Zygote Body: A New Interactive 3-Dimensional Didactical Tool for Teaching Anatomy

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Abstract

Introduction: As medical education has progressed exponentially over the past decades, there are unanimous concerns regarding the decline in students' knowledge of anatomy. Teaching anatomy is becoming increasingly challenging as students are becoming more technology-dependent and have to gain an understanding of complex anatomical structures in a relatively short time. Zygote Body® is a novel interface with potential to facilitate learning of human anatomy. This study investigates its relevancy and appropriateness for use in anatomy education for medical students.

Methods: After integration of the web-based application, questionnaires were used to gain feedback from first year medical students (n=73).

Results: Data analysis revealed significant improvements in student’s comprehension as well as their excitement for such innovations.

Discussion: The software succeeds at engaging students and suggests that their comprehension of complex 3D structures was improved. However, because of its limitations, this web-based tool cannot be used as a definite tool for learning anatomy. Although multimedia may compliment the learning process, nothing can substitute living anatomy in a safe environment before handling patients.

Introduction

Anatomy education: Time for creativity and innovations

Because of the progressive evolution of student populations, medical curricula and university teaching mission, teaching anatomy is becoming increasingly challenging [1]. New medical students also face challenges in gaining an understanding of the three-dimensional shapes of anatomical components and the interconnections between them [2]. Functional anatomy is traditionally learned by reading books and by studying anatomical models, but because of the dynamic nature of movement, many concepts of functional anatomy are not well portrayed in standard textbooks and figures [3]. This is why conventional anatomy education based on dissection has some shortcomings. Also, the quality of dissection and learning outcomes may depend on individual factors such as prior knowledge, cognitive factors, visuospatial ability, motivation, and emotional concerns. Secondly, many students encounter poor quality material and sometimes non-preservation of essential structures because of limitations in the number of cadavers, the number of teachers, time spent on dissection, and self-instruction time [4, 5]. Anatomy educators are expected to teach more students and more content as the practice of medicine requires an increasingly large, enriched, integrated, and applied knowledge base [6] with fewer resources as budgets are cut and anatomy contact hours are reduced. Undergraduate anatomy educators are confronted with low student achievement and retention rates, an academically diverse cohort of students, and the preparation of students for admission into a vast array of competitive health science programs [7]. It is now more important than ever to make anatomical instruction increasingly maximized, efficient, and lifelong.

In hopes of coping with modern practice, the conventional pedagogy of dissection is in the process of being revolutionized and enhanced if not replaced by more innovative modalities [8]. Many institutions have officially deemed conventional cadaveric dissection obsolete in lieu of model substitutes and technology [9, 10].

Innovative, multimodal approach in teaching anatomy

Multimodal methods to teach anatomy have gradually become the most popular options among the majority of medical institutions [11]. Regardless, dissection still seems to be the favorite method of teaching as well as providing optimal examples of pathology by students and teachers alike [12-14].

Computer-aided techniques have been proposed for teaching anatomy, including: hypertext access to a large collection of data; cross-sectional imaging; animated 3D computer models; interactive self-assessment; and multimedia database systems [2].

Many research studies have compared the effectiveness of computer-assisted instruction for medical students with traditional lecture and/or textbook. Test scores repeatedly show that users perform equally well, and sometimes slightly better, if
they have used computer-assisted instruction rather than attended a lecture or viewed print materials [15, 16].

**Zygote Body**: Interactive multimedia learning resource for medical education

Recently, we have decided to implement some modern technologies in the anatomy course at the Medical Faculty at the University of Maribor (MF UM). While considering various commercial options, the release of Zygote Body® was officially announced as Beta version in December 2010 and was upgraded at the end of March 2011.

Zygote Body® is a website (zygotebody.com) that allows users to navigate through a 3D anatomical model of the human body. It uses WebGL technology, based on Open Graphics Library for Embedded Systems (OpenGL ES) 2.0, which provides a programmatic interface for 3D graphics. The technology uses the Hypertext Markup Language 5 (HTML5) canvas element and is accessed using Document Object Model interfaces. WebGL is a context of the canvas HTML element that provides a 3D graphics Application Programming Interface (API) implemented in a web browser without the use of plug-ins. ([http://www.khronos.org/webgl/](http://www.khronos.org/webgl/)).

Zygote Body® as a learning tool falls into the category of “Open Educational Resources” (OER) as has been introduced and promoted in the context of UNESCO’s aim to provide free access to educational resources on a global scale. The term was first adopted by UNESCO in 2002 to refer to “the open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes”. [17]

Open source and open standards are defined as the basis of the “Open educational resource movement” that has been forming on a global level over the last decade [18]. We perceive Zygote Body® to be an important and valuable contribution to the idea of the OER.

Clearly open content itself (though a high-quality one personalized for the end user) is not enough for effective learning. Before addressing useful open content, tools and licenses, one must consider the pedagogical-didactical approaches in which these resources can make a difference, i.e. by being used in innovative forms of teaching and learning.[19]

From the didactical point of view, the main principles of the Zygote Body® as a learning tool are the principles of the “Constructivist school of learning”. Constructivists see learners as active rather than passive. Knowledge is not received from the outside or from someone else, but rather, the individual learner interprets and processes what is received, through the senses, to create knowledge. The learner is the center of the learning, with the instructor playing an advising and facilitating role. Learning is consequently moving away from one-way instruction towards construction and discovery of knowledge [20]. Zygote Body® as a learning tool has the following attributes of the Constructivist’s school views on Online learning:

- Learning with Zygote Body® is a proactive process for the learner. He has no other option but to navigate and explore on his own.
- The learner constructs his own knowledge rather than accepting knowledge produced by the instructor (knowledge construction in Zygote Body® on the other hand is not (yet) facilitated by good interactive online instruction).
- The learner is in control of the learning process. He autonomously decides on the learning pace and direction.

**Methods**

After the release of Zygote Body® in January 2012, we decided to evaluate its potential relevance in teaching anatomy at MF UM. We wanted to confront students who recently passed the exam in osteology and muscle attachments with simulation of complex 3D structures and spatial relations before working with cadavers. We use a state-of-art desktop computer and an LCD-projector, both located in the dissecting room, allowing us to use Zygote Body® at the same time as we work with cadavers. After using Zygote Body® for 3 months, an upgraded version with some additional features was released.

At MF UM, students must learn the entire anatomy along with histology and embryology in only two semesters. They attend traditional anatomy lectures along with histology and embryology in only two semesters. They attend traditional anatomy lectures followed by a practical course in the dissection room. Before working with cadavers, we again briefly repeat the theoretical frame relevant for practical education. Working in groups of about 15 students, we try to use Zygote Body® to achieve better understanding of some complicated anatomical structures and their relation to each other in order to visually prepare students for the dissection work. Working in this way allows educators to examine student’s knowledge as well as providing students with the ability to repeat previously learned subjects and gain relevant self-feedback.

First, we tested Zygote Body® in presenting the axillar, scapular and deltoid regions as well as all the upper limbs. We wanted to present anatomical walls of axillary fossa as well as its content. In the deltoid...
region, we wanted to show anatomical structures according to layers. In the upper limb, we wanted to show the muscles, nerves and arteries.

**Participants and data collection**

After using Zygote Body® for more than 3 months and experiencing its first and upgraded version, we used questionnaires to gather information from the students about their rating of the tool, acceptance, motivational and educational role. A set of six questions to be answered on a 5-level scale ranging from “Agree completely” to “Completely disagree” was used. Additional questions offered more options for students to provide their opinions about the best relevancy of the tool according to anatomical systems and relations between them.

The main focus of the trial was a group of first year medical students enrolled in the anatomy course. After we handed out 81 questionnaires, 73 of them were completed and returned. These were the subject of statistical analysis. Table 1 shows classification of anatomical systems, offered as optional answers.

**Results**

Students accepted the virtual human model with enthusiasm. Their initial reaction was encouraging for the educators. It turned out to have a relevant motivational role as it meant something new for students in the educational process as well as providing a better visual, which gave the educators very positive feedback. Another sign of the student’s acceptance of the “learning tool” was that they were also interested in trying it at home (Figure 2). 90% of students use Zygote Body at least occasionally when studying anatomy at home, while more than 30% use it on a regular basis. The number could be even higher if it weren’t for the fact that it takes some effort to make the web-based application to work at home and all students are not capable of managing this themselves. However, we find this an important component of learning anatomy as it provides self-motivation for students to study during their free time.

The majority of students liked the lectures better after the implementation of Zygote Body®. This is due to the motivational role as mentioned above and better comprehension of complex anatomical structures and their relations (Figure 2, Table 2). 88% of students are certain to have better understanding of anatomy (Figure 2) and graded this effect of Zygote Body® in learning anatomy at an average of 4.1 (Table 2). However, the situation is not the same when comparing the use of Zygote Body® with working with cadavers. These offer more realistic insight into the human body and provide a stronger psychological effect. Only 18% of students prefer to use Zygote Body® over working with cadavers.

Zygote Body® is most efficient when learning about muscles and relations between anatomical structures according to the students’ opinions (Figure 3). Muscles are the most superficial structures, being just under the skin, which is why their form, origin and insertion are well understood. With an option to select and isolate a single muscle, Zygote Body® provides a nice feature for better visualization of the muscle course. Bones, on the other hand, are also well modeled, but contain too small an amount of anatomical information that students have to learn. Inner organs are well presented, especially due to the function allowing the user to remove individual structures. This allows users to observe relations between anatomical structures, which represents the second most effective function according to the students’ opinions (Figure 3). However, there are some concerns about Zygote Body® being a definite tool for learning anatomy, even since the release of the upgraded version. In Table 3, we evaluate the features of Zygote Body® according to the list of features described by Temkin et al. [21], in which one can see that only the basic features are enabled, whereas the more sophisticated ones are not. Moreover, there are some other issues with the tool primarily noticed by educators while presenting anatomical structures to students as well as by some students expressing their opinion in the survey.

Firstly, educators had major problems while presenting peripheral lateral parts of the body, such as the whole upper limb distal to elbow. This occurred because of the inability to rotate the human model in all dimensions. What happens, for example, while zooming into the palmar vasculature, is that one cannot center it on the screen. The model can be rotated only on its sagittal axis and moved frontwards up and down and not also left and right. By zooming in, lateral body parts move to the edge of the screen. By rotating the model on its sagittal axis, these can be centered on the screen, but they are also rotated along with the whole human model. The lack of the option to move the zoomed-in model left and right disables the observer to see the frontal layer of the anatomical structures, for example, the superficial and deep palmar arterial arch as well as all other structures of the arm. The only option to rotate the model in all directions is to select an individual structure, which is insufficient for overall comprehension.

Another impractical issue arises from a good feature with which the user can pinpoint and highlight selected
structures to visualize them separately from others, while it remains impossible to remove the name tags (Figure 4a). These are annoying, especially when there are lots of structures selected, as they are always in front of the anatomical model no matter what user does to navigate away from them. There is, however, another way to present all relevant structures by deleting one structure at a time (Figure 4b). This method is more inconvenient and time consuming for educators during anatomy courses, but is more efficient.

Structure selection, however, is critical in many ways. First, multiple-structure selection is not optional. This means that when the user wants to have a look at the mouth cavity, for example, he has to delete the outside structures individually, structure by structure (e.g. teeth), which is again time consuming. We miss the option of grouped anatomical structures, which would facilitate the selection process. Second, while individual structure deletion (hiding) is enabled, the user cannot reverse this action in the same way, as the command automatically un-hides all previously hidden structures at once. This means that by making a mistake or accidently clicking a neighboring structure, the user has to start all over again, hiding structure by structure. Finally, there is a problem with identifying anatomical structures (especially bigger or longer ones) while looking at an area at a high zoom level. By clicking on the desired anatomical part, the screen moves towards the center of the selected part and moves the area of interest away and thus distracts the user.

However, Zygote Body® has the potential to become more valuable as an educational tool for anatomy students. This is true not only because it may be used for the anatomy course to better visualize some anatomical structures, but because it has a great benefit as a free tool that students can launch at home.

Discussions and Conclusion

The website is easy to operate and, with an intuitive user interface, even inexperienced computer users can make good use of the program [2]. This is why educators had no problems handling the virtual human 3D model, rotating it in different directions and finding the relevant anatomical structures. Educators all appreciated the “tool”, as they were able to show what they wanted while attracting the students’ focus towards the important structures.

According to the previously mentioned point of view (Constructivist’s school of online learning – reference:22), Zygote Body®, in its future development, has the potential to enhance the overall learning experience in the following ways:

* When browsing specific details, learners can be directed to research on the Internet or link to online information and libraries to acquire further information (reading textual materials, listening to audio materials, and viewing additional visuals or video materials).
* Appropriate application exercises could be embedded throughout the online lesson to establish the relevance of the materials.
* Activities with feedback and assessment tools should be included to allow learners to monitor how they are performing.
* Clear learning paths and scenarios could be defined.
* Opportunities could be provided for learners to transfer what they learned to real-life applications, so that they can be creative and go beyond what was presented in the online lesson.
* Intelligent support with suggestions for individualized paths for specific learning goals.

But in order to achieve these enhancements, Zygote Body® would have to implement additional control features for educators that are common in modern e-learning environments (use of assessment, group work tools, application of employing learning paths with outcomes, etc.).

However, although multimedia may compliment the learning process, nothing can substitute the practical experience gained within peer-groups [23] along with familiarizing oneself with living anatomy in a safe environment before handling patients. However, use of advanced computer graphics has been shown to provide substantial improvements for medical teaching in general [24, 25]. Students who access web-based computer-aided instruction resources score significantly higher on examinations than those who never access the online content [8].

Yet, the trial we performed has some limitations. First, we did not perform such a survey before the implementation of Zygote Body®, therefore the definite interpretation of results is limited. Also, the fact that Zygote recently released an updated version of Zygote Body® with some of the disadvantages we found here having been eliminated could be another reason for limited results, but it is in our opinion of minor importance and does not influence the results.

As medical education has progressed exponentially over the past decades, there are unanimous concerns regarding the decline in students’ knowledge of anatomy, as discussed [26]. It is vital to tackle this
problem head on; otherwise, the deconstruction of anatomy education and undermining of crucial knowledge and skills gained from the course will inevitably lead to under-qualified educators for future generations [27] as well as unsafe and incompetent doctors.

The future of the anatomical sciences in medical school curricula is currently being shaped. It is crucial that we think outside the boundaries of traditional educational modalities and be creative [28]. This is the reason for implementation of such and further learning tools in our curriculum at MF UM.

References

Illustrations

Illustration 1

Figure 1

Figure 1: Zygote Body® screenshots
Illustration 2

Table

Table 1: Classification of anatomical systems, offered as optional answers when grading relevancy and appropriateness of Zygote Body® in learning anatomy.

<table>
<thead>
<tr>
<th>Anatomical systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bones</td>
</tr>
<tr>
<td>Muscles</td>
</tr>
<tr>
<td>Internal organs</td>
</tr>
<tr>
<td>Cardiovascular</td>
</tr>
<tr>
<td>Peripheral nervous system</td>
</tr>
<tr>
<td>Central nervous system</td>
</tr>
<tr>
<td>Relations between organs</td>
</tr>
<tr>
<td>Anatomical spaces</td>
</tr>
</tbody>
</table>
Figure 2: Questionnaire answers of medical students (n=73). The standard 1 – 5 scale is not asking about an agreement in the fourth question but the frequency: 1 = never; 2 = sometimes; 3 = occasionally; 4 = often; 5 = always. An average grade students gave to each question is presented on the right.
Illustration 4

Figure 3

Which anatomical structures can be best seen with Zygote Body®?

Figure 3: Questionnaire answers of medical students showing how students \( n = 73 \) graded individual anatomical structures or their relations according to relevancy in Zygote Body® (in %). Students were allowed to select more than one answer. CVS = Cardiovascular system; CNS = Central Nervous System; PNS = Peripheral Nervous System; Relations = relations between anatomical structures; Anat. spaces = Anatomical spaces.
Illustration 5

Table

Table 2: List of features enabled in Zygote Body® according to Temkin et al.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomical information</td>
<td>Yes</td>
</tr>
<tr>
<td>Searching/locating structures</td>
<td>Yes</td>
</tr>
<tr>
<td>Slice navigation</td>
<td>No</td>
</tr>
<tr>
<td>Add/remove structures</td>
<td>Yes</td>
</tr>
<tr>
<td>Structure highlighting</td>
<td>Yes</td>
</tr>
<tr>
<td>Structure labeling</td>
<td>Yes</td>
</tr>
<tr>
<td>Anatomical animation generation</td>
<td>No</td>
</tr>
<tr>
<td>Saving/retrieving previous work</td>
<td>Partially</td>
</tr>
<tr>
<td>Haptic capabilities</td>
<td>No</td>
</tr>
<tr>
<td>Evaluation of tests taken</td>
<td>No</td>
</tr>
</tbody>
</table>
Illustration 6

Figure 4

Figure 4: Zygote body offers selection, pinning and deletion of anatomical structures. In this way, the user can present important anatomical spaces and structural relations. (a) Ischiadical foramina shown using pinning function; (b) ischiadical foramina shown using deleting function.
## Reviews

### Review 1

**Review Title:** Modern Anatomy

Posted by Dr. Janja Topolovec on 20 Jan 2012 02:28:43 PM GMT

<table>
<thead>
<tr>
<th>Question</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Is the subject of the article within the scope of the subject category?</td>
<td>Yes</td>
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<tr>
<td>Are the interpretations / conclusions sound and justified by the data?</td>
<td>Yes</td>
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<tr>
<td>Is this a new and original contribution?</td>
<td>Yes</td>
</tr>
<tr>
<td>Does this paper exemplify an awareness of other research on the topic?</td>
<td>Yes</td>
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<tr>
<td>Are structure and length satisfactory?</td>
<td>Yes</td>
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<tr>
<td>Can you suggest brief additions or amendments or an introductory statement that will increase the value of this paper for an international audience?</td>
<td>No</td>
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<tr>
<td>Can you suggest any reductions in the paper, or deletions of parts?</td>
<td>No</td>
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<tr>
<td>Is the quality of the diction satisfactory?</td>
<td>Yes</td>
</tr>
<tr>
<td>Are the illustrations and tables necessary and acceptable?</td>
<td>Yes</td>
</tr>
<tr>
<td>Are the references adequate and are they all necessary?</td>
<td>Yes</td>
</tr>
<tr>
<td>Are the keywords and abstract or summary informative?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Rating:** 9

**Comment:**
The Zygote Body seems to be offering a comprehensive and in-depth approach for teaching anatomy. Although this method cannot wholly replace the prosection and dissection of the cadaver, nor the plastic models, as stated by the author, it clearly draws the attention of young medical students as one would expect considering the ever-growing science modernization.

**Invited by the author to make a review on this article?:** Yes

**Experience and credentials in the specific area of science:**
Dissection course participant.

**Publications in the same or a related area of science:** No

**How to cite:** Topolovec J. Modern Anatomy [Review of the article ‘Zygote Body: A New Interactive 3-Dimensional Didactical Tool for Teaching Anatomy’ by ], WebmedCentral 1970;3(1):WMCRW001408
Review 2

Review Title: Interesting article on an important topic

Posted by Dr. Uros Bele on 20 Jan 2012 01:17:37 PM GMT

1. Is the subject of the article within the scope of the subject category? Yes
2. Are the interpretations / conclusions sound and justified by the data? Yes
3. Is this a new and original contribution? Yes
4. Does this paper exemplify an awareness of other research on the topic? Yes
5. Are structure and length satisfactory? Yes
6. Can you suggest brief additions or amendments or an introductory statement that will increase the value of this paper for an international audience? No
7. Can you suggest any reductions in the paper, or deletions of parts? No
8. Is the quality of the diction satisfactory? Yes
9. Are the illustrations and tables necessary and acceptable? Yes
10. Are the references adequate and are they all necessary? Yes
11. Are the keywords and abstract or summary informative? Yes

Rating: 9

Comment:
Good research work with appropriate methodology. The topic is very up-to-date and important for anatomical education. Results of the study are nicely presented in tables. The author has also presented his views on the future development opportunities for Zygote Body® in the discussion. The article has numerous and recent cited literature.

Competing interests: None.

Invited by the author to make a review on this article? : Yes

Experience and credentials in the specific area of science:
Working as an teaching assistant for anatomy.

Publications in the same or a related area of science: No

How to cite: Bele U. Interesting article on an important topic [Review of the article 'Zygote Body: A New Interactive 3-Dimensional Didactical Tool for Teaching Anatomy' by]. WebmedCentral 1970;3(1):WMCRW001407
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