Medical students' learning of anatomy: memorisation, understanding and visualisation

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INTRODUCTION There is much subjective discussion, but few empirical data that explore how students approach the learning of anatomy.

AIMS Students' perceptions of successful approaches to learning anatomy were correlated with their own approaches to learning, quality of learning and grades.

METHODS First-year medical students ($n = 97$) studying anatomy at an Australian university completed an online survey including a version of the Study Process Questionnaire (SPQ) that measures approaches to learning. The quality of students' written assessment was rated using the Structure of Observed Learning Outcomes (SOLO) taxonomy. Final examination data were used for correlation with approaches and quality of learning.

RESULTS Students perceived successful learning of anatomy as hard work, involving various combinations of memorisation, understanding and visualisation. Students' surface approach (SA) scores (mean 30 ± 3.4) and deep approach (DA) scores (mean 31 ± 4.2) reflected the use of both memorisation and understanding as key learning strategies in anatomy. There were significant correlations between SOLO ratings and DA scores ($r = 0.24$, $P < 0.01$), between SA scores and final grades ($r = -0.30$, $P < 0.01$) and between SOLO ratings and final grades ($r = 0.61$, $P < 0.01$) in the subject.

CONCLUSIONS Approaches to learning correlate positively with the quality of learning. Successful learning of anatomy requires a balance between memorisation with understanding and visualisation. Interrelationships between these three strategies for learning anatomy in medicine and other disciplines require further investigation.

KEYWORDS humans; anatomy/*education; *learning; *education, medical, undergraduate; perception; students, medical/*psychology; questionnaires; *memory; Australia.

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INTRODUCTION

The teaching of anatomy to medical students has undergone major changes over the past 2 decades. New anatomy curricula have been established in addition to the traditional regional lecture-based approach, with problem-based learning (PBL), system-based and integrated clinical curricula emerging on the academic landscape.[1,2] In America, the United Kingdom and elsewhere, there is concern that these new curricula involve less anatomy teaching time[3] and may have an adverse effect on the level of anatomical knowledge of medical graduates.[4] As increasing numbers of medical students enter university and new technologies emerge, anatomy teaching budgets have shrunk. The teaching of anatomy is involving less dissection and greater use of prosected and plastinated specimens,[5] fewer lectures, more tutorials and peer learning[6] and the greater availability and use of web-based and computer-based resources.[7] While the impact of these changes has been explored to varying degrees, Marks[8] and Miller[9] contend that, overall, we understand little about how students learn anatomy, as much discussion is based largely on anecdote rather than empirical research.

Overview

What is already known on this subject

Empirical evidence supports the importance of visualisation skills in learning anatomy. There are many anecdotal reports of how students approach learning of anatomy, but little research about how students learn anatomy.

What this study adds

This study confirms students' perceptions of the importance of memorisation, understanding and visualisation as necessary strategies in learning anatomy.

Deep approaches to learning anatomy correlate with higher quality learning and higher grades.

Suggestions for further research

Interviews and observations with students will shed light on the interrelationships between memorisation, understanding and visualisation.

Further research on how students learn anatomy in medicine and other disciplines will provide a better evidence-base upon which to make decisions and to assess innovative teaching developments in the field.

Student learning of anatomy

The literature on student learning of anatomy is dominated by studies comparing teaching methods using immediate recall of facts or examination grades as the metric. Often there was little difference between research outcomes,[10,11] although it is unclear to what extent examinations focused on factual recall rather than the quality of depth of learning. Research with experienced radiologists indicates that spatial ability underlies their practice,[12] and Garg *et al.*[7] confirm that students' spatial abilities appear to be a predictor of student success in learning anatomy. In a study focusing explicitly on how students learn anatomy, Eizenberg[13] interviewed medical students about how they approached various anatomical learning tasks. He identified 5 categories of approaches: (i) avoid the task; (ii) memorise facts; (iii) memorise chunks of information (e.g. key diagrams); (iv) understand selected aspects of the anatomical site/structure/concept; and (v) try to comprehend the whole anatomical site/structure/concept and its constituent elements. While Miller[14] believes firmly that 'understanding is the goal and that memorising is not understanding', Eizenberg's study indicates that memorising and understanding may not be mutually exclusive aspects of the learning process.

Student learning

Researchers have distinguished 2 different approaches to learning as deep approaches and surface approaches.[15,16] Surface approaches to learning (e.g. memorisation) are associated with an intention to memorise facts and information, and recite them back in response to questions. The deep approach is characterised by an attempt to understand the information, by seeking a structure within the material and manipulating the information to make sense of it in relation to what is known of the subject matter. Deep and surface approaches to learning are not mutually exclusive (i.e. deep learners may use surface and deep approaches), nor are they stable traits. Students may choose different approaches at different times, or a combination of approaches depending on the nature of subtasks and context. Ramsden[16] suggests that the differences between surface and deep approaches appear to be generalisable across disciplines, but that the meaning of the distinction across various discipline areas is not clear. In the sciences, where there is a complex vocabulary associated with learning, a deep approach 'may require a preliminary stage of rote learning [that is] difficult to distinguish from a surface approach'.[17] Rote learning in this instance might be an example of an intention to understand, even though memorising jargon or symbols is part of the learning process.[18] Similarly, in an exploration of methods used by students to prepare for exams, Entwistle and Entwistle[19] found that some students developed an overarching framework of the disciplinary content by reading from multiple sources, then used memorisation as a strategy to remember detailed information accurately. Anatomy is a discipline with its own language to describe the organisation and structures of the body, and requires considerable intellectual effort to identify the various structures and their internal organisation, as well as their relationships with other structures of the body. It may be one discipline area where the distinctions between deep and surface learning strategies are blurred.

The link between how students approach learning and what they learn is well established in studies that use methods to measure different approaches to learning (the Study Process Questionnaire, SPQ)[20] and quality of learning (e.g. the Structure of Observed Learning Outcomes (SOLO) Taxonomy).[21] Boulton-Lewis[22] reported a positive relationship between student scores on the SPQ and use of SOLO on assessment items. She found that students with a more structured organisation of knowledge were less concerned with surface motives and strategies and more concerned with deep strategies than those with less organised conceptions of learning. Deep approaches to learning are associated with an understanding of the interrelationships between facts and the ability to abstract and generalise, whereas surface approaches are more likely to lead to a fragmented knowledge base. Biochemistry students studying anaemia, using deep learning approaches, were more likely than others to achieve a high quality of learning.[23] Similarly, Balla *et al.*[24] have demonstrated that medical students who learned to make diagnoses by 'listing symptoms and diseases' were less likely to make a correct diagnosis than students who sought to see relationships between symptoms and investigations related to particular diseases. In studies of psychology students[25] academic performance correlated significantly with a deep approach to learning.

Teaching and learning context

Participants in this project were enrolled in a gross anatomy of head and neck subject that has been taught over a 13-week period as part of a course in the pre-clinical years of medicine.[26] Almost all students enrolled in this subject were school-leavers, Australian-born with South-East Asian heritage, and would have studied a mathematics/science curriculum at high school to achieve scores necessary to gain a place in the highly competitive medicine programme. Teaching the 200 students enrolled in the subject involved 4 hours per week of formal tuition: a 1-hour (large class) lecture and a 3-hour (small group) tutorial in the laboratory. The lectures were co-ordinated with pre-assigned independent learning activities and laboratory work. Practical and theory examinations were held at the end of the semester. The theory examination consisted of multiple-choice questions, written essay questions and short-answer questions focusing on the application of anatomical concepts to clinical and real-life situations.

The aim of this research

This project involves exploring relationships between medical students' perceptions of how to learn anatomy successfully, their approaches to the learning of anatomy, use of particular resources and quality of learning. This project focuses necessarily on the knowledge base of anatomy as taught for medical degree programmes. Here we report on the quantitative aspects of the study – the frequency of perceptions and an examination of the relationship between approaches to learning (measured by the SPQ), quality of learning (measured by the SOLO taxonomy) and assessment results and grades.

METHODOLOGY

Students' self-reported study approaches with various resources and their responses to the SPQ were collected using a survey conducted within the regular cycle of evaluation of the anatomy course. Students were asked to complete all of a series of open-ended questions that focused on their perceptions of successful approaches to learning anatomy, and their own approach to learning anatomy during the current semester. The survey was conducted after completion of teaching, but before the final examinations in the course, using a website (http://www.SurveyMaker.com.au) that generates online surveys with a range of automated e-mail and reporting features. The questionnaire was voluntary and administered in closed, confidential mode; hence all students participating in the study did so after explicitly providing consent. The online survey was attempted by 109 of the 217 (50%) students who were available to complete the survey. Surveys with incomplete data were removed from the data set, leaving a total of 97 complete cases for analysis. Numerical data were analysed using SPSS (version 12). Correlations among variables were assessed with statistical significance indicated by $P < 0.05$. Only significant correlations greater than or equal to 0.30 were considered important for major discussion.[27]

Survey instruments

How to learn anatomy

Three survey questions covered this terrain. The first question asked students: 'What is the best approach to learning anatomy?'. The second question asked: 'How did you go about learning anatomy?'. The third question asked students to elaborate about resources that they used to study anatomy during the semester. Qualitative data were read by the authors to provide evidence for interpretations of individual responses to questions. The qualitative data were read collec-

tively to identify general themes in students' approaches to studying anatomy.

Approaches to learning

The short form of the SPQ, R-SPQ-SF,[1] was used to distinguish between surface and deep learning approaches used by students for studying anatomy. The SPQ data were treated according to recommendations by Biggs *et al.*[20], and scale subscores, surface approach score (SA) and deep approach score (DA) were calculated accordingly.

Quality of learning

The SOLO taxonomy was used to establish the quality of learning demonstrated in answers written for essay questions on the final theory examination. No equivalent was possible in the practical examination, due to time constraints. Students' answers to these questions were rated by 2 independent markers according to a pre-negotiated understanding of the different levels of the taxonomy. Answers were rated on a scale of 1–5, where 1 referred to a pre-structural-level answer (SOLO 1) and 5 referred to an extended abstract-level answer (SOLO 5). The ratings from the 2 markers were compared, and where there were discrepancies the markers were asked to discuss their rating and come to a consensus on a final rating.

Academic performance

Examination marks and grades in anatomy were used as the primary measure of academic achievement. The students' raw percentage marks for theory and practical examinations in this course and their final grade for anatomy were used as measures of academic performance.

RESULTS

Frequently mentioned perceptions and approaches required for success in learning anatomy were time on task/hard work ($n = 51$) and associated constant revision ($n = 30$) (Table 1). A significant number of students' perceptions of learning anatomy (15%) were focused on the qualities of other people, e.g. good lecturer or tutor rather than themselves. In terms of academic activity, approximately one-third of students suggested, or used, approaches that involved memorising ($n = 39$), understanding ($n = 36$) and visualising ($n = 29$). Interrelationships between the 3 approaches are illustrated in Fig. 1. Almost one-third of the students surveyed used approaches that involved memorising and understanding, understanding and visualising or memorising and visualising; only a handful of students invoked all 3 strategies. There was overlap between their self-reported perceptions/approaches, such that most students tended to consider learning to involve memorisation in combination with understanding or visualisation.

Table 1 Students' views of successful approaches to learning anatomy

Approach	*No. of students (n = 99)*
Attendance and preparation	12
Time on task/hard work	51
Constant revision	30
Interest	10
Note taking, drawing	5
Using specimens	9
Discussion with others	7
Good memory or memorising, rote learning	39
Visualising	29
Understanding	36

The relationship between memorising and understanding is best illustrated by the following comments from students:

> I learnt a lot at anatomy prac classes every week, especially if I had at least memorised the names of the structures we were learning.

> My memorising was put off till later (after) understanding was emphasised.

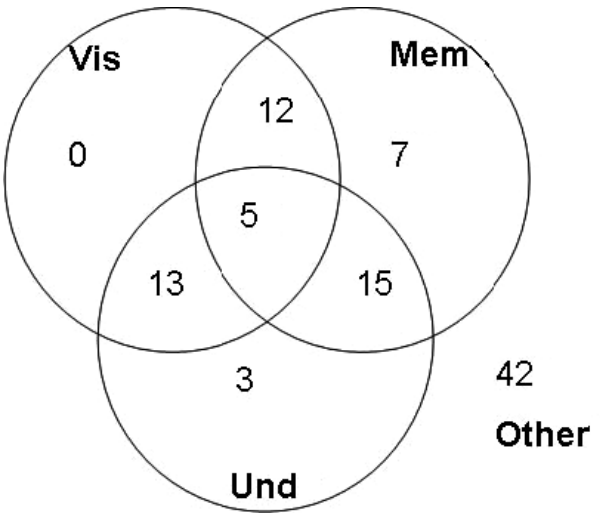

Figure 1 Diagram illustrating the range of approaches to studying anatomy, focusing on memorising (Mem), visualising (Vis) and understanding (Und).

> Understanding the material – this is the basis. But after you understand it, you then need to memorise all the details.

> Gain a basic understanding, learn the pictures in both the picture and photo atlas, then memorise essential terms.

There was a difference in emphasis by some students as well as differences in sequence, i.e. memorising before understanding, or understanding the overall picture before memorising details.

The calculated scores from students' responses to the SPQ showed that most students in this anatomy subject had both a range of SA scores and high DA scores (Table 2). For the majority of students (63%), their DA score was greater than their SA score and for around 10% of students their DA and SA scores were equal (Fig. 2). Memorisation strategies were reported by 44% of students with high SA scores, compared with 33% of students with high DA scores. Similarly, 44% of students with high DA scores reported the use of meaning-orientated approaches (e.g. combining information from multiple sources), while visualisation strategies were used reportedly by 25% of students with high SA scores, compared with 36% of students with high DA scores. Visualisation and understanding appear to be associated with deep approaches to learning anatomy.

Students' SA and DA scores were analysed in relation to their raw percentage marks in the subject and their final grade. The mean raw percentage for the theory examination was 74 ± 14%, and for the practical examination was 48 ± 5%. There was a small correlation between DA scores and raw percentage in the theory examination ($r = 0.241$, $P < 0.01$), but not with their raw percentage in the practical exam or final grade. There was also a significant negative correlation between SA scores and their raw percentage in the theory examination ($r = -0.300$, $P < 0.01$), in the practical examination ($r = -0.325$, $P < 0.01$) and their final grade ($r = -0.348$, $P < 0.01$) for the subject.

Table 2 Student approaches to learning (from SPQ)

	Mean subscore	*Total score*
Surface motivation	14 ± 2.1	
Surface strategy	16 ± 2.0	
Surface score (SA)		30 ± 3.4
Deep motivation	14 ± 2.6	
Deep strategy	17 ± 2.9	
Deep score (DA)		31 ± 4.2

Student answers to 4 short-answer theory examination questions were rated independently by 2 reviewers, according to the quality of their answers as described by SOLO (Table 3). Low (surface) level learning was demonstrated by 65 of the 97 students, while deeper learning was demonstrated by just 12 of the 97 students. There were 60/97 students who produced answers rated at SOLO level ≥ 4 on at least 2 questions and of these 60 students, 37 students had DA scores greater than their SA scores. Students with SA scores greater than their DA scores tended to have lower mean SOLO scores. There was a small significant correlation between SOLO score and DA score ($r = 0.248$, $P < 0.01$). However, there were significant strong correlations between mean SOLO score and final percentage in the theory examination in this subject ($r = 0.683$, $P < 0.01$), the final grade awarded for the subject ($r = 0.654$, $P < 0.01$) and a small significant correlation between mean SOLO score and the final percentage in the practical examination ($r = 0.264$, $P < 0.01$).

DISCUSSION

There are two main findings from this work. First, students showed a great reliance on both surface learning approaches and deep learning approaches when learning anatomy. Secondly, there was a positive relationship between students' approaches to learning and demonstrated quality of learning in anatomy.

Overall, the students' perceptions of what it takes to learn anatomy successfully and their approaches are generally consistent with the literature. It was not surprising to see that nearly half of students adopted memorising strategies as the key to learning anatomy, although this strategy was used most commonly in combination with understanding and visualisation. Ramsden[16] suggests that 'surface approaches [alone] never lead to understanding' and there are many examples of anatomists recalling anecdotes about the Herculean task of memorising names of anatomical structures and information for examinations. The factual load in medical courses is high, and the UK General Medical Council argues that 'undue emphasis on detail was [is] not required'.[28] A syllabus overloaded with content and assessment that promotes recall of factual knowledge will produce courses that promote surface learning strategies by students.[16,21] In such instances, students perceive academic success to come through surface rather

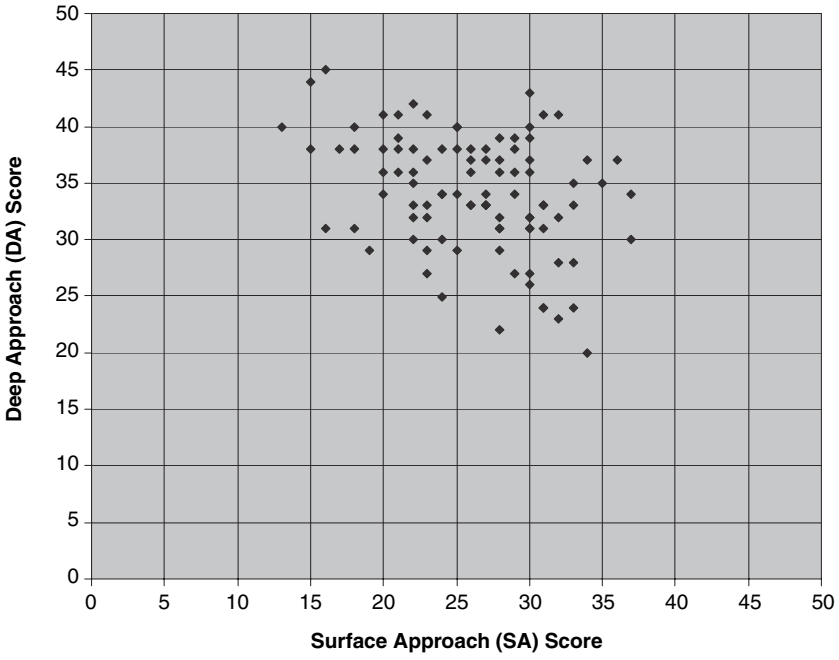

Figure 2 Plot of SA (surface scores) vs. DA (deep scores) for first-year students ($n = 97$) studying anatomy of the head and neck in first-year medicine.

Table 3 Quality of learning outcomes as mean SOLO ratings of student answers to the four examination questions and mean SA and DA scores for those students

SOLO level	*No. of students*	*Mean SA score*	*Mean DA score*
Pre-structural	13	31.5	29.5
Uni-structural	52	29.3	30.7
Multi-structural	20	30.5	30.9
Relational	11	29.0	30.5
Extended abstract	1	33.0	31.0

than deep approaches, so it is not surprising that students adopt surface learning strategies, such as memorising facts and lists, and using mnemonics to pass examinations. A group of anatomy teachers[14] also reports that students have an unhealthy focus on memorisation in learning anatomy at the expense of understanding, while the curriculum needs to focus on important concepts and better assessment strategies. Indeed, the key to changing perceptions (in favour of understanding) may be through curriculum innovation (e.g. peer teaching) and improved assessment practices that reward understanding and higher order cognitive skills.

Surface learning approaches and deep learning approaches are not mutually exclusive. They are best considered as hierarchical, as the 2 general approaches encompass a range of overlapping learning strategies. The important difference between the 2 approaches is intention – is memorising the last strategy for the under-prepared, or part of a 'process' of managing the volume of information necessary for understanding or examinations? While students perceive academic success to come from memorising or understanding, many students showed a reliance on both approaches rather than memorisation alone. This dual approach is supported by the illustrative student comments and research. Eizenberg[13] showed that students do indulge in multiple strategies involving memorising of facts, of pre-structured chunks of information (either from the text or their own notes) and developing a relational view of structure and function. Clearly, some students can memorise answers to past examination questions with no understanding at all, which becomes evident when the question is changed slightly. Others may use memorisation to cope with the complex language of anatomy as an endpoint, whereas others see it as part of a process of becoming familiar with the jargon so that they can progress onto learning.[18,29] Ferm and Lyons[28] believe that strategies need to be used to help students develop a useable vocabulary for articulating anatomical knowledge. For the students in this course, it appears that significant time was spent grasping terminology, generating and memorising mnemonics than was spent understanding the relationships between elements referred to in the mnemonic. Memorisation strategies can be part of an overall deep learning approach (whether they should be is another matter). Thus in the case of learning anatomy, students might read sections of their text and atlas to understand them, and then draw a diagram or write some notes, then commit their diagram or 'dot point'

summary to memory.[19,30] Surface learners never see the overall picture, and recall only the list of dot points rather than their related anatomical context. For deep learners using surface strategies, the mnemonic could form part of an information base from which they articulate their broader understanding about a particular structure, or to provide detailed information usually required in examinations. Analysis of assessment overall and of the students' explanations about how they learned anatomy using various resources may shed more light on the relationship between these strategies and the forces that drive them.

Visualisation, or spatial skill, was considered by one-third of students to be important in learning anatomy. It is uncertain exactly how our students used visualisation for learning anatomy. For the disengaged student, it could be simply memorising or copying an 'image';[19] for others it may be part of a deeper process of establishing relationships between structures, and between structure and function by drawing their own images *de novo*, although some students mentioned attempts to rotate images in their mind. There is little doubt that visual ability underpins the learning of anatomy[7] and practice of surgeons and radiologists,[12] but there are few empirical data to indicate how students develop their ability. Garg's study[7] of students using rotating 3-dimensional images on computer simulations demonstrated that, rather than using all rotational images of a 3-dimensional object, students tended to use a few key images as frames of reference. To answer questions, they would mentally rotate the image. It seems that using the key image and several close-by images allows learners to gain experience in predicting and projecting the effect of rotation, with immediate feedback, so that they can develop the ability to rotate the image mentally. This is not the only visual skill needed, however, as expert radiologists have a well developed capacity to transform visual images (e.g. plain films) into 3-dimensional representation.[12] Further research needs to help us to find how best to teach and facilitate the development of students' visual skills necessary for understanding anatomy.

This study confirms, for the first time in anatomy, that approaches to learning and the quality of resultant learning are related. Deeper approaches to learning correlated with higher quality learning in the course. Because students use both deep and surface approaches, it is the balance between them that is important. Memorising was a key strategy for nearly half of students in this course, although it was one of several strategies. Students with DA > SA scores had higher mean SOLO ratings of their written work, while those with SA > DA scores tended to have lower SOLO ratings. This project has focused on the knowledge base of anatomy as taught for medical courses, and ought to be examined in anatomy courses taught for disciplines.

Implications

There are two key messages from this research. We need to consider how best to teach anatomy and design curricula, so that students see clearly that understanding is the goal of our efforts and will be rewarded. There is evidence that problem-based learning curricula shifts students from reproductive surface approaches to deep approaches,[31] although there are concerns about medical graduates' knowledge of anatomy in PBL curricula.[32] Eizenberg[13] suggests that careful structuring of the curriculum to promote the development of conceptual frameworks should be a priority. The use of active learning strategies and peer learning[6] also appear to have potential for improving learning. Finally, Miller *et al.*[16] call for a refocusing on important concepts and better assessment strategies that require more understanding than memorisation. It would be interesting to compare student learning approaches and quality of learning in traditional and new medical curricula (e.g. in PBL or integrated clinical curricula, where there is no discipline of anatomy and integrated assessment) and in anatomy courses taught for science or other health science disciplines. Further research will provide a better evidence-base upon which to make decisions and to assess new developments in the field.

CONCLUSIONS

Students view successful learning of anatomy to require memorisation in combination with understanding and visualisation. Critical for learning is the appropriate balance between memorisation and these other strategies. In this group of students, many adopted both surface and deep approaches to learning. Deeper approaches were associated with quality learning of anatomy, while surface strategies were related negatively to assessment in the subject. We propose that deep learning of anatomy involves the development of a personal framework of understanding in which memorisation is used as a strategy for managing information and the accurate recall of detail.

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