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Original Research Article

Three - Dimensional embryology models as teaching aids for first-year medical students

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Abstract

Objective: This complete-enumeration, before-and-after type of study (without controls) was conducted at a municipal medical college in Western India to comparatively evaluate the cognitive domain scores of the participating first-year MBBS students before and after model-based teaching using three-dimensional embryology models as the educational tool.
Methodology: After obtaining permissions, the purpose of the study was explained and written informed consent was obtained from all willing participants. The study was conducted in two different batches of students (Batch A: n=36; Batch B: n=51). The pre-test was conducted after traditional didactic embryology lectures and the post-test was conducted after model-based teaching, using identical questionnaires. The outcome studied was the difference in cognitive domain scores after attending traditional didactic embryology lectures and model-based teaching.
Results: Highly significant differences were observed between the mean pre- and post-test scores for Batch-A students (Z=4.282; p<0.0001) and Batch-B students (Z=12.466; p<0.0001). The gender differences in question-wise mean scores was more evident among Batch-A students, as compared to their Batch-B counterparts.
Conclusion: The significant differences between the cognitive domain scores in the pre- and post-tests indicate that use of three-dimensional embryology models enable learning.
Keywords: Anatomic Models, Three Dimensional Models, Embryology.

1. Introduction

The reduction in the duration of the first-year of the Bachelor of Medicine, Bachelor of Surgery (MBBS) course has motivated many medical teachers to seek novel teaching methods for optimum utilisation of the available time for students' learning.

Though similar methods are used for teaching anatomy and embryology, teaching of embryology requires explanation of dynamic changes in the development of an embryo. [1] Use of artificial models enables learning, since the students can appreciate the three-dimensional (3D) aspects of the structures [1,2]

Various studies have reported the educational effectiveness of commercially available 3D web-based models [3], 3D computer and mobile-based models [4,5] and non-digital 3D models [6] for teaching-learning. Effectiveness of digital models is determined by the student's level of computer skills, [7] gender of the student, [8] inherent ability of the student to comprehend spatial anatomy, [9] level of orientation to 3D technology, [10] and cognitive burden on the student. [11] Since most commercially available digital embryology models are expensive, commercially available 3D embryology models were used as educational tools in the present study.

The objectives of this study were to evaluate (pre-test) the cognitive domain scores of the participating first-year MBBS students after attending traditional didactic lectures (TDLs) on embryology. Their cognitive domain scores were also evaluated (using an identical post-test) after model-based teaching (MBT) using commercially available 3D embryology models as the educational tool.

2. Methodology

2.1. Study Area

The complete-enumeration, before-and-after type of study (without controls) was conducted in a municipal medical college in Kalwa, Thane, located about 30 kilometres from Mumbai city in the state of Maharashtra in Western India.

2.2. Procedure

After obtaining permissions from the Institutional Ethics Committee (IEC) and institutional authorities for conducting the study, the purpose of the study was explained to first-year MBBS students and written informed consent was obtained from those willing to participate in the study. The study was conducted in two segments comprising two different batches of students (Batch A: n=36; Batch B: n=51). TDLs were delivered on embryology as per the syllabus for the first-year MBBS course. The pre-test, conducted after the TDLs, comprised nine questions (one mark per question). The post-test was conducted one month after MBT using a questionnaire that was identical to that of the pre-test. The scores obtained by two different batches of students were analysed separately. The outcome studied was the difference in cognitive domain scores after attending TDLs (by a pre-test) and MBT (by post-test after one month).

2.3. Materials

Commercially available 3D embryology models (G. D. Biological Model Works, Ambala Cantt, Haryana - 133001, India) were used as educational tools in this study.

2.4 Statistical Methods

The obtained data were tabulated and statistically analysed using EpiInfo Version 7.0 (public domain software package from the Centers for Disease Control and Prevention, Atlanta, GA, USA). Continuous data were presented as Mean and Standard Deviation (SD). Confidence interval (CI) was stated as: [Mean-(1.96)* Standard Error)] - [Mean+(1.96)* Standard Error)]. The standard error of difference between two means was calculated and statistical significance was determined at p<0.05.

3. Results

3.1. Scores obtained by all students

The mean scores obtained by the Batch-A students (n=36) in the pre-test and post-test were 3.99±1.61 (CI: 3.46-4.52) and 5.58±1.54 (5.08-6.08), respectively. The differences were highly significant (Z=4.282; p<0.0001). The mean scores obtained by the Batch-B students (n=51) in the pre-test and post-test were 4.04±1.31 (CI: 3.68-4.40) and 7.06±1.13 (CI: 6.75-7.37), respectively. The differences were statistically significant (Z=12.466; p<0.0001).

3.2. Gender-wise distribution of scores obtained by Batch-A students

Among female Batch-A students, significant differences were observed between the mean scores obtained during the pre- and post-tests for question Nos. 1, 2, 6, 8 and 9. (Table 1) Among male Batch-A students, the mean scores obtained during the pre- and post-tests in question Nos. 2, 6, and 8 were statistically significant. (Table 2) For question Nos. 4 and 5, the mean scores in the post-test were lower than that for the pre-test among students of both genders. (Tables 1 & 2)

Table 1: Distribution of scores obtained by Batch-A female students (n=22)

Q. No.	Pre-test Mean (SD)	Post-test Mean (SD)	Z value #	p value
1	0.48 (0.45)	0.75 (0.34)	2.25	0.0244 *
2	0.50 (0.27)	0.82 (0.29)	3.79	0.0002 *
3	0.86 (0.35)	0.91 (0.29)	0.52	0.603
4	0.55 (0.51)	0.41 (0.50)	0.92	0.3576
5	0.68 (0.48)	0.64 (0.47)	0.28	0.7794
6	0.25 (0.40)	0.52 (0.29)	2.56	0.0104 *
7	0.09 (0.29)	0.32 (0.48)	1.92	0.0548
8	0.23 (0.34)	0.61 (0.38)	3.50	0.0004 *
9	0.32 (0.48)	0.61 (0.49)	1.98	0.0478 *

# Standard error of difference between means
SD = Standard deviation; * Statistically significant

Table 2: Distribution of scores obtained by Batch-A male students (n=14)

Q. No.	Pre-test Mean (SD)	Post-test Mean (SD)	Z value #	p value
1	0.54 (0.46)	0.50 (0.39)	0.25	0.8026
2	0.54 (0.37)	0.93 (0.18)	3.55	0.0004 *
3	0.79 (0.43)	0.86 (0.36)	0.47	0.6384
4	0.36 (0.50)	0.14 (0.36)	1.34	0.1802
5	0.71 (0.47)	0.64 (0.50)	0.38	0.704
6	0.14 (0.31)	0.50 (0.34)	2.93	0.0034 *
7	0.43 (0.51)	0.71 (0.47)	1.51	0.131
8	0.11 (0.29)	0.54 (0.50)	2.78	0.0054 *
9	0.43 (0.51)	0.75 (0.43)	1.79	0.0734

# Standard error of difference between means
SD = Standard deviation; * Statistically significant

3.3. Gender-wise distribution of scores obtained by Batch-B students

Among both female and male Batch-B students, significant differences were observed between the mean scores obtained during the pre- and post-test for all questions except question Nos. 3 and 5. (Tables 3 & 4)

Table 3: Distribution of scores obtained by Batch-B female students (n=36)

Q. No.	Pre-test Mean (SD)	Post-test Mean (SD)	Z value #	p value
1	0.86 (0.36)	1.00 (0.00)	2.30	0.0214 *
2	0.11 (0.25)	0.60 (0.50)	5.19	0 *
3	0.74 (0.44)	0.83 (0.38)	0.92	0.3576
4	0.49 (0.51)	0.89 (0.32)	3.93	0 *
5	0.71 (0.46)	0.86 (0.36)	1.52	0.1286
6	0.49 (0.26)	0.99 (0.08)	10.87	0 *
7	0.29 (0.46)	0.60 (0.50)	2.70	0.007 *
8	0.03 (0.12)	0.54 (0.41)	7.06	0 *
9	0.63 (0.49)	0.97 (0.17)	3.88	0.0002 *

# Standard error of difference between means
SD = Standard deviation; * Statistically significant

Table 4: Distribution of scores obtained by Batch-B male students (n=16)

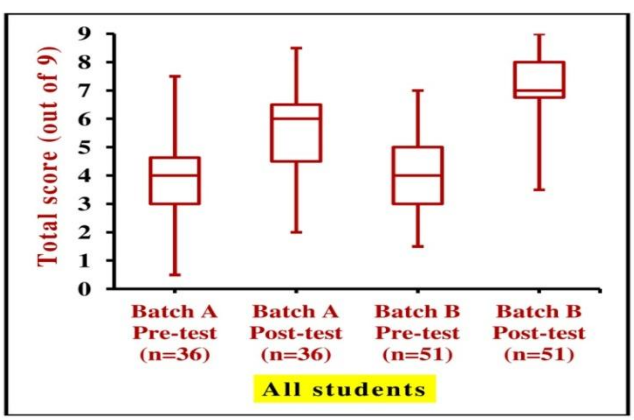
Q. No.	Pre-test Mean (SD)	Post-test Mean (SD)	Z value #	p value
1	0.63 (0.50)	0.94 (0.25)	2.22	0.0264 *
2	0.06 (0.17)	0.38 (0.50)	2.42	0.0156 *
3	0.81 (0.40)	0.88 (0.34)	0.53	0.5962
4	0.31 (0.48)	0.88 (0.34)	3.88	0.0002 *
5	0.75 (0.45)	0.88 (0.34)	0.92	0.3576
6	0.59 (0.27)	0.81 (0.36)	1.96	0.05 *
7	0.00 (0.00)	0.31 (0.48)	2.58	0.0098 *
8	0.00 (0.00)	0.66 (0.44)	6.00	0 *
9	0.22 (0.41)	0.88 (0.34)	4.96	0 *

# Standard error of difference between means
SD = Standard deviation; * Statistically significant

3.4. Box plots for scores obtained by all students in Batches A & B

The median and the third quartile in the box plot for pre-test (Batch-A) indicate that more than 50% of the students scored less than 4 marks and more than 75% scored between 4 and 5 marks. In the post-test (Batch-A), the first quartile is between 4 and 5 marks, implying that nearly half the students of Batch-A improved their scores in the post-test. However, the improvement in the minimum score was marginal. Though the median and the third quartile in the box plot for pre-test (Batch-B) is nearly identical as that for Batch-A, the minimum score of Batch-B students improved considerably in the post-test. (Figure 1)

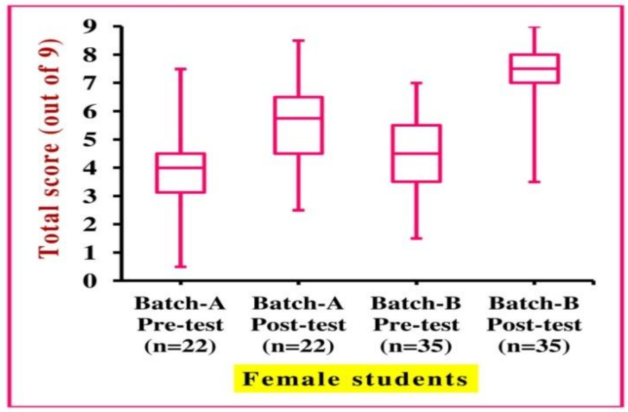
Figure 1: Box plots showing scores obtained by all students in Batches A & B



3.5. Box plots for scores obtained by female students in Batches A & B

The third quartile in the box plot for pre-test (Batch-A female students) was lower that the first quartile for the post-test indicating that a majority of female students of Batch-A improved their scores in the post-test. Moreover, the improvement in the minimum score was also considerable. The first quartile in the box plot for post-test (Batch-B) was much higher than the maximum score in the pre-test for Batch-B denoting substantial improvement in scores. (Figure 2)

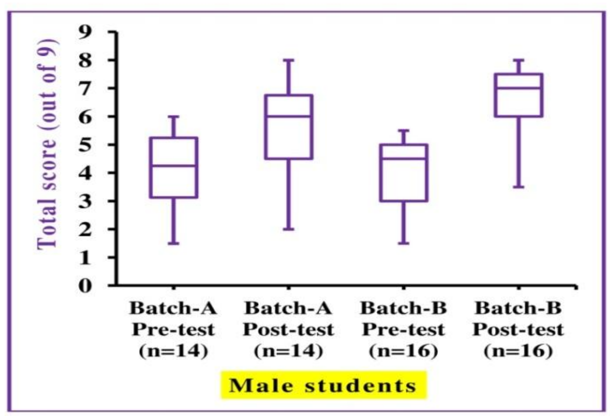
Figure 2: Box plots showing scores obtained by female students in Batches A & B



3.6. Box plots for scores obtained by male students in Batches A & B

The maximum scores in the box plot for pre-test (Batch-A & Batch-B male students) was lower than the median for the post-test indicating that a majority of male students of both batches had improved their scores in the post-test. (Figure 3)

Figure 3: Box plots showing scores obtained by male students in Batches A & B



4. Discussion

Spatial visualization is crucial to understanding embryology because students ought to know the inter-structure relationships in various views and planes. [12] Unlike 3D models, comprehending the development of the human embryo from two-dimensional (2D) figures in text books and atlases has its limitations. [13] Many learners may find it difficult to visualize 2D figures in 3D format. Visual-spatial ability is the ability to mentally manipulate objectives in three dimensions. [14] 3D printing (a process where a physical object is created from a three-dimensional computer model through successive material layering) has been used to produce 3D models for medical education. [15]

The purpose of this study was to determine whether the use of 3D embryology models would enhance or assist learning by first-year MBBS students. The highly significant differences observed between the mean pre- and post-test scores for Batch-A students ($Z=4.282$; $p<0.0001$) and Batch-B students ($Z=12.466$; $p<0.0001$) imply that the cognitive domain scores increased when 3D embryology models were used. A single post-test has been found adequate and learning was found to be retained even after six months. [16]

In the present study, female students obtained higher scores during the pre- and post-tests. In contrast, another study [8] has reported that males scored better than females in the anatomy learning process.

TDLs provide fundamental basic knowledge, while the use of 3D embryology models, as an adjunct method of teaching, enhances the knowledge transfer. Thus, the students actively participate in the teaching-learning process. Self-learning is facilitated by structural alignment between two similar domains: an unknown domain (called the "target") and a relatively known domain, termed the "source". [17,18] The 3D embryology models serve as the "source" and the human embryo is the "target".

Learning occurs more effectively if the student experiences the information to be learned through sensory (auditory, visual, and tactile) channels. [19,20] In the absence of active teaching-learning methods, the student becomes a passive receiver of information. [20] The information processed by the sensory channels must be accumulated as long-term memory for subsequent retrieval. [19] The formation of several interconnected mental models during the course of meaningful learning enables students to take a broad view and to apply their knowledge in practical settings. [21]

5. Limitations

The present study was conducted on two small batches of first-year medical students. A larger study with a range of models pertaining to the entire curriculum of Embryology would be necessary in order to generalize the results.

6. Conclusion

The significant differences between the cognitive domain scores in the pre- and post-tests indicate that use of 3D Embryology models enable learning.

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