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Effects of Reading a Free Electronic Book on Regional Anatomy with Schematics and Mnemonics on Student Learning

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ABSTRACT

Background: To help medical students learn anatomy effectively in limited hours, a regional anatomy book enhancing students' memorization was developed.

Methods: Only anatomical terms essential for basic cadaver dissection are included along with schematic figures which enable memorization of complicated anatomical structures. Learning comics and comic strips that depict anatomy mnemonics and jokes were appended and sentences were written to be comfortably readable. The electronic book titled “Visually Memorable Regional Anatomy” has been distributed without payment or registration. With the help of 246 volunteer students from three Korean medical schools, the book's learning effects were evaluated.

Results: These students' book reading led to increase in their anatomy scores, including written examination scores and tag examination scores. It was an encouraging result that almost 20% of students spontaneously read the book no matter who presented their lecture or examination. A webpage version of the book was visited by thousands of users.

Conclusion: The book with unique features may suggest a new perspective in the field of anatomy learning. After having acquaintance with essential structures from reading the book, students are able to and willing to study more from other resources.

Keywords: Regional Anatomy; Education; Illustrated Books; Cartoons; Internet

INTRODUCTION

After the publication of the “Gray's Anatomy” in 1858,¹ most anatomy books are similar to each other for the following reasons: 1) Figures of anatomical structures have been copied with tiny modification between multiple books. 2) Once figures were drawn with computer graphics, characteristic drawing styles have disappeared even more. 3) Writings or tables are also copied between books since copyright policy for writing is indistinct. 4) Being afraid

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Author Contributions

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of criticism, anatomists have hardly tried bold simplification or ellipsis of lengthy anatomy contents. 5) Many anatomists followed expanded topics of anatomy education, such as clinical anatomy, which is advantageous but difficult for students learning anatomy for the first time.

While anatomy books have kept their past style, time spent for gross anatomy coursework is being reduced in medical schools around the world, owing to the application of numerous new curricula such as integrated lecture or flipped learning. Even with such reduced time, medical students still have to memorize enormous amounts of anatomical structures.^{2,3} If the burden of memorization is too much, medical students may lose interest in the subject of anatomy, causing lower academic performance.^{4,5} Moreover, excessive emphasis on anatomy memorization might result in insufficient emphasis on anatomy comprehension.⁶ Although conventional anatomy textbooks have been well established for decades,^{7,8} novel methodology should be developed to help medical students memorize anatomy efficiently in limited time.

In the case of a Korean medical school (School I) where the first author and corresponding author of this study are affiliated, gross anatomy class occupies only 4 weeks of teaching (50 hours for lecture, 50 and extra hours for cadaver dissection) (Table 1). To teach anatomy effectively in a short time, the authors of this study have produced lecture videos⁹ and digital learning tools.^{10,11} After investigating a book “Clinical Anatomy Made Ridiculously Simple” that breaks through the solemnity of existing anatomy textbooks,¹² the authors decided to produce another anatomy book with the following features.

First, regional anatomy was chosen when arranging chapters of the book to directly assist medical students to dissect cadavers. In the case of the other authors' publication, systemic anatomy was chosen, although the level of the book was for medical students.¹²

Second, the amount of anatomy information in the book was reduced. For novice students, conventional textbooks contain too much information to grasp in a short time period. It would be desirable that students obtain essential knowledge first and then compensate with various materials. The amount of information in the role model publication was adequate. However, its clinical information was too difficult for students.¹²

Third, the book was written with high readability. Simply reducing the amount of information is not enough for our purpose. A pocket anatomy book is like an anatomy dictionary without logically successive sentences.¹³ The anatomy book should be a storybook to help students read with more concentration.¹⁴

Table 1. Situations of teaching gross anatomy in three medical schools where the book is evaluated

Variables	School I	School II	School III
Survey year	2016, 2017, 2018	2016	2016
No. of participating students	136 ^a	46	64
Sex of participating students	92 males, 44 females	30 males, 16 females	36 males, 28 females
State of participating students	38 from undergraduate studies, 98 from premedical course	All from undergraduate studies	All from premedical course
No. of professors	1	3	3
No. of teaching assistants	1	0	4
Total lecture time, hr	50	40	60
Total dissection time, hr	50 + extra time	70	90
Duration of gross anatomy curriculum, week	4 ^b	10	32
No. of cadavers used per year	9	6	9
Chapters taught based on the book	All chapters	Upper limb chapter	Upper limb chapter

^a38 students in year 2016, 50 students in year 2017, and 48 students in year 2018; ^bNot along with other subjects.

Fourth, schematics of anatomical structures were drawn in an extremely simple style. Highly accurate and sophisticated pictures of conventional textbooks and digital learning materials are useful for locating detailed anatomical structures. However, for anatomy beginners, schematic drawings of the human body that can be sketched by hand are more advantageous.¹⁵ Although the previous publication contained schematics, they were insufficiently simplified for students.¹²

Fifth, mnemonics for anatomy were included in the book. Even if anatomy students can spontaneously develop various mnemonics, it is difficult to find suitable ones because they are not collected or organized. A book with well arranged mnemonics can facilitate students' memorization.

Sixth, anatomy humor was included. Such humor can relax students and keep them interested in the subject of anatomy. To deliver the humor, anatomy comics were embedded in proper places of the book.

Seventh, the book was distributed online free of charge. Along with propagation of Internet and smart phones, free online encyclopedias enable students to obtain anatomical information ubiquitously. It was hoped that the book could contribute like an online encyclopedia.¹⁶

The purpose of this study was to assess the effect of the presented electronic book on students' anatomy learning with regard to the memorization of anatomy knowledge and dissection. Moreover, this study determined whether students would read the book regardless of lecture or examination.

METHODS

Composition of chapters

The book was composed of eight region chapters: back, upper limb, neck, head, thorax, abdomen, pelvis and perineum, and lower limb.

Drawing

For three decades, the corresponding author had given a white/black board lecture without using a projector. By omitting detailed appearance of anatomical structures, he drew schematic figures on the board to effectively explain their morphology and functions. For instance, an arrow in the figure represents the origin and insertion of a muscle (**Fig. 1A**). For the book, 371 schematic figures from board lectures were digitized in black and white on Adobe Illustrator CC (Adobe Systems, Inc., San Jose, CA, USA) (**Fig. 1B**).

Among his work, 24 frames of anatomy learning comics were chosen to deliver anatomy knowledge in a relaxed atmosphere (**Fig. 2A**).¹⁷ Concurrently, 211 episodes of anatomy comic strips containing humorous, relevant jokes and helpful mnemonics were selected (**Fig. 2B**).^{18,19}

Writing

In addition to the mnemonics of comic strips, other mnemonics were devised or gathered from the reference book,¹² the Internet, other anatomists, and medical students to be included in the writing.

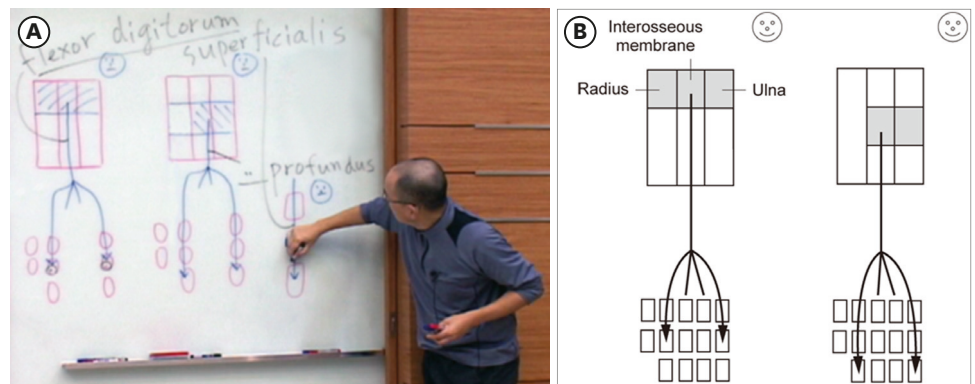


Fig. 1. Simplified anatomical structures. (A) Flexor digitorum muscles are drawn for a white board lecture. (B) The same figures are digitized for the book.

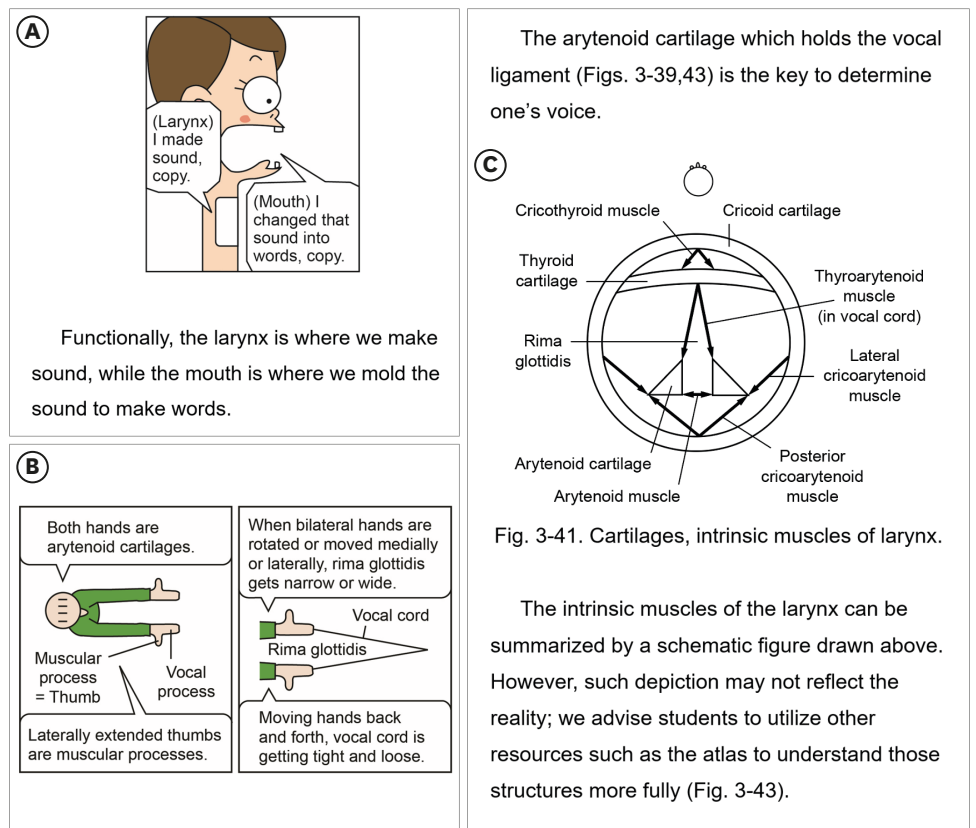


Fig. 2. A part of the book including specific illustrations. (A) Learning comics. (B) Comic strip. (C) Schematic drawing.

In Microsoft Word 2016 (Microsoft Corp., Redmond, WA, USA), the schematics and comics were arranged and texts were written to explain them (Fig. 2). In writing the text, the official anatomical terms were chosen.²⁰

In the book, the anatomical terms were decreased to a minimum as follows. Some structures not essential for understanding other structures (e.g., cutaneous nerves) were excluded. Some structures that are difficult to identify by routine cadaver dissection (e.g., liver segments) were not introduced. Clinical knowledge was seldom mentioned. The focus of

the book was anatomy itself and supportive embryology, not clinical anatomy. Complicated numbers were omitted. Occasionally, the exact information was appended in *Italic font*.

Distribution

The book was titled “Visually Memorable Regional Anatomy” to emphasize the aspect of its useful schematics and mnemonics. The document (DOCX) file was saved as a PDF file (27 MBytes). The PDF file's security properties were set to the minimum to allow readers to copy the figures and texts freely.

The electronic book was uploaded to the homepage,²¹ where all educational contents are available without charge or registration.²² Each chapter of the book, such as abdomen, was made into a separate web page. The authors also made the main web page where the separate web pages could be selected and the PDF file of whole chapters could be downloaded.

In December 2016, Flag Counter²³ was installed on the main web page and the separate web pages to count visitors from different nations. Besides, the number of times the PDF file was downloaded was also counted.

Google search may represent the popularity and usefulness of educational contents.²⁴ Thus, the authors also searched numerous anatomical terms on Google to determine if web pages of the book appeared.

Survey for evaluation

To assess the book's learning effects, students in three medical schools (I, II, III) in Korea were invited to volunteer. Situations of the three medical schools are summarized in **Table 1**.

At School I where the first author and the corresponding author work, white board lectures were presented for all chapters (**Fig. 1A**). The majority (80%) of written examination was a fill-in-the-blank quiz made from the book (**Fig. 3A and B**). The remainder (20%) of the written examination was a self-drawing quiz where students would draw and explain schematic figures of the book on blank sheets of paper (**Fig. 3C**). Additionally, tag

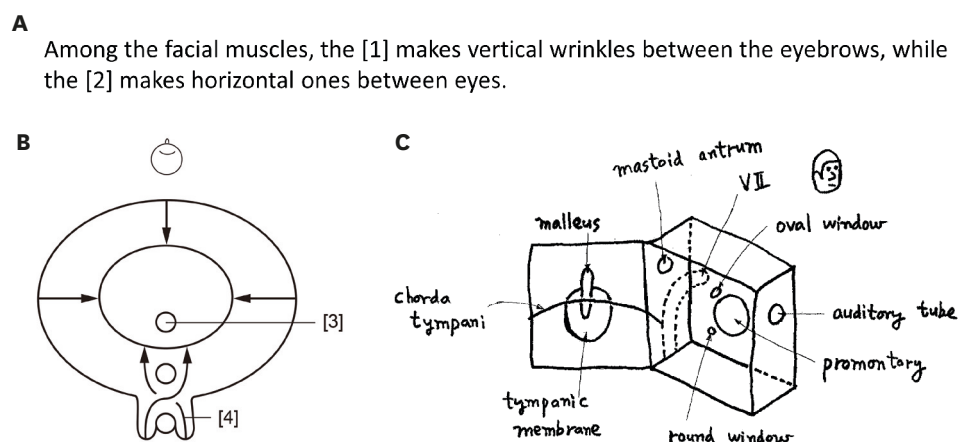


Fig. 3. Sample of the written examination. **(A)** Fill-in-the-blank quiz made from texts of the book. Correct answers are “corrugator supercilii” for [1] and “procerus” for [2]. **(B)** Fill-in-the-blank quiz made from illustrations of the book. Correct answers are “caval opening” for [3] and “left crus” for [4]. **(C)** Self-drawing quiz. The answer for “tympanic cavity” is drawn by the corresponding author.

examination was performed using dissected cadavers. Unlike the written examination, conventional tag examination had no direct relationship with the book.

At School I, 38 students, 50 students, and 48 students participated in the first year (2016), the second year (2017), and the third year (2018), respectively (**Table 1**). Results of examination in three years were standardized and combined in order to establish three dependent variables (scores for the fill-in-the-blank quiz, self-drawing quiz, and tag examination).

In the questionnaire survey, the students were asked to write their names on the paper, because individual students' scores should be obtained. The authors promised to absolutely keep participants' privacy.

After the course, the students in School I were asked to answer how many times they had read the book. The reading times and the scores of fill-in-the-blank quiz, self-drawing quiz, and tag examination were statistically analyzed by calculating the Pearson's correlation coefficient and *P* value. Statistical Package for the Social Sciences (SPSS), version 20 (IBM Corp., Armonk, NY, USA) was employed for all statistical analysis.

At Schools II and III, the corresponding author gave a one-day lecture on the upper limb chapter. The style of written examination on the chapter in Schools II and III was only a fill-in-the-blank quiz, like that in School I (**Fig. 3A and B**). After the course, 46 students from School II and 64 students from School III answered (**Table 1**) how many times they had read the book chapter (upper limb) taught by the corresponding author as well as other book chapters. These reading times and the scores of all examinations were analyzed in the same manner.

An objective of performing the survey in Schools II and III was to determine if the students utilized the book not only for the upper limb chapter, but also for other chapters. For this purpose, the lecture and introduction of the book were scheduled at the early part of the curriculum. Moreover, Schools II and III were regarded as a control group for School I where all chapters are taught with the book.

From all three schools, participants were asked to provide their positive and negative opinions on the book. Opinions gathered in Korean language were translated into English by the authors for this report. These opinions were then categorized into opinions about schematics, jokes and mnemonics, writing, understandability, and summarization.

Ethics statement

The whole procedure of this research was examined by the Institutional Review Board (IRB) of Ajou University School of Medicine. The IRB granted an exemption of deliberation (AJIRB-SBR-EXP-15-254).

RESULTS

Several signs indicated that the book was being actively distributed through the Internet. During three years, the number of views of the main web page was 10,863 excluding repeated IP addresses and 80,936 including repeated IP address. Most visitors were from Korea, followed by those from the United States and Great Britain (**Fig. 4A**). Among the separate web pages, the thorax chapter was visited the most often, followed by the pelvis and

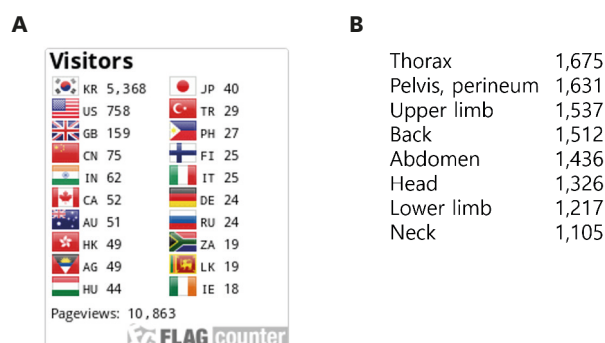


Fig. 4. The numbers of visitors to the web page from December 2016 to December 2019 that was recognized by the Flag Counter. **(A)** Visitors from multiple nations to the book's main web page where the PDF file and separate web pages for each chapter can be accessed. **(B)** Visitors to the separate web pages for each chapter of the book.

perineum chapter, upper limb chapter, and back chapter (**Fig. 4B**). During the same period, the electronic book (PDF file) was downloaded 2,105 times. When anatomical terminology was searched on Google, the web page of the book was sometimes introduced.

Regarding results of the questionnaire survey conducted in the three schools, there were no differences in results according to students' sex or whether they were conducting undergraduate studies or attending premedical course (**Table 1**).

A lot of students read the book for their anatomy learning. Proportions of students who read the book at least once were as follows. In School I, 91.9% students read all chapters. In Schools II and III, 84.8% and 68.8% students, respectively, read the chapter taught by the corresponding author. In Schools II and III, 19.6% and 15.6% students, respectively, also read other chapters of the book, although lectures or examinations were not made from this book (**Table 2**).

The number of times students had read the book (less than once, once, twice, three times, more than three times) and their scores were analyzed. In School I, the reading times were correlated with the scores of the fill-in-the-blank quiz (**Fig. 3A and B**) (Pearson's correlation coefficient, 0.429), scores of self-drawing quiz (**Fig. 3C**) (Pearson's correlation coefficient, 0.338), scores of tag examination (Pearson's correlation coefficient, 0.402), and total anatomy scores (Pearson's correlation coefficient, 0.464) (**Table 3**).

Table 2. Proportions of students who read the book at least once

Variables	Chapter(s) taught by authors	Other chapters
School I (136 students)	91.9% (125 students)	NA
School II (46 students)	84.8% (39 students)	19.6% (9 students)
School III (64 students)	68.8% (44 students)	15.6% (10 students)

NA, not applicable.

Table 3. Pearson's correlation coefficients for the number of times students had read the book and examination scores

Variables	Fill-in-the-blank quiz	Self-drawing quiz	Tag examination	Total scores
School I (136 students)	0.429**	0.338**	0.402**	0.464**
School II (46 students)	0.360*			0.327*
School III (64 students)	0.266*			0.113

* $P < 0.05$; ** $P < 0.01$.

Table 4. Narrative remarks from students who read the book

Themes	Strong points of the book	Weak points of the book
A. Schematics	The stereoscopic structures are well expressed in the schematics that can be painted by hand (71).	The two-dimensional figures are too simple for students to get the real morphology (65).
B. Jokes and mnemonics	Intermittent jokes relieve the boredom (62). Mnemonics assist in memorizing the anatomical terms (50).	The humor and mnemonics interrupt the smooth reading; they are often old-fashioned (61).
C. Writing	The English is logical and can be read with ease (8).	The story-telling style of writing rather than the classical style confuses students (42).
D. Understandability	One principle is applied to the different structures (13). The relevant embryology makes the anatomy understandable (9).	
E. Summarization		There is no table to summarize the complex contents (6). There is no paragraph to summarize each chapter or subsection (4).

(Repeated number of opinions among 246 students).

In School II and School III, the reading times were also correlated with scores of the fill-in-the-blank quiz on the chapter taught by the corresponding author (Pearson's correlation coefficient, 0.360 and 0.266, respectively). The reading times were correlated with the total anatomy scores in School II (Pearson's correlation coefficient 0.327), while not in School III (Pearson's correlation coefficient, 0.113) (**Table 3**).

Their narrative remarks showed that characteristics of the book had both strong and weak points (**Table 4**).

DISCUSSION

In this study, an unusual regional anatomy book was elaborated and its educational effect was estimated. This book's possible contribution to anatomy learning is as follows.

First, this book is approachable. The fact that it is free is good for students who are under financial constraints, especially for those in underdeveloped countries.^{21,22} Additionally, because electronic release of the book does not pass through a publishing company, its annual upgrade is very convenient.

The book's web pages can be easily viewed on a typical Internet browser using personal computers or smart phones. Therefore, these web pages can be utilized even in anatomy classrooms or dissection rooms.^{21,22} In the future, the contents of the book can be converted into a smart phone application.

The downloaded PDF file of the book can be opened with free Adobe Acrobat Reader (Adobe Systems) which allows the figures and texts to be browsed in real time regardless of network condition. Moreover, anatomical terms that the reader is interested in can be searched on Adobe Acrobat Reader. This is more convenient than the typical style index of printed books. In addition, students can print the PDF file and bind it to make a paper book (232 pages) if they prefer.

Second, this book has been voluntarily chosen. The main web page of the book has been continuously visited by many people from various countries. Korean visitors are the most dominant in number because the book is well known in Korea so far (**Fig. 4A**). The number of visits for separate web pages did not differ significantly according to chapters (**Fig. 4B**). These separate web pages are recommended by Internet search sites such as Google. Thus, new users around the world are expected to have access to these web pages. The fact that the number of page

views including repeated IP addresses (80,936) is about 7 times larger than that excluding repeated IP addresses (10,863) means that first-time visitors tend to repeatedly visit the web pages.

The PDF file of the book has been downloaded more than 2,000 times. The PDF file might be possessed by more students than the download number because it can be copied and distributed without any restriction.

Concerning the questionnaire survey, as expected, more than two-thirds of students (68.8%–91.9%) read the book to prepare for the written examination made from the book (Fig. 3). It was encouraging that 15.6% to 19.6% of students spontaneously read chapters of the book that were not related to a lecture or examination (Table 2).

Third, this book is reader-friendly. Components of the anatomy book correspond to those of the white board lecture. The schematics are like a teacher's drawing on the board (Fig. 1), the text is like a teacher's explanation during the lecture, and the comics are like a teacher's memorizing tips and jokes (Fig. 2).

The average sentence length is only 15 words, and sentence length is known to be a predictor of readability.²⁵ Moreover, comfortably readable sentences are written without difficult vocabulary. However, colloquial writings were not welcomed by some students (Table 4, C), which was an unexpected result.

Comics are included in the book to relax students who are busy acquiring anatomy knowledge (Fig. 2A and B) (Table 4, B). A positive effect of the comics was found. Students may laugh at comical situations only after they acquire anatomy knowledge. They then can recognize how anatomy enriches them.^{17,19} Since comics, schematics, and writings were made by the same authors, they corresponded to each other well, making readers comfortable.

Unexpectedly, humorous comic strips were not always preferred by students (Table 4, B). It might be because Korean medical students are too familiar with decent learning to accept humor. Regardless whether the response was positive or negative, comics as a concise and symbolized form of art have been suggested to be utilized in learning anatomy.²⁶⁻³³ Beyond anatomy class, comics could be a potential teaching material for creative medical students.³⁴⁻³⁶

Fourth, the book is helpful for memorizing anatomy. Both comic strips and writings include lots of mnemonics so that students can select their favorites among them, like shopping.^{37,38} In addition, principles applicable to different structures are emphasized (e.g., teres major is inferior to teres minor, just as zygomaticus major is inferior to zygomaticus minor); the supportive embryology is introduced (e.g., dorsal is sometimes different from posterior because of the head fold). These efforts were generally approved by the students (Table 4, B and D).

Reading times were found to be correlated with scores of the fill-in-the-blank quiz (Fig. 3A, B, and Table 3). A definite way to make students read the book is to present a fill-in-the-blank quiz from the book.

Reading times were also found to be correlated with scores of the self-drawing quiz (Fig. 3C and Table 3). A strong point of this book is that the schematics, composed of simple lines in black and white, can be easily replicated by students (Figs. 1B, 2C and 3B). It is well known

that self-drawing highly affects memorization.^{39,40} The students agreed with the usefulness of the figures (**Table 4, A**).

It was a favorable result that the reading times were correlated with scores of tag examination (**Table 3**). This implies the schematics in the book may contribute to cadaver practice. After being acquainted with simple drawing, students can easily figure out the realistic drawings of anatomy atlas and dissected cadaver.^{41,42} It is like a rough map to orient first-time visitors to a destination.

When students took an examination beyond the book, the reading times were correlated with scores in School II, but not in School III (**Table 3**). This result might be due to various situations of schools. In case of this study, the examination in School II kept a style similar to that in School I, but that in School III was different from that in School I.

Fifth, this book not only fits the conventional anatomy curriculum, but also fits the integrated curriculum where students do not have enough time to read lengthy existing anatomy books.⁴³⁻⁴⁵ This book enables students to obtain concise anatomy knowledge in limited time and prepare for debate in class.⁴⁶

Moreover, after students learn clinical medicine, clinical information (e.g., surgical procedures) can be added to the simplified figures of the book for summarization. Students can also create their own schematics and even comics with anatomy and medical knowledge to preserve and distribute their understanding.

Sixth, the book can be compensated by other learning materials. This book involves simple illustrations drawn by amateur artists (**Figs. 1B, 2C and 3B**). These simple schematics are praised and criticized at the same time (**Table 4, A**). These illustrations must be compensated by gorgeous ones drawn by professionals. Digital learning tools including online atlas and videos that are frequently utilized by students these days can compensate these simple illustrations of the book.^{47,48} For the same purpose, the authors also provide Visible Korean products including sectioned images of cadaver and stereoscopic models even for three-dimensional printing.^{10,11,49,50}

Not only the schematics, but also the writings, need to be compensated. This book does not include lots of anatomical information. It is like the corresponding author's white board lecture which cannot deliver much information (**Fig. 1A**). Students' minor complaint was that there was no summarizing table or paragraph (**Table 4, E**). It is suggested that students obtain such summarizing contents from another existing book or online encyclopedia,¹⁶ or make ones by themselves.

Students can read this concise and amusing anatomy book and complement their knowledge with a conventional anatomy book and cadaver dissection. This is like watching interesting historical dramas and then enhancing one's knowledge with a detailed history book and field trip. Making novice medical students lose their interest in anatomy with a complicated anatomy book is like making children lose their interest in history with a complicated history book.

The evaluation of this study has several limitations. A control group containing students who did not read the book at all or students who read another book was absent. Moreover, the survey was not performed at schools where the corresponding author did not give a lecture.

In conclusion, the presented book containing schematics and mnemonics could be a paradigm shifting material to help students softly start regional anatomy. Simultaneously, this book could be a motivation so that other anatomists can devise their unique anatomy figures and writings, similar to the case that a previous publication¹² inspired the authors to prepare this book. This regional anatomy book will be succeeded by complimentary or commercial books on systemic anatomy, neuroanatomy, and histology, written by the first and corresponding authors.

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