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User perception and anatomical understanding from use of 3D anatomy technology by exercise science students: A pilot study

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ABSTRACT

Understanding anatomy poses a significant challenge for non-medical university students, particularly those without prior science knowledge, such as exercise science students. Technology-Enhanced Learning (TEL) resources, including 3D anatomy platforms, have been explored to support student engagement and improve academic outcomes with variable results.

Objectives: This pilot study investigated the potential of the Complete Anatomy (CA) 3DTEL resource, combined with traditional blended learning methods, to enhance anatomy knowledge of first-year, undergraduate exercise science students.

Design: Cohort observational study.

Methods: The study followed 36 participants (46 % female, 54 % male) across two 13-week units. Guided implementation of CA was introduced during unit 1, while students engaged with the resource independently during unit 2. User satisfaction was assessed via surveys, and academic performance evaluated by comparing final unit grades with a 2022 cohort that did not use the resource.

Results: Results indicated stable student satisfaction and a significantly different academic performance for the 2023 cohort, with median grades increasing from a Pass (50.0–64.9 %) to a Credit (65.0–74.9 %).

Conclusion: These findings suggest that integrating 3DTEL resources with blended learning can positively support anatomy learning for science-naïve students.

1. Introduction

Learning anatomy is widely recognised as challenging due to its volume and complexity [1–3]. While Technology Enhanced Learning (TEL) resources such as eBooks, e-learning platforms and 3D anatomy software have been adopted to support medical students, their effectiveness depends on learner motivation, spatial ability, and prior science knowledge [4,5]. Medical students enter their studies with a strong science background, but students, such as those in Exercise Science undergraduate degrees, often begin with no prior knowledge [6]. These science-naïve learners face additional barriers to mastering anatomy and are at higher risk of disengagement and attrition [1,7,8]

Traditional interventions, including cadaver-based teaching, workbooks and weekly quizzes, have been trialled to support non-medical cohorts, yet attrition rates remain concerning [9]. Science-naïve learners may benefit from educational strategies that explicitly support spatial learning through multimodal, interactive visualisation resources. These immersive resources gained growing interest across applied and vocational education sectors for their capacity to simulate real-world complexity and enhance learner engagement, with bibliometric trends highlights a rising global emphasis on the pedagogical potential of virtual and 3D technologies [10].

A promising 3DTEL tool already integrated into academic curricula is Complete Anatomy (CA) by 3D4Medical (Elsevier) [11]. The resource allows the user to manipulate detailed anatomical structures and presents an opportunity to enhance spatial skills and bridge the gap between two- and three-dimensional anatomical understanding. It is a portable and interactive tool that supports both teaching and learning, particularly suited to science-naïve students who may benefit from a hands-on, visual learning experience that enhances anatomical understanding outside of traditional lab settings [11]. Boomgaard et al. [12] examined the benefits of a concurrent immersive 3DTEL resource for exercise science students and reported good student engagement with the resource [12]. The software, delivered via the 3DTEL platform,

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potentially supported differentiated learning by allowing students to explore 3D models at their own pace, choose from various interactive tools, and revisit content as needed, aligning with individual learning needs and preferences, rather than a one-size-fits-all approach [13]. However, academic performance was not examined, nor student's perceived satisfaction with the resource; a crucial factor for determining if the resource would address the potential challenges of digital information skill, competency and literacy [13], particularly for self-directed learning.

This pilot study explored the use of a 3DTEL technology, CA, alongside traditional blended learning to support first-year exercise science students in learning anatomy. We anticipated that the platform would be viewed as user-friendly and beneficial, particularly for students with limited science backgrounds, and that it would enhance academic performance. Additionally, by providing initial guided support, the study aimed to address common challenges of adaptive learning technologies and personalised environments, ultimately promoting self-directed learning.

2. Materials and methods

2.1. Study design

The current investigation was a cohort observational study that employed the CA resource alongside traditional blended learning, which included 15-minute online videos for each learning objective, one face-to-face lecture, one cadaver lab, and a one-hour tutorial each week, all delivered by the same instructor. We followed first-year undergraduate Exercise Science students across two 13-week units in 2023. In Unit 1, students received guided instruction on using the CA resource during tutorials to support early engagement and reduce digital learning barriers. In Unit 2, this guidance was deliberately withdrawn to evaluate whether students could independently use the platform after initial support. This design enabled comparison of student perceptions and academic outcomes under differing levels of instructional scaffolding, aligning with the study's aim to explore the role of adaptive technologies in promoting self-directed learning. Outcomes included student perceptions for using and valuing the 3DTEL resource (measured via survey) in week 8 of unit 1 (baseline) and week 11 of unit 2. Outcomes also included the final grades of unit 1 and unit 2.

2.2. Participants

Participants had no prior knowledge of biological sciences and included 36 adult learners (46 % female, 54 % male) enrolled in a 3-year undergraduate exercise science university program with an university entry score (ATAR) greater than 64 out of 99.95 (cohort mean score 77.7). For comparison, an ATAR score greater than 90 or above guarantees entry into most JCU courses with all subject prerequisites waived. Applicants awarded an ATAR of greater than 73 will be guaranteed entry into many undergraduate programs, however, will also need to meet the course subject prerequisites. Participants provided written informed consent prior to participation in accordance with local human research ethics approval (James Cook University, H9073).

2.3. . DTEL software

The software application employed was CA (3D4Medical, Elsevier, San Diego, CA), a 3DTEL method bespoke for learning anatomy and underpinned by Gray's Anatomy [14], the recommended text for these units that provides a fundamental understanding of the human body including, but not limited to, the Musculoskeletal, Nervous, Cardiovascular, Gastrointestinal and Reproductive systems. The 3DTEL software was downloaded by participants to their personal device (i.e. iPhone 5 and Android 7, Windows 10, and tablet devices beyond 2009) (Sara K [11]) and permitted the participant to manipulate images including zooming, rotation and viewing of inferior, superior, sagittal and coronal sections, and modifying the layers of structures and connective tissue (3D4Medical, Elsevier).

2.4. Procedure

The 3DTEL Complete Anatomy (CA) software was introduced in Week 7 of Unit 1, following six weeks of instruction focused on foundational physiological concepts. At this point, we invited students to attend an optional face-to-face tutorial, where they received structured, instructor-led navigation of the software. Tutorials are non-mandatory and attendance is not recorded, anecdotally an average of 75 % of students attend. This 60-minute session included demonstrations of the platform's core features (e.g., zooming, rotating, hiding/viewing structures, adding labels) and integration with weekly learning objectives from the unit content. The instructor guided students through a step-by-step exploration of relevant anatomical regions using CA in real time, with opportunities for students to practice and ask questions. This scaffolding aimed to reduce barriers to engagement and support students unfamiliar with self-directed digital platforms. The tutorial was designed to build early confidence in using the tool as part of weekly independent study.

After one week of using the CA software with guided instruction (by Week 8), students completed a baseline user satisfaction survey capturing their early perceptions of the tool's usability and educational value.

Following the completion of Unit 1, end-of-term assessments, and a break period, students commenced Unit 2, another 13-week program. In Unit 2, the CA software remained available, but no further guided instruction was provided. Instead, students engaged with the platform independently and at their own discretion, representing a withdrawal of the initial instructional scaffolding.

To assess changes in perceptions over time, the user satisfaction survey was re-administered in Week 11 of Unit 2, capturing student views after several weeks of self-directed use of the platform.

For objective academic outcomes, final unit grades from both 2022 and 2023 were used as the primary performance measure. While individual quiz scores and group presentation results were available, final grades were chosen because they reflected cumulative performance across standardised assessment components (e.g. exams, practicals, assignments) that were consistently aligned with the unit learning outcomes and assessed by the same teaching staff. This approach provided a more reliable and equitable measure of overall academic performance across the two learning environments.

2.5. Data collection and analysis

We assessed user satisfaction with the 3DTEL software via paper surveys, which included eight questions that took ~5-minutes to complete. We custom designed the survey based on previously validated usability and engagement tools used in TEL evaluations [4,5]. It comprised four constructs assessed by two items each: perceived ease of use, time of use, perceived usefulness, and perceived educational value. All questions used a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The survey underwent review by two subject-matter experts in anatomy education and we piloted for clarity and time burden with a small group of non-participant students prior to deployment (Table 2). Significant ($p < 0.05$) changes in survey responses during the 3DTEL implementation were examined via Mann-Whitney U tests.

Academic performance of participants was determined as the final grade (i.e. Fail – result of <50 % and grade point [GP] of 3; Pass– result of 50.0–64.9 % and GP of 4; Credit – result of 65.0–74.9 % and GP of 5; Distinction – result of 75.0–84.9 % and GP of 6; High Distinction – result of >84.9 % and GP of 7) of units 1 and 2. For both cohorts in 2022 and 2023, on-course assessments included completion of weekly quizzes, a group presentation, and a final exam comprising of both theory and cadaver practical specimens. All assessments were aligned to the learning objectives of each unit that were unchanged between cohort years. Descriptive characteristics for the two student cohorts are shown in Table 1. Additionally, final grades and GP were compared between the current participants (2023) and a comparable cohort undertaking the same units (i.e. units 1 and 2) from the previous year (2022) that did not have access to the 3DTEL resources. The 2022 cohort were like the 2023 cohort in terms of university entry scores (ATAR 77.7 and 75.4, respectively out of 99.95) and early performance in unit 1 (i.e., mean quiz results of 7/10 and 6/10, respectively). Significant ($p < 0.05$) differences in cohort final grades and GP were examined via Mann-Whitney U tests.

3. Results

During the 3DTEL implementation, user satisfaction remained unchanged except for simplicity of use (Question 1 and 2), which was greater following unit 2 (Table 2).

The final unit 1 and unit 2 grade distributions for the 2022 and 2023 cohorts are presented in Figs. 1 and 2, with the median grade in 2022 for both units being a Pass (GP of 4), which is significantly lower than the median grade of Credit (GP of 5, $p < 0.05$) in 2023. For unit 1, the average GP is significantly lower for 2022 compared to 2023 (4.34 ± 0.87 vs. 4.95 ± 1.20, $p = 0.025$). For unit 2, the average GP is significantly lower for 2022 compared to 2023 (4.43 ± 0.74 vs. 4.97 ± 1.02, $p = 0.028$).

Overall unit grades were selected as the primary measure of academic performance, as they represent cumulative achievement across all assessment tasks and are critical for student progression and meeting both university and accreditation requirements. While individual assessment items contribute to subject learning outcomes, they are not independently required for progression. The use of final unit grades allowed for a consistent and reliable comparison between cohorts, given the assessments were structurally and proportionally equivalent across both years. These results point to a modest but meaningful influence of 3DTEL on student learning outcomes, underscoring the need to consider how such tools are best embedded into first-year anatomy curricula.

4. Discussion

This pilot study investigated the perceptions and academic outcomes of a group of first-year exercise science students using 3DTEL software, CA, in their study of anatomy. Participants rated high and stable satisfaction with the 3DTEL software, which became more user-friendly during the study. The stability of satisfaction may suggest that students recognised the utility of CA from the outset, with expectations already met during the guided introduction. In this sense, the absence of an increase in satisfaction does not necessarily imply limited impact but may reflect a ceiling effect in survey ratings. Alternatively, stable satisfaction could indicate that students maintained user confidence and perceived value of the tool even after the withdrawal of guided support, reinforcing its potential for sustained independent use. Median final grades were greater for the 2023 cohort who engaged 3DTEL compared to the 2022 cohort that did not use this additional resource. These results indicate that integration of 3DTEL with traditional blended learning, (described above), can positively impact upon science-naïve participants' learning of anatomy.

Previously, TEL usage was reported to be well received by medical students that engaged with the resources however, there was no impact upon assessment outcomes [5]. Others have also reported no improvement in assessment outcomes following use of TEL [15]. These discrepancies may reflect differences in participant characteristics, software design (3D vs 2D), or implementation strategy (e.g. guided vs unguided use).

Differences between the current and previous studies could be

Table 1
Descriptive characteristics of 2022 and 2023 cohorts.

Variable	2022 Cohort ($n = 35$)	2023 Cohort ($n = 37$)
Gender Distribution (male/female)	50 %	54 % 46 %
Age distribution	56 % <19 years	60 % <19 years
	33 % <25 years	27 % <25 years
	11 % >25 years	13 % >25 years
Average Entry Score (ATAR)	75.4	77.7
Quiz Performance (Unit 1)	6/10	7/10
Final Grade	Fail 6	Fail 5
	GPA4 14	GPA4 8
	GPA5 12	GPA5 12
	GPA6 3	GPA6 8
	GPA7 0	GPA7 4
First in family To attend university	44 %	46 %

Table 2
User Satisfaction survey.

Survey Question	*Mean ± SD*	
	Pre	*Post*
Q1 After downloading the software onto my device, I attempted to use it and found it to be simple to use	*4.40 ± 0.65*	*4.73 ± 0.45**
Q2 After downloading the software and the investigator familiarisation of the software, I found it to be simple to use	*4.46 ± 0.51*	*4.70 ± 0.47**
Q3 I often used the software outside my planned learning activities, including as reference for my other subjects	*4.03 ± 0.95*	*4.03 ± 0.85*
Q4 I will use the software to prepare for the 2023 end of semester exams for both BM1061 and BM1062 and other subjects	*4.60 ± 0.65*	*4.50 ± 0.68*
Q5 Using the software has helped my learning and understanding of anatomical content and concepts in BM1061 and BM1062	*4.46 ± 0.70*	*4.57 ± 0.57*
Q6 I have or will likely demonstrate the software to others how the program works family friends partner etc.	*4.11 ± 0.80*	*4.27 ± 0.79*
Q7 I would continue to pay the subscription in 2024 to help with subsequent studies and my career practice (~$85)	*3.46 ± 1.09*	*3.60 ± 1.19*
Q8 I believe I am far more engaged with the content for BM1061 and BM1062 because of the software	*4.23 ± 0.81*	*4.33 ± 0.76*

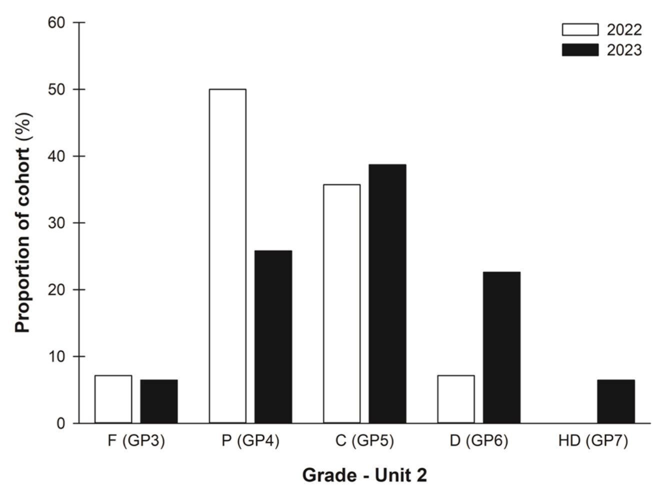

Fig. 1. Unit 1 grade distribution for 2022 and 2023 cohorts.
GP – Grade point; F – Fail; P – Pass; C – Credit; D – Distinction; HD – High Distinction.

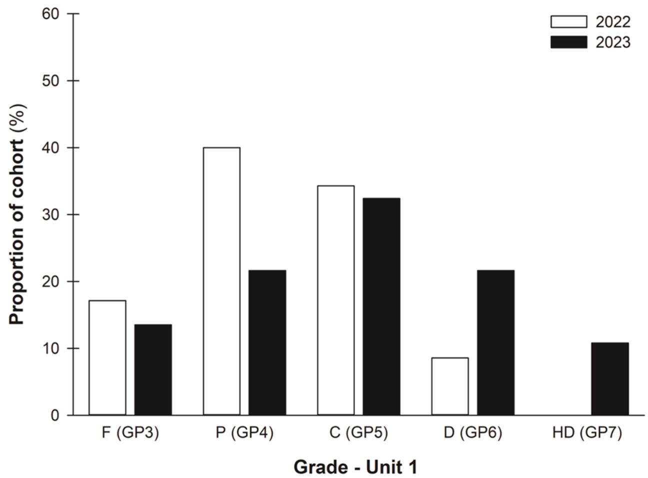

Fig. 2. Unit 2 grade distribution for 2022 and 2023 cohorts.
GP – Grade point; F – Fail; P – Pass; C – Credit; D – Distinction; HD – High Distinction.

attributed to variations in the TEL tools used, guided support, student population characteristics, and the mode of delivery. For example, this study utilized 3DTEL tool accessible on personal devices like mobile phones, rather than a 2DTEL system [5] that was limited to personal computers. The combination of mobile accessibility and 3D functionality may enhance students' learning experience. Smartphones offer two key technological advantages over personal computers: wireless internet connectivity and mobile service technology [16]. These features enable portability, mobility, and 24/7 accessibility [16], allowing users to quickly search for information anytime, anywhere, or engage with the app while commuting or waiting in queues.

Further, the current study included guided implementation during teaching sessions, unlike some of the previous studies [4,5,12,17–19]. Instructor-led guidance and student familiarisation with 3DTEL could be crucial for those struggling with initial engagement and lacking the patience to explore the app's various features. Some students may abandon the tool if they do not grasp it immediately, particularly when already overwhelmed by the challenges of first-year university and a complex subject like anatomy [20,21]. Providing a structured, hands-on learning experience with the instructor, directly linked to course content, may help build the science-naïve student's confidence in using TEL independently. This approach may encourage self-regulated study habits, for Exercise Science and other Allied Health students, ultimately integrating the tool into their learning process. While it may require additional time from instructors, the long-term benefits could outweigh the investment by fostering independent study behaviors and enhancing anatomy comprehension through an engaging platform.

An important design feature of the current study was that the 3DTEL resource was used in unison with a suite of gold standard teaching strategies including weekly cadaver sessions / workbook activities, weekly online quizzes (12 per Unit), guided tutorials aligned with graduate destinations, and peer-assisted learning [7,8,22]. The integration of TEL with other strategies may be ideal for greater learning outcomes compared to the solitary use of TEL [5,17]. Future studies examining different combinations of teaching strategies with and without TEL may identify the optimal teaching design for student engagement and learning of anatomy.

For students with limited anatomical knowledge and low spatial ability, 3DTEL provides an interactive and manipulable tool that helps bridge the gap between 2D and 3D representations [4,17]. It allows learners to begin with basic structures before progressing to more complex anatomical systems [4,15,17,18]. These immersive experiences may reduce cognitive load by presenting information in a way that removes the need for abstract mental reconstruction while simultaneously enhancing spatial reasoning skills and comprehension of complex anatomical relationships.

This pilot study provided support for the use of a 3DTEL resource for students without prior science knowledge for learning anatomy. Student engagement with the resource and academic outcomes were positive, and conceivably the resource itself bridged 2D to 3D images, suggesting a potential improvement of spatial ability, essential for anatomy learning [4,18]. This 3DTEL approach may have supported engagement and retention, making it more inclusive for science-naïve students who may struggle with lone traditional blended learning methods.

The practical and theoretical implications of this study are noteworthy. From a theoretical perspective, the results reinforce the view that spatial reasoning is not fixed but can be developed through targeted tools and environments [4]. Practically, the implementation of CA, an interactive, portable, and self-paced platform aligns well with the needs of science-naïve students who may lack traditional academic preparation. By improving engagement and offering flexible learning support, the tool may contribute to reducing the high attrition rates commonly observed in non-medical anatomy units. This aligns with broader goals of inclusive education and learner-centred support in tertiary health programs.

This study has several strengths. A guided introduction to 3DTEL provides structured support that reduced early barriers to digital engagement. Integration of the resource with established teaching strategies such as cadaver laboratories, online quizzes, and tutorials ensured ecological validity and reflected authentic teaching practice. The mobile accessibility of the platform enabled learning to extend beyond the classroom, supporting self-directed engagement. Further, the focus on a non-medical student cohort, a population rarely studied in anatomy education research, represents a novel contribution that addresses an important gap in the literature. Offering accessible, visual, and interactive 3DTEL resources, the intervention provides additional scaffolding for science-naïve students. This approach aligns with inclusive teaching practices that prioritise equitable access to complex content and support for diverse learners, contributing to more inclusive and supportive learning environments within higher education.

This study has several limitations. Although cohort characteristics (e.g., ATAR, instructional format, and assessments) were matched between 2022 and 2023, potential confounding variables, such as lecture or tutorial attendance, engagement with supplementary materials, instructor-student rapport, and personal factors like motivation or study behaviours, were not controlled and may have influenced outcomes. The modest sample size and use of a historical rather than concurrent control group further limit generalisability. Voluntary participation in the guided CA tutorial introduces potential self-selection bias, particularly if more motivated students opted in. Approximately 90 % of the cohort ($n = 32$ / 36) attended the guided session, while the remainder engaged with the software independently, which may have influenced subsequent perceptions and outcomes. Although cohort characteristics such as ATAR entry score and early unit quiz results were matched between 2022 and 2023, other unmeasured differences (e.g., lecture/tutorial attendance, cohort demographics, or broader institutional changes across years) cannot be ruled out. Finally, the study did not include long-term follow-up, so it remains unclear whether the observed academic improvements and stable satisfaction ratings were sustained into later semesters or subsequent years.

Importantly, the academic improvements observed in this study may also reflect the combined effect of blended learning methods and cannot be solely attributed to the CA platform. Future research should include larger, multi-site RCTs and mixed methods approaches to better evaluate the impact of 3DTEL resources in blended learning environments.

In conclusion, the current study identified that the 3DTEL software is user-friendly, well-received by students, and is associated with improved academic performance compared to a cohort that did not use 3DTEL. However, this observational finding should be interpreted cautiously given the lack of a concurrent control group and potential confounding variables. The inclusion of 3DTEL (CA) as an instructor guided supplement tool may provide valuable support for students without prior science knowledge to better manage the complexities of anatomy learning at university. Further, implementation of TEL may reduce student attrition, enhance spatial skill development, and support equitable academic success in non-medical cohorts.

CRediT authorship contribution statement

Leesa Anne Grier: Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Anthony Leicht:** Writing – review & editing, Visualization, Supervision, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further reading

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