleid=2750983>
- 44 Access Economics. February 2006 Listen hear!: the economic impact and cost of hearing loss in Australia : a report. Available from: <https://www.flyingcolours.org.au/research/listen-hear-the-economic-impact-and-cost-of-hearing-loss-in-australia/>
- 45 Son C, Hegde S, Smith A, Wang X, Sasangohar F. Effects of COVID-19 on college students' mental health in the United States: interview survey study. *J Med Internet Res.* 2020;22(9):e21279. <http://dx.doi.org/10.2196/21279>. PMID: 32805704
- 46 Usher AMK, Jackson D, Massey D, et al. The mental health impact of COVID-19 on pre-registration nursing students in Australia: findings from a national cross-sectional study. *J Adv Nurs.* 2023;79(2):581–92. <http://dx.doi.org/10.1111/jan.15478>. PMID: 36453452
- 47 Ramachandran S, Shayanfar M, Brondani M. Stressors and mental health impacts of COVID-19 in dental students: a scoping review. *J Dent Educ.* 2023;87(3):326–42. <http://dx.doi.org/10.1002/jdd.13122>. PMID: 36349431
- 48 Reuter PR, Forster BL, Kruger BJ. A longitudinal study of the impact of COVID-19 restrictions on students' health behavior, mental health and emotional well-being. *PeerJ.* 2021;9:e12528. <http://dx.doi.org/10.7717/peerj.12528>. PMID: 34993018
- 49 Dhar BK, Ayithey FK, Sarkar SM. Impact of COVID-19 on psychology among the University Students. *Global Challenges.* 2020;4(11):2000038. <https://doi.org/10.1002/gch2.202000038>
- 50 Stamatis CA, Broos HC, Hudiburgh SE, Dale SK, Timpano KR. A longitudinal investigation of COVID-19 pandemic experiences and mental health among university students. *Br J Clin Psychol.* 2022;61(2):385–404. <https://doi.org/10.1111/bjc.12351>. PMID: 34850405
- 51 Paucsik M, Leys C, Marais G, Baeyens C, Shankland R. Self-compassion and savouring buffer the impact of the first year of the COVID-19 on PhD students' mental health. *Stress Health.* 2022;38(5):891–901. <https://doi.org/10.1002/smi.3142>. PMID: 35286765
- 52 Kumari P, Gupta P, Piyooosh AK, Tyagi B, Kumar P. COVID 19: impact on mental health of graduating and post graduating students. *J Stat Manag Syst.* 2021;24(1):67–79. <https://doi.org/10.1080/09720510.2020.1833449>
- 53 Baltà-Salvador R, Olmedo-Torre N, Peña M, Renta-Davids AI. Academic and emotional effects of online learning during the COVID-19 pandemic on engineering students. *Educ Inf*

- Technol (Dordr). 2021;26(6):7407–34. <https://doi.org/10.1007/s10639-021-10593-1>. PMID: 34108843
- 54 Yu Y, She R, Luo S, et al. Factors Influencing depression and mental distress related to COVID-19 among University Students in China: online cross-sectional Mediation Study. *JMIR Ment Health*. 2021;8(2):e22705. <https://doi.org/10.2196/22705>. PMID: 33616541
- 55 Rodrigues IL, Nunes TP, Cortez CS, Lourenço AM. E-learning impact on veterinary medical student's mental health during the COVID-19 pandemic. *J Vet Med Educ*. 2023;50(3):343–353. <https://doi.org/10.3138/jvme-2021-0052>. PMID: 35737894
- 56 Carney K, Thompson RR. Grief in response to uncertainty distress among veterinary students during the early stages of the COVID-19 pandemic. *Front Vet Sci*. 2021;8:1–9. <https://doi.org/10.3389/fvets.2021.662198>. PMID: 34307521
- 57 Cifuentes-Faura J, Obor DO, To L, Al-Naabi I. Cross-cultural impacts of COVID-19 on higher education learning and teaching practices in Spain, Oman, Nigeria and Cambodia: a cross-cultural study. *J Univ Teach Learn Pract*. 2021;18(5):135–51. <https://doi.org/10.53761/1.18.5.8>

## AUTHOR INFORMATION

**Karina Jones**, BAnVetBioSc(Hons), PhD. College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville, Australia and School of Veterinary Medicine, Murdoch University, Perth, Australia. She is lecturer in Veterinary Anatomy and Physiology and the Second year co-ordinator and Assessment Lead. Her research interests include veterinary education, student transition experience, quality assurance in assessment and wildlife health.

**Dan J Miller**, BA-BJourn, BPsych(Hons), PhD (Psychology) ( 0000-0002-3230-2631). College of Healthcare Sciences, James Cook University, Townsville, Australia. He is a lecturer in Psychology. His research interests include the psychology of learning and teaching and quantitative methods.

**Prisca Noble**, BSc, DVM, MSc, PhD (Veterinary Sciences). College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville, Australia. She is a senior lecturer in Veterinary Anatomy. Her research interests include veterinary education with a particular focus on blended teaching and competency-based teaching. Email: [prisca.noble@jcu.edu.au](mailto:prisca.noble@jcu.edu.au).