

Learning Brainstem Anatomy using Plastic Cup Models

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Abstract : New didactic methods have been introduced for teaching gross anatomy and neuroanatomy, which include modern IT technology such as 3-dimensional (3D) printing and virtual (VR) or augmented reality (AR). These methods have been reported to be educationally effective. Despite several 3D or mnemonic devices used for teaching brainstem anatomy, this part of the brain remains difficult to teach and learn. The difficulty may be associated with the compact localization of the components, with many nuclei and tracts packed in a limited space, which are not easily observed by dissection. Cross sectioning and staining of the brainstem have presented obstacles at the authors' institution, due to limited laboratory time and inconsistent staining results. To overcome these difficulties and improve students' understanding of brainstem anatomy, we introduced a hands-on practice of modeling during the neuroanatomy course. Students were required to model the brainstem including the nuclei and nerves using three transparent plastic cups (for midbrain, pons, and medulla oblongata), colored clay, thin wire, and colored threads. The brainstem models made by students were evaluated by the teacher. The results of a feedback survey based on a five-point Likert scale showed positive effects of this method.

Keywords : Anatomy education, Neuroanatomy, Brainstem, Modeling

INTRODUCTION

Neuroanatomy is one of the most challenging subjects for students, and they often experience difficulty grasping the complex three-dimensional (3D) spatial relationships [1], because the subject requires abstract visualization and strong spatial reasoning [2]. Revised methods of brain dis-

section have been developed [3-5], and diverse IT technologies representing the digital era of the 21st century have been introduced for teaching neuroanatomy, including 3D virtual reality (VR) [6,7], mobile augmented reality (AR) [8], 3D printing [9], 3D online learning modules [1], 3D teaching tools [10], 3D graphic models [11], and digital brain atlases [12,13]. Nevertheless, neuroanatomy remains a complex sub-discipline of anatomy.

Among the nervous system structures, the brainstem is an especially difficult site for students to conceptualize although mnemonic devices such as the rules of 4 (4 medial and 4 side structures: motor pathway, medial lemniscus, medial longitudinal fasciculus, and motor nuclei of III, IV, VI, and XII cranial nerves/spinocerebellar pathway, spinothalamic pathway, sensory nucleus of V cranial

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nerve, and sympathetic pathway), 5 (every cranial nerve nucleus that contains the Roman numeral V, namely V, VI, VII, VIII, is located in the pons with the exception of IV), and 12 (any nucleus that is a factor of 12, inclusive of 12, namely III, IV, VI, XII, is medial, and the remainders are lateral) [14,15]. The brainstem is also complicated for instructors to teach due to the close proximity of nuclei and tracts inside the structure. The packed arrangement of brainstem structures causes difficulty in identification by dissection, contrary to the structures of gross anatomy. Considering the financial burden of implementing IT devices and the educational effectiveness of hands-on exercises, a new didactic method using transparent plastic cups was applied for teaching of the brainstem in the neu-

roanatomy class at the authors' institution in 2017, 2018, and 2019. A feedback survey was conducted at the end of the course to determine the utility of this method for learning brainstem structures.

METHODS

At Sungkyunkwan University School of Medicine, approximately 40 students spend 10 weeks in the neuroanatomy course (20 hours of lectures and 10 hours of laboratories) in their third year of a six-year program, or the first year of a four-year program (Table 1). Students dissected neuroanatomical specimens following a manual developed by the

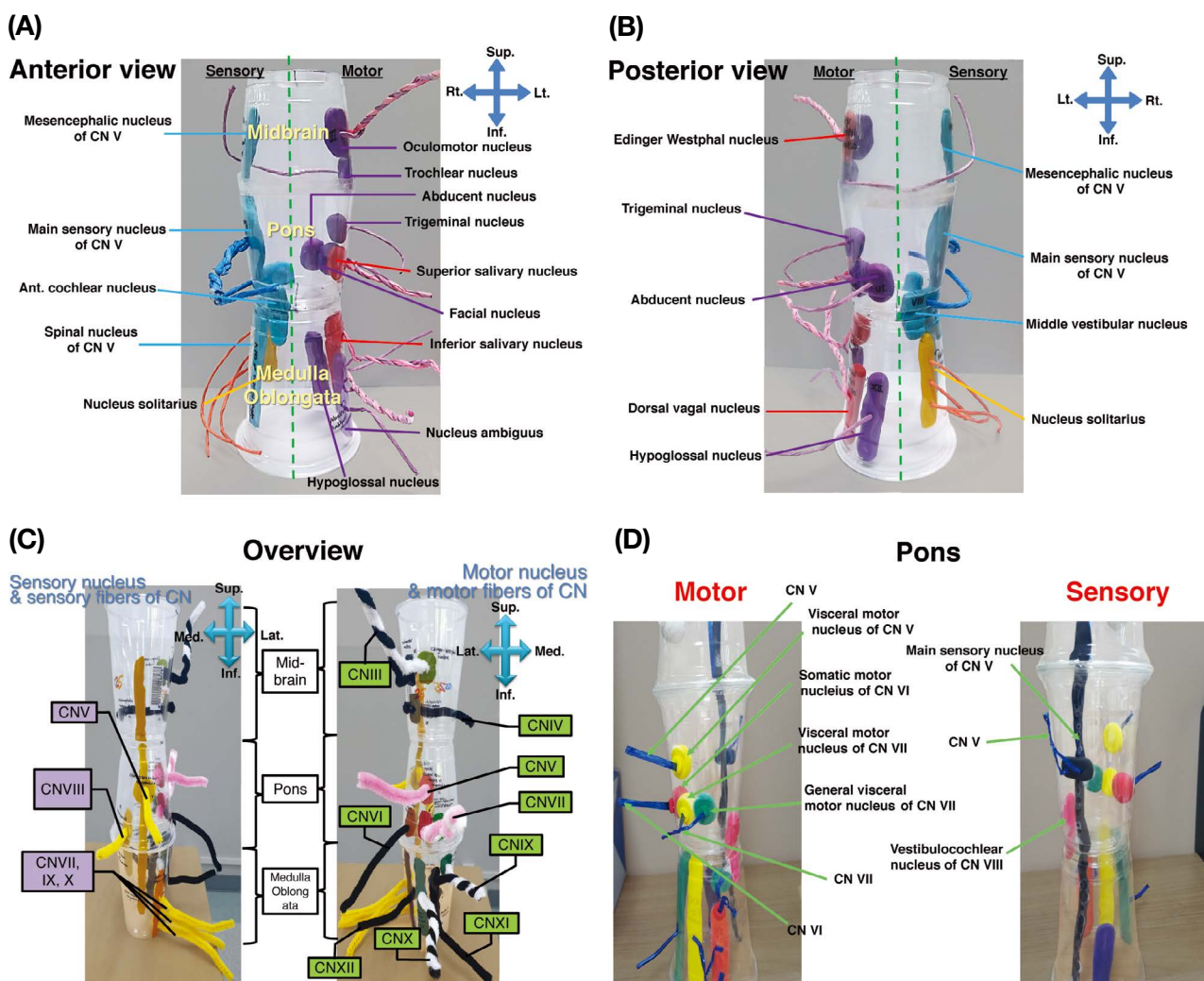


Fig. 1. Brainstem models using transparent plastic cups, which were made, photographed, labeled, and uploaded by students. Nuclei are expressed by colored clay, and various components of each cranial nerve by colored wires or/and threads. Sup, superior; Inf, inferior; Lat, lateral; Med, medial; Lt, left; Rt, right.

authors [16], and were required to model the brainstem as their homework at the class for brainstem, which included the nuclei and cranial nerves, using three transparent plastic cups (representing the midbrain, pons, and medulla oblongata), colored clay, thin wire, paper, and colored threads.

The students made the brainstem using the materials, based on their knowledge of the structure with referring to many sources of neuroanatomy, on the internet or/and printed on paper. Colored clay was used to represent the nuclei in the brainstem, and colored wire or/and thread were used to represent the various components of cranial nerve (Fig. 1). Each student explained his or her model to the anatomy teacher, who evaluated the models. Students were required to upload the labeled photographs of their models on the website for the anatomy laboratory course developed by the authors' institution, named 'Touch Manual and Digital Report' [16]. The models stored on the website were referred by the students in the following years.

A feedback survey was conducted at the end of the neuroanatomy course in 2017, 2018, and 2019. The survey was composed of 1 open-ended and 16 questions (Table 2), the

Table 1. Demographics of participating students

		6 Yr Program		4 Yr Program	
		N	Age	N	Age
2017	Male	19	(21.1±1.2)	5	(23.2±0.8)
	Female	10	(20.4±0.7)	5	(23.2±1.5)
2018	Male	23	(21.2±1.2)	8	(23.6±2.0)
	Female	7	(21.0±1.0)	4	(23.0±0.8)
2019	Male	32	(20.7±0.7)		
	Female	7	(20.6±1.0)		

Number in the parenthesis is age (Mean ± SD).

Table 2. Survey questionnaire for brainstem modeling using plastic cups

Questionnaire	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. I like what I learned in this class of brainstem modeling.	①	②	③	④	⑤
2. It is important for me to learn what was taught in this class.	①	②	③	④	⑤
3. I think that what we learned in this class is interesting.	①	②	③	④	⑤
4. I think I will receive a good grade in this class.	①	②	③	④	⑤
5. I am sure I can do an excellent job on the tasks and examination in this class.	①	②	③	④	⑤
6. I know I could learn the most difficult material for this class.	①	②	③	④	⑤
7. I am certain I can understand the ideas about 3D structure of brainstem taught in this class.	①	②	③	④	⑤
8. I think that what I learned in this class is useful for me to know.	①	②	③	④	⑤
9. I expect to do very well in this class, when considering the level of difficulty, teacher, and my capacity.	①	②	③	④	⑤
10. I think I will be able to use what I learned in this class later.	①	②	③	④	⑤
11. I learned the contents of brainstem through modeling, which could not be obtained in other methods.	①	②	③	④	⑤
12. Modeling was helpful to study the brainstem.	①	②	③	④	⑤
13. Modeling was helpful to conceptualize the internal structure of brain stem.	①	②	③	④	⑤
14. Modeling was time consuming.	①	②	③	④	⑤
15. Modeling costed much.	①	②	③	④	⑤
16. I recommend the method of modeling to be maintained for the class of next year.	①	②	③	④	⑤

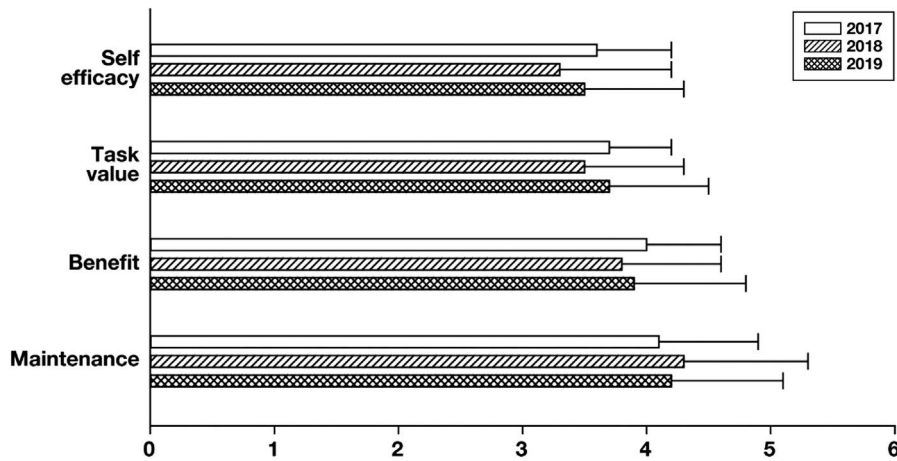


Fig. 2. Results of the feedback survey. Data are presented as means (\pm SD) from a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

Table 3. Analysis of comments from open-ended questions regarding the reasons for the effectiveness of brainstem modeling using transparent plastic cups

	2017 (24 respondents)	2018 (30 respondents)	2019 (26 respondents)
Helpful for understanding 3D structures of brainstem	8	16	14
Helpful for long-term memory or memorizing	6	3	5
Helpful for using the knowledge and referring to other sources	3	1	2
Strongly recommend for the following year		2	1
Enjoyable			1
Others	7	8	3

latter of which evaluated the self-efficacy (question numbers 4, 5, 6, 7, and 9), task value (question numbers 1, 2, 3, 8, and 10), and benefit (question numbers 11, 12, and 13) of the modeling method for learning the brainstem anatomy and asked whether keeping the modeling method for the neuro-anatomy course in the following year was helpful for the students to study the brainstem. Survey questions for self-efficacy and task value were basically modified from MSLQ (Motivated Strategies for Learning Questionnaire) [17], and those for benefit were created by the authors. Cronbach’s alpha was calculated to estimate internal consistency of survey questions, and that for self-efficacy, task value, and benefit was 0.89, 0.91, and 0.88, respectively. In the years of 2017, 2018, and 2019, 39, 42, and 39 students, respectively, were given the survey and responded to the questions using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

RESULTS

The survey results showed that students’ perceptions regarding the effectiveness of the brainstem modeling were fairly positive as follows: self-efficacy in 2017, 2018, and 2019, were 3.6 ± 0.6 , 3.3 ± 0.9 , and 3.5 ± 0.8 , task value in 2017, 2018, and 2019, were 3.7 ± 0.5 , 3.5 ± 0.8 , and 3.7 ± 0.8 , benefit in 2017, 2018, and 2019, were 4.0 ± 0.6 , 3.8 ± 0.8 , and 3.9 ± 0.9 , and maintenance for the method in 2017, 2018, and 2019, were 4.1 ± 0.8 , 4.3 ± 1.0 , and 4.2 ± 0.9 , respectively (Fig. 2). The values for the questions regarding time and cost (question numbers 14 and 15) in 2017, 2018, 2019, were 2.9 and 2.6, 3.6 and 3.1, 3.5 and 2.8, respectively. Students commonly stated that the most beneficial aspect of brainstem modeling was helpfulness for understanding 3D structures of the structure (Table 3). The average time students took to make the models in 2017, 2018, and 2019, were 1.4, 2.3, and 2.2 hours, respectively.

DISCUSSION

The advanced technologies in the current IT era have been continuously introduced in anatomy education methods, and have shown positive influence on learning. A MagicBook developed using mobile AR technology, for example, was applied for neuroanatomy, and a higher achievement and lower cognitive load was reported because the students could access the materials anytime and anywhere, and learned better and more efficiently by exerting less cognitive effort and benefitting from real time interaction with the environment [8]. Anatomic models using 3D printing, which included liver, lung, the circle of Willis, and corticospinal tract, were created to enhance the understanding of the complex anatomy [9]. Despite the educational effectiveness of the modern technologies, however, the financial issue appears to be an obstacle for implementation in the classroom or laboratory, as indicated by the statement that high technology equals high cost [18].

Conversely, various didactic methods with relatively low economic burden using various everyday items have also been introduced in anatomy education. For example, white cotton pantyhose and color transparencies for facilitating students' understanding of a 3D integration of dermatomes with peripheral cutaneous nerve field [19], and simple tools, such as an apron and a large piece of rectangular cloth for demonstrating midgut rotation and the relationship between the uterus and the peritoneum, respectively, have been used [20]. An eye model simulation using floral foam balls to demonstrate the movements of extraocular muscles [18], a functional model of the digital extensor mechanism using hair bands [21], thoracic skeleton and respiratory muscles drawn on t-shirts and facial expression muscles on the face [22], and clay modeling of anatomic structures such as brain, heart, and larynx [22-25] have also been used. In the current study, the transparent plastic cups, colored threads, steel wires, and clays were used, and they presented no financial issue for the instructor or students.

Students took 0.5 to 4.5 hours to make the models, which varied depending on students' handcraft skills and/or learning strategy. From the teacher's viewpoint, an important advantage of brainstem modeling was that students used their knowledge of the structure and referred to many sources including textbooks when making the models. This process helped the students solidify their learning and memory of the

complicated brainstem structure including the various components of each cranial nerve, as described in the open comments (Table 3). The brainstem models made by students were evaluated by the anatomy teacher, and then students were required to upload the labeled photographs of their models on the website for the anatomy laboratory course developed by the authors' institution [16]. The photographs saved on the website, as shown in Figure 1, were helpful as a guideline for the brainstem modeling in the neuroanatomy class in the following year.

Results of the feedback survey of this study were fairly positive in benefit, self-efficacy representing the students' belief that he or she could successfully perform the task, task value referring to their interest and perceptions of the usefulness, importance, and cost of a task [26]. In particular, the importance of maintaining the brainstem modeling in the subsequent year was higher than for other themes, which was expressed in students' open comments (Table 3). The stereoscopic neuroanatomy education using a 3D VR showed the students rated the 3D method superior to 2D teaching in four domains: spatial understanding, application in future classes, effectiveness, and enjoyment [7]. The spatial understanding was most frequently described in the open comments in the feedback survey of the present study (Table 1) and appeared to contribute most to the effectiveness of the current method.

This study had several limitations. First, there was no control group because of the small class size (approximately 40 students). Furthermore, any benefits in the experimental group would have unethically disadvantaged any students assigned to a control group. Second, the brainstem tracts, such as corticospinal tract, medial lemniscus, medial longitudinal fasciculus, and spinothalamic tract, have not been included in many brainstem models made by students. The anatomy teacher needs to emphasize to include the tracts in the models. Third, a correlation between the survey results and examination scores was not evaluated because the feedback survey was conducted anonymously. Conclusively, this study showed that brainstem modeling using transparent plastic cups was useful and beneficial for students to learn brainstem anatomy. Conventional effects of hands-on exercise as well as spatial perception of the structures confirmed the effectiveness of this method, which can be applied with no financial burden in other institutions.

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