



# The impacts of three-dimensional anatomical atlas on learning anatomy

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**Abstract:** Gross anatomy has traditionally been the foundation of medical education. Medical students have learned the structure of the human body through dissection, lecture, and textbooks. As tablets and three-dimensional (3D) applications are developed, 3D atlas applications are utilized in learning anatomy by medical students. The purpose of this research is to investigate the impacts of 3D atlas applications on students' understanding of gross anatomy. This research was targeted at medical students taking the Anatomy and Embryology class in 2017 and 2018, at Ewha Womans University. The correlation between use of 3D atlas and student's results on the Anatomy and Embryology test was analyzed. An open-book anatomy quiz was also carried out to analyze the correlation between the type of atlas each student refers to and the results of the quiz. Independent *t* test between groups did not show statistically significant difference in the results of the Anatomy and Embryology test. However, the group referring to 3D atlas showed significantly higher results on the simple questions of the open-book anatomy quiz ( $P < 0.05$ ). In conclusion, 3D atlas is not very helpful in acquiring deep anatomical knowledge or memorizing the location of anatomical structures, but it can simply aid in the rapid identification of anatomical structures. Additionally, the 3D atlas will show good synergy with the two-dimensional atlas if used properly in anatomy education, because most students think it is useful to use the 3D atlas.

**Key words:** 3D atlas, Application, Anatomy, Medical education, Learning

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## Introduction

Gross anatomy is considered as an important field of study in medical college. A majority of the residency programs report that gross anatomy is either extremely important or very important to mastery of their discipline and rank it as the most important basic science [1]. The ability to conceptualize and visualize the structure in three-dimensional (3D) space, which is developed in the gross anatomy curriculum, is also

important in the clinical setting when operating or performing invasive medical tests [2]. Traditional learning methods in gross anatomy are lecture-based learning, problem-based learning, and dissection [3, 4]. However, students who have low-spatial ability have difficulties in understanding the structures in 3D space and finding muscles, nerves, and organs during dissection.

As interactive multimedia and tablets are developed, 3D atlas applications are invented as new learning materials for the study of gross anatomy. 3D atlas applications are tablet-based software that enables medical students to touch and rotate virtual bodies and understand the spatial relationships. Nowadays, there are students who utilize 3D atlas applications as well as two-dimensional (2D) atlas apps, such as Netter's atlas of human anatomy and Grant's atlas of anatomy. There is the possibility of utilizing 3D atlas applications as effective learning materials for the study of gross anatomy.

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One study showed that 3D anatomy models were effective instructional multimedia material tools in teaching human anatomy [5]. But another study showed that a computer-based anatomy model has several disadvantages compared to traditional teaching [6]. According to the review which identified studies exploring 3D anatomy models and their impact on learning, there was no solid evidence that the use of 3D models is superior to traditional teaching, and more studies are needed to examine the impacts of 3D models on learning using valid and appropriate tools [7]. 3D models which were utilized in previous research were 3D computer-based, web-based, and physical models [7]. Majority of the 3D models were 3D computer-based models, but they were of a quite different modality from the 3D atlas applications and dealt with only specific parts of the body such as the ear [8], larynx [9], or liver [10]. In contrast, 3D atlas applications deal with entire body structures including muscles, nerves, vessels, and organs. As the application manuals are easy to understand and the contents specific, they can be helpful in the learning of gross anatomy. The aim of this research is to investigate the impacts of 3D atlas applications on the students' understanding of gross anatomy and the possibility of incorporating it into the gross anatomy curriculum. 3D atlas applications such as Complete Anatomy (3D4Medial.com), Human Anatomy Atlas (Visible body), and Essential Anatomy (3D4Medical.com) were utilized by medical students in the research.

## Materials and Methods

This research was carried out at Ewha Womans University School of Medicine. The target of this research was first-year medical students taking the Anatomy and Embryology I, II, and III courses in 2017 and 2018. The numbers of students were 77 students and 78 students each in year 2017 and 2018. All the students gave prior consent before joining the research.

Anatomy and Embryology I, II, and III consist of lectures and cadaveric dissection mainly on macroscopic anatomy. Students taking the courses were encouraged to study independently using any anatomy atlas of their preference to prepare for exam. Six exams including written tests and cadaveric tests were conducted to evaluate each student's understanding of human anatomy.

Interview questions posed to target students included which kind of anatomy atlas each student prefers during individual study, the reason for preference, how they utilize 3D

atlas, and their thoughts on the effectiveness of 3D atlas. The interview questions are shown in the Appendix 1.

First-year students in 2018 were also asked to participate in an extra open-book quiz on anatomy, on June 11, 2018, when most of the anatomy classes are over. Students were allowed to choose and refer to any atlas they were familiar with (between 2D and 3D atlas) during the quiz. Questions for the quiz were set by professor Jung-A Shin of the Department of Anatomy, Ewha Womans University School of Medicine. The questions consisted of nine simple questions, which could be solved by referring to a single page of an anatomy atlas, and six complex questions, which required reference to several pages of an anatomy atlas to be solved. Sample questions are shown in the Appendix 1.

An analysis of the correlation between use of 3D atlas and student's results on the Anatomy and Embryology I, II, and III tests was performed. How the type of atlas each student refers to affects the result of the open-book anatomy quiz was also analyzed. Statistical analysis of this research was performed by IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Statistical significance was defined as <5%.

## Results

Of the 155 students who joined the research, 120 students used 3D atlas for individual study (77.42%) and 35 students did not (22.58%). Sixty-seven students used Complete Anatomy (3d4Medical), 37 used Human Anatomy Atlas (Visible Body), and 19 used Essential Anatomy (3d4Medical). Some used more than one kind of 3D atlas. Reasons for not using 3D atlas were absence of electronic equipment for the 3D atlas (n=10), not finding it necessary (n=5), functional inconvenience (n=5), high costs (n=3), and others.

Among the 120 students who used 3D atlas, 99 students (82.5%) found 3D atlas to be easier to use than 2D atlas when searching for unfamiliar structures of the human body. Students who found 3D atlas to be more helpful than 2D atlas when understanding 3D structures of the human body were 108 (90%). Eighty-seven students (72.5%) answered that 3D atlas was convenient to use overall. However, only 51 students (42.5%) agreed that 3D atlas would be able to substitute 2D atlas entirely in next 10 years.

The 120 students who used 3D atlas were asked to choose the body parts they found useful studying about with 3D atlas. Multiple answers were allowed. As Table 1 shows, the most frequent answers were "the pelvis and perineum" (n=55),

followed by “the lower limb” (n=29), “the head” (n=29), and “the upper limb” (n=28) respectively.

The 120 students who used 3D atlas were also asked to choose the body systems they found useful studying about with 3D atlas. Multiple answers were allowed. The most frequent answer was “the muscular system” (n=76), respectively followed by “the circulatory system” (n=44) and “the nervous system” (n=43) as shown in Table 2.

The average difference in the results of the Anatomy and Embryology I, II, and III tests between the group that used 3D atlas and the group that did not was analyzed by indepen-

**Table 1.** Students' answer on which body parts 3D atlas was most useful while studying in (multiple responses allowed)

Body part	2017	2018	2017+2018
Back	3 (3.7)	3 (3.2)	6 (3.4)
Thorax	6 (7.3)	4 (4.3)	10 (5.7)
Abdomen	2 (2.4)	0 (0)	2 (1.1)
Pelvis and perineum	23 (28.0)	32 (34.0)	55 (31.2)
Upper limb	14 (17.1)	14 (14.9)	28 (15.9)
Lower limb	13 (15.9)	16 (17.0)	29 (16.5)
Neck	7 (8.5)	10 (10.7)	17 (9.7)
Head	14 (17.1)	15 (15.9)	29 (16.5)
Total	82 (100)	94 (100)	176 (100)

Values are presented as number (%). 3D, three-dimensional.

**Table 2.** Students' answer on which body systems 3D atlas was most useful while studying in (multiple responses allowed)

Body system	2017	2018	2017+2018
Skeletal	9 (11.3)	4 (3.6)	13 (6.8)
Joint	4 (5.0)	1 (0.9)	5 (2.6)
Muscular	34 (42.5)	42 (35.7)	76 (39.6)
Nervous	15 (18.8)	28 (25.0)	43 (22.4)
Circulatory	11 (13.8)	33 (29.5)	44 (22.9)
Digestive	3 (3.8)	1 (0.9)	4 (2.1)
Respiratory	0 (0)	0 (0)	0 (0)
Urinary	2 (2.5)	2 (1.8)	4 (2.1)
Reproductive	0 (0)	1 (0.9)	1 (0.5)
Endocrine	0 (0)	0 (0)	0 (0)
Integumentary	2 (2.5)	0 (0)	2 (1.0)
Total	80 (100)	112 (100)	192 (100)

Values are presented as number (%). 3D, three-dimensional.

**Table 3.** Statistics for results in embryology and anatomy tests

Results in test	No.	Mean±SD	SEM
Written test (3D atlas)	116	260.84±28.87	2.68
Written test (2D atlas)	34	262.35±32.52	5.58
Cadaveric test (3D atlas)	116	67.16±11.80	1.10
Cadaveric test (2D atlas)	34	70.67±13.01	2.23
Total (3D atlas)	116	328.0±37.71	3.50
Total (2D atlas)	34	333.02±42.43	7.28

SD, standard deviation; SEM, standard error of mean; 3D, three-dimensional; 2D, two-dimensional.

dent *t* test. Homogeneity was tested by Levene's test. Among the 155 students who joined the research, five did not provide their test results for the research. Therefore, 150 cases were analyzed. The group that used 3D atlas showed lower average results (by 5.018 points) than the group that did not. To be specific, the average result of the written tests was lower by 1.509 points and the average result of the cadaveric tests was lower by 3.510 points. However, the difference was not statistically significant (Tables 3, 4).

The average difference between the group that referred to 3D atlas and the group that referred to 2D atlas in the open-book human anatomy quiz was analyzed by independent *t* test. Homogeneity was tested by Levene's test. Seventy-six students participated in the quiz; 62 used 3D atlas and 14 used 2D atlas. The group that used 3D atlas showed higher average results (by 0.878) than the group that used 2D atlas. The difference was not statistically significant. However, the average result of the simple questions by the group that used 3D atlas was higher by 0.853 points, which is a statistically significant difference ( $P<0.05$ ) (Tables 5, 6).

**Table 4.** Comparison of 2D and 3D test results using independent *t* test

Test type	Mean difference	SEM	<i>t</i>	<i>P</i> -value
Written test	1.509	5.797	0.260	0.795
Cadaveric test	3.510	2.356	1.490	0.138
Total	5.018	7.569	0.663	0.508

2D, two-dimensional; 3D, three-dimensional; SEM, standard error of mean; *t*, *t*-statistics.

**Table 5.** Statistics for results in open-book human anatomy quiz

Results in quiz	No.	Mean±SD	SEM
Simple questions (3D atlas)	62	7.71±1.43	0.18
Simple questions (2D atlas)	14	6.86±0.95	0.25
Complex questions (3D atlas)	62	3.56±1.41	0.18
Complex questions (2D atlas)	14	3.57±1.34	0.36
Total (3D atlas)	62	11.31±2.42	0.31
Total (2D atlas)	14	10.43±1.95	0.52

SD, standard deviation; SEM, standard error of mean; 3D, three-dimensional; 2D, two-dimensional.

**Table 6.** Independent *t* test results comparing results in open-book human anatomy quiz

Question type	Mean difference	SEM	<i>t</i>	<i>P</i> -value
Simple questions	0.853	0.402	2.121	0.037
Complex questions	-0.007	0.414	-0.017	0.987
Total	0.878	0.694	1.266	0.210

SEM, standard error of mean; *t*, *t*-statistics.

## Discussion

Traditionally, anatomy is considered as the foundation of medicine [1] but many students find it difficult owing to the complex 3D anatomical structure and low-spatial ability, which have led to many studies in anatomy education [11, 12]. Along with the development of a variety of smart devices, 3D anatomy applications such as Complete Anatomy, Human anatomy atlas, and Essential Anatomy have appeared. Previous studies that investigated the impacts of 3D anatomical models on learning have mainly used 3D computer and mobile-based models, and there are only few reports on the impacts of 3D atlas on the learning of gross anatomy [7]. The purpose of this study was to investigate whether the use of 3D atlas improves academic achievement and to examine the influences of 3D atlas applications on future anatomy curricula.

In this study, researchers asked the first-year students in year 2017 and 2018 at a single medical school through questionnaires about their use of 3D atlas, frequency of use, reason for use, etc., and compared their grades on the anatomy test, which consisted of both written and practical tests.

The students who responded that they used 3D atlas constituted 77.42% of the total number of respondents. Most of the students who used the 3D atlas apps responded that it was helpful in understanding anatomical structures and convenient to use. However, only 42.5% of the students who used 3D atlas agreed that it would be able to substitute 2D atlas entirely in next 10 years. This result is consistent with the findings of Tam et al. (2009) [13] who have already reported that there is insufficient evidence to show that computer resources can truly replace traditional methods of teaching anatomy. The results indicate that students have a positive attitude towards 3D atlas, but it is hard for the 3D atlas apps to completely replace the 2D ones. Based on the above results, rather than using only 3D atlas, the appropriate use of the 3D atlas as an adjunct to the 2D will make it easier for students to approach anatomy.

The result of comparing and analyzing the grades on the anatomy test showed that the average value of the group that used the 3D atlas apps was lower than that of the group that did not in both the written and cadaveric tests. Nevertheless, the difference was not statistically significant. In addition, there was no significant relationship between the frequency of 3D atlas use and grade (data not shown). In the anatomy open book test conducted in the first year in 2018, the average result of the group that used 3D atlas was higher only in the

simple questions, and the result was statistically significant.

Our results did show that on the simple questions of the open book test, the mean score of the 3D atlas user group was significantly higher than that of the 2D atlas user group. From the results above, it can be concluded that 3D atlas can aid in the quick identification of anatomical structures, although it is not as powerful as 2D atlas in acquiring deep anatomical knowledge or memorizing the location of anatomical structures. In other words, it would be difficult for 3D atlas to completely replace 2D atlas in the next 10 years, though 3D atlas is thought to be of additional benefit in finding anatomical structures when there is a fundamental understanding of anatomy. Taking together the results of this article that 82.5% of the students thought the use of 3D atlas is easier to find unknown structures than 2D atlas, 90% of the students thought 3D atlas is more helpful when understanding the 3D structure of the human body than 2D atlas, and 72.5% of the students reported that 3D atlas was convenient to use overall, researchers can assume that 3D atlas will have a good synergy with 2D atlas if used properly in anatomy education. Besides, with the study by Murakami et al. (2014) [14] who found that using 3D models yielded strongly positive student perspectives and significant improvements in radiology skills in later clinical courses, it is thought that 3D atlas may be helpful for reading various radiological data by quickly matching anatomical structures in the medical field, especially when the use of magnetic resonance imaging and computed tomography is more important.

As highlighted in this study, the majority of students are positive about 3D atlas, and 3D atlas is more useful than 2D atlas for matching simple anatomical structures. In addition, as highlighted in the article by Lewis et al. (2014) [15], 3D atlas has a number of advantages such as portability and accessibility. Although these are merits, there are entry barriers to the additional use of 3D atlas in anatomy education. Students who did not use 3D atlas said that the reason for not using it was mainly the absence of a smart device, functional inconvenience, and the high price of software applications. If there is adequate guidance on how to use 3D atlas, the functional inconvenience will be easily resolved. What really matters are that the initial cost of purchasing anatomical applications and smart devices is so expensive that many students cannot afford to buy them. Therefore, in order that 3D atlas can be effectively used for anatomy training, these infrastructure problems must be resolved by affiliating schools with application or device providers and providing the needed devices to

students.

This study has the following limitations. First, students were not randomly assigned to the 3D atlas user group and the 2D atlas user group. The students who used 3D atlas were relatively more than those who used 2D atlas, and the study did not take into account the students' individual abilities. Second, it is assumed that students who used 3D atlas would have also used some 2D traditional books, considering the results of Lujan and DiCarlo (2006) [16] who found that first year medical students prefer multiple learning styles. Even if they did not actually use the book, most of the lecture notes are made up of drawings taken from the 2D atlas, so it is hard to say that students who used 3D atlas used it exclusively. Third, this study was conducted on two grades of a single school, so the number of research subjects is admittedly small, and the observation period is short. Therefore, further research needs to be carried out with a bigger and more randomized sample of participants.

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**Appendix 1.** Interview questions and sample questions.

## 1. Questions from interview on target students

1. Did you use 3D anatomy atlas program or application for macroscopic anatomy study?  
(1) Yes (2) No
  - 1-1. If you answered no, what is the reason for not using it?
  - 1-2. If you answered yes, which program did you mostly use for study?  
(1) Complete Anatomy (2) Human Anatomy Atlas (Visible Body)  
(3) Essential Anatomy (4) Others
2. Did you find 3D atlas to be easier to use than 2D atlas when searching for unfamiliar structure of human body?  
(1) Strongly agree (2) Somewhat agree (3) Neither agree nor disagree  
(4) Somewhat disagree (5) Strongly disagree
3. Did you find 3D atlas more helpful than 2D atlas when understanding 3D structure of human body?  
(1) Strongly agree (2) Somewhat agree (3) Neither agree nor disagree  
(4) Somewhat disagree (5) Strongly disagree
4. Did you find 3D atlas convenient to use overall?  
(1) Strongly agree (2) Somewhat agree (3) Neither agree nor disagree  
(4) Somewhat disagree (5) Strongly disagree
5. Do you expect 3D atlas to be able to substitute 2D atlas entirely in next 10 years?  
(1) Strongly agree (2) Somewhat agree (3) Neither agree nor disagree  
(4) Somewhat disagree (5) Strongly disagree
6. In which body parts 3D atlas was most useful while studying?  
(1) Back (2) Thorax (3) Abdomen (4) Pelvis and perineum  
(5) Upper limb (6) Lower limb (7) Neck (8) Head
7. In which body systems 3D atlas was most useful while studying?  
(1) Skeletal system (2) Joint system (3) Muscular system (4) Nervous system  
(5) Circulatory system (6) Digestive system (7) Respiratory system (8) Urinary system  
(9) Reproductive system (10) Endocrine system (11) Integumentary system

## 2. Sample questions from human anatomy open-book quiz

<Simple question>

Which of the following is insertion of brachialis?

- (1) Ulnar tuberosity (2) Radial tuberosity (3) Humeral tuberosity (4) Radial head

<Complex question>

Which of the following is wrong about lungs?

- (1) Rt. superior lobar bronchus is located anterior to Rt. pulmonary a.  
(2) Lt. main bronchus is located inferior to Lt. pulmonary a. at the hilum.  
(3) Groove for aortic arch can be seen from medial side of Lt. lung.  
(4) Rt. Bronchus is shorter and thicker than Lt. bronchus.