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Medical Student Retention of Embryonic Development: Impact of the Dimensions Added by Multimedia Tutorials

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The purpose of this project was to develop Web-based learning modules that combine (1) animated 3D graphics; (2) 3D models that a student can manipulate independently; (3) passage of time in embryonic development; and (4) animated 2D graphics, including 2D cross-sections that represent different "slices" of the embryo, and animate in parallel. These elements were presented in two tutorials, one depicting embryonic folding and the other showing development of the nervous system after neural tube formation. The goal was to enhance the traditional teaching format—lecture combined with printed diagrams, text, and existing computer animations—with customized, guided, Web-based learning modules that surpassed existing resources. To assess module effectiveness, we compared quiz performance of control groups who attended lecture and did not use a supporting module, with study groups who used a module in addition to attending lecture. We also assessed our students' long-term retention of the material, comparing classes who had used the module with students from a previous year that had not seen the module. Our data analysis suggests that students who used a module performed better than those given only traditional resources if they used the module *after* they were already somewhat familiar with the material. The findings suggest that our modules—and possibly computer-assisted-instruction modules in general—are more useful if used toward the later stages of learning, rather than as an initial resource. Furthermore, our data suggest that the animation aids in long-term retention. Both medical students at the University of Cincinnati and medical faculty from across the country commented favorably on their experiences with the embryonic development modules. Anat Sci Ed 1:252–257, 2008. © 2008 American Association of Anatomists.

Key words: animation; computer-assisted instruction; embryology; embryonic folding; multimedia; nervous system development; medical education

INTRODUCTION

There are unique challenges inherent to teaching and learning embryonic development—it is important for students to thoroughly understand many facets of the 3D temporal processes that occur as the embryo develops and to be able to envision these processes from different views. Texts use static, two-dimensional pictures, and students have expressed frustration over learning the details of these processes. In a survey conducted at the University of Cincinnati College of Medicine in 2005 (n = 36), embryology was one of only two focused topics (the other being renal physiology) that students repeatedly mentioned as an area in which they would appreciate a multimedia tutorial.

Our investigation of existing products yielded nothing that satisfactorily conveyed the 3D temporal processes of either embryonic folding or nervous system development. Existing multimedia embryology tutorials have represented processes in various creative ways—through animated computer graphics or scanned electron micrographs (Watt et al., 1996), or 3D representations from sliced specimens (Komori et al., 1995). In

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2001, Montoya and O'Laughlin at Indiana University began to build a rich collection of embryonic development animations, opting not to include embryonic folding or nervous system development (Montoya and O'Loughlin, 2003; O'Loughlin and Montoya, 2003). We chose to focus on two specific areas of embryonic development that had not been included in the Indiana University collection and to present a unified look at the processes in each event as much as possible.

In designing multimedia tutorials for these two topics, we gave careful consideration to the most effective means of combining animated 2D cross-sections and 3D animations presented on a timeline, and 3D models that students could rotate independently. We paid special attention to fully labeling and identifying elements of the changing 3D structure and 2D cross-sections, with the ability to freeze changes as needed. We included an optional voiceover that describes each step of what is happening and textual representation of what is being said, which can be stopped, restarted, and repositioned at will. In this way, we hoped to help students identify key components in a changing 3D structure.

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 (Lillenfield and Broering, 1994; Santer et al., 1995; D'Alessandro et al., 1997; Baumlin et al., 2000; Williams et al., 2001; Lewis, 2003). Similar studies have been carried out in the realm of patient education (Erkonen et al., 1994; Patel et al., 2008). All of these studies combined have shown that the multimedia medium itself is not a deterrent to learning, and may even provide an opportunity to enhance learning. Fewer studies have looked at long-term retention of information learned via computer, as compared with lecture and print materials. Erkonen et al., (1994), D'Alessandro et al. (1997), and Patel et al. (2008) did include a study of retention in their work. Patel et al. (2008) found improved retention among patients. Erkonen et al. (1994) and D'Alessandro et al. (1997) both found no statistically significant difference between long-term test scores of students who had used computer-assisted instruction versus traditional materials. Still fewer studies have focused on a unique aspect of the multimedia tutorial that they have designed the tutorial to test.

We chose to focus on creating a multimedia package that exclusively presented material that is challenging to present on paper or via lecture. Paper and lecture could only provide guideposts to the process. This was the first time the instructor could present students with actual representations of animated cross-cuts and three-dimensional models that took the learning from start to finish in the process, complete with labels, narration, and accompanying text.

A NOTE ON THE EDUCATIONAL PROGRAM AT THE UNIVERSITY OF CINCINNATI

At the University of Cincinnati College of Medicine, the first year focuses on the basic sciences. Our curriculum is partitioned into "blocks" of material (e.g., Cardiovascular Block). Under this format, our students are exposed to embryonic folding twice. During their first exposure, in the fall during our Molecules, Cells, and Tissues Block, we cover the first 4 weeks of development, including establishing the basic body plan. Embryonic folding is revisited in January during the Gastrointestinal, Endocrine, and Urogenital Block, so that it can be applied to issues such as gastroschisis and omphalocele. As explained later, this format offered us a unique opportunity to test our embryonic folding animation on a group of students who are just being introduced to the topic, and comparing that group to one that has already seen and been tested on the material, and is relearning it again.

METHODS

Volunteers for the study were recruited by distributing an IRB-approved study description and consent form. For the short-term retention studies, we offered a small incentive ($5 campus cash coupon).

For the short-term retention studies, we recruited students from within the same class who studied embryonic folding at the same time during the first year curriculum. Volunteers were randomly distributed into control and study groups. Both groups attended the lecture(s) on embryonic folding, whereas only students in the study group were allowed access to the animation module via our Blackboard course management system (see Table 1). After the lecture and an opportunity for the study group to view the animation, both groups completed the same 14-question quiz, also using Blackboard. Test results from the control and study groups were analyzed using a one-tailed student's t-test ($\alpha = 0.05$). In addition, students were allowed to provide feedback regarding their impressions of the animation. After the study, all students in the class were given access to the animation module well in advance of their official examination in the course.

For the long-term studies, we tested students at the beginning of an optional review session, either for the USMLE Step 1 Examination or our Brain and Behavior course. The quiz for this portion of the study contained eight questions that were different from the questions used in the short-term study. As indicated in Table 2, the control group tested (Class of 2008) had never seen the animation module (this was confirmed during the announcements preceding the quiz). Both study groups (Classes of 2009 and 2010) had access to the animation previously, with the Class of 2010 having more extensive exposure.

RESULTS

Embryonic Folding—Short-term Retention Study

Because of the timing of completion of our module, we initially tested the effectiveness of our animation with first-year students (Class of 2009) who had previously been tested on embryonic folding as part of our regular curriculum and were studying embryonic folding for the second time (January 2006). The mean quiz scores were 8.9 in the control group and 10.6 in the study group (Table 3). A student's t-test indicates that the difference in the two means is statistically significant ($P = 0.02$). Based on these results, as well as informal student comments, we were encouraged by the fact that our animation appeared to increase student comprehension of the complicated events that occur during embryonic folding.

We attempted to confirm our initial results by testing the effectiveness of our animation with the next group of first-

Table 1.

Testing Protocol for Short-term Retention of Embryonic Folding Knowledge

Control Group (Class of 2009)	Study Group (Class of 2009)	Control Group (Class of 2010)	Study Group (Class of 2010)
1st exposure to embryonic folding lecture (Sep 2005)	1st exposure to embryonic folding lecture (Sep 2005)	1st exposure to embryonic folding lecture; quiz testing short-term retention (Sep 2006)	1st exposure to embryonic folding lecture and ***animation module;*** quiz testing short-term retention (Sep 2006)
2nd exposure to embryonic folding lecture; quiz testing short-term retention (Jan 2006)	2nd exposure to embryonic folding lecture and ***animation module;*** quiz testing short-term retention (Jan 2006)		

year students (Class of 2010). In this case, we used a format similar to our initial study, with the difference being that it occurred when the students were exposed to embryonic folding for the very first time, before they were officially tested on the material as part of our regular curriculum (September 2006). The mean quiz scores for this study were 7.6 in the control group and 8.0 in the study group (Table 2). Although the animation helped a little, we were quite surprised that the advantage was not statistically significant ($P = 0.27$).

Embryonic Folding—Long-Term Retention Studies

To ascertain the effectiveness of our animation on the long-term retention of the material, we tested groups of students several months after they had studied embryonic folding. For these studies, we tested volunteers from an entire class during an optional review session. These groups included students who had participated in the study previously, as well as students who were not part of the initial study.

For the control group of this study, we used the Class of 2008; this group had studied embryonic folding twice during the first year curriculum without the benefit of our animation (Table 2), with the quiz taking place 16 months after they had thought about the material. Oral confirmation was made at the time of the long-term retention quiz that they knew nothing about the recently developed animation. This group had a mean score of 3.4.

Our initial study group for our long-term retention analysis was the Class of 2009; this group had studied embryonic folding twice during their first year and had access to the animation during their second exposure to the material. This group had an average score of 3.6 (Table 2), which was not statistically different from the control group ($P = 0.29$).

The second study group for the long-term retention analysis was the Class of 2010; this group also studied embryonic folding twice, but had access to the animation for both exposures to the material. We initially tested this group 4 months after they had studied embryonic folding. Their average score of 4.6 was significantly higher than the control group ($P = 0.005$), suggesting that the animation could be helpful in the long term.

To make a more direct comparison with our control group, we tested the Class of 2010 a year later, 16 months after they had studied embryonic folding. Again, their average score (Table 2) was significantly higher than the control group ($P = 0.04$). In conjunction with the other test results, this suggests that the animation has a positive impact on long-term student test scores.

FORMATIVE EVALUATION—NEURAL TUBE DEVELOPMENT AND EMBRYONIC FOLDING MODULES

We conducted a formative evaluation to gather student impressions of both the ease of use of the modules and how favorably the modules compare with textbook/lecture. In terms of ease of use, 100% of the neural tube development study group and 91% of the embryonic folding study group either agreed or strongly agreed that the module was easy to use. A full 85% of the neural tube development study group and 73% of the embryonic folding study group either agreed or strongly agreed that the modules helped them to understand the material above and beyond what they could learn from a textbook or lecture. Student comments reflected an appreciation for the different views presented by the modules—3D animations, 2D cross-section "slice" animations, and rotatable 3D models.

We also sent an evaluation survey to anatomical science faculty at medical schools across the country, accompanied by a complimentary copy of the embryonic folding module (on CD). In addition to positive feedback, several faculty expressed an intention to make the module available via a Local Area Network at their respective institutions and to adopt the module into their curricula. When asked, on a scale of 1–5, "How likely is it that you will offer the animation to students as an adjunct to your current curriculum?" the average response was 4.7. When asked, "How likely is it that you will incorporate the animation into your lecture?" the average response was 3.8. In addition, faculty responses served as a peer review of the quality and accuracy of the work, with an average response of 4.7 when asked the degree to which they agreed with the statement, "The animation accurately displays the major events that occur during embryonic folding." The average response was 4.6 when faculty were asked the degree to which they agreed with the statement, "The anima-

Table 2.

Testing Protocol for Long-term Retention of Embryonic Folding Knowledge

Control Group (Class of 2008)	Study Group (Class of 2009)	Study Group (Class of 2010)
1st exposure to embryonic folding lecture (September 2004)	1st exposure to embryonic folding lecture (September 2005)	1st exposure to embryonic folding lecture and ***animation module*** (September 2006)
2nd exposure to embryonic folding lecture (January 2005)	2nd exposure to embryonic folding lecture and ***animation module*** (January 2006)	2nd exposure to embryonic folding lecture and ***animation module*** (January 2007)
Quiz testing long-term retention (at 16 months in May 2006)	Quiz testing long-term retention (at 16 months in May 2007)	Quiz testing long-term retention (at 4 and 16 months in May 2007 and 2008)

tion provides a visual representation of events of embryonic folding that is significantly better than can be portrayed in textbook."

Noteworthy faculty comments included the following: "Best animation of early folding that I've seen! Great Job. As you develop further, let me know, as we would purchase a complete package, if available! Excellent job"; "The lead-in was very engaging and quickly got my attention. The growth of the amnion and obliteration of the exocoelomic cavity was particularly well presented"; "A good effort for a difficult subject. Will be viewed favorably by students. Best part is transverse folding at midgut and hindgut. Another good part is final obliteration of the chorionic cavity. Colors are easy for those with color vision issues—Did not need to distinguish red and green." In addition, we received valuable suggestions such as: "Like most illustrations in embryology text books, the animations show the foldings but the chorionic cavity remains the same size. As you know this is not reality. Perhaps a comment about this would help the viewer's understanding," or "What about including an accelerated version of the entire folding process right at the start, to show the students an overview of how the cell layers will be transformed, and then going back through the folding process in more detail (as you have it now)? That way, they would have a visual image of the transformation already in mind, before focusing in on the details. This is a strategy that I have tried to incorporate into my lectures (with slides and models), but I think doing it with animation would be much more effective." We are considering these suggestions as we look at ways to improve the module in the future.

DISCUSSION

Even with a cash incentive, it was difficult to recruit and retain volunteers. We had significant dropout rates with each cohort. We have had experience conducting a number of similar studies and have found this to be the case each time. We believe this is a challenge of conducting a study that involves a time commitment from busy medical students, and that repeating the study in subsequent years would be a possible solution. At the same time, we believe that the numbers as they stand provide meaningful results.

Students were self-selected for the study, which could have influenced the overall outcome in terms of test scores and formative evaluation. With regard to test score comparison, this factor should not affect results, as it would influence both the study group and control group in a like manner. However, with regard to formative evaluation, it could influence student responses toward the more positive.

Partway through our study, the embryonic folding animation was published on MedEdPortal (2008). However, there is no evidence of a UC medical student accessing it that way, according to MedEdPortal evidence (MedEdPortal, 2008). We are confident that the control groups, who understood that they were not to look at the module during the study, did not violate these terms by seeking out the module through a colleague who had access to the animation on Blackboard as part of the study group. There would be no strong incentive to do so, as all students had access to the animation immediately following the end of the study and before formal testing on the subject.

When students were quizzed at the time of module use following their first exposure to the material, the difference in scores was not statistically significant (Table 3). However, when they were quizzed at the time of module use following their second exposure to the material, the difference in the two means was statistically significant (Table 3). Here it is important to note that the group who was tested on first exposure had just recently been introduced to the topic and had not been officially tested on the material under our curriculum, whereas the group that was tested on second exposure had already learned and been tested on the material in an official setting. The results of these two study groups suggest that the animation is more useful once students have a base familiarity with the material and the accompanying terminology. Whether this is true of all animations, as opposed to an idiosyncratic phenomenon specific to this animation, remains to be seen. However, it would seem intuitively obvious that someone with a poor grasp of the terminology and processes will find the amount of material presented in the animations to be overwhelming, whereas someone who has a good grasp on the material but needs to fill in a few gaps will find the time spent with the animation more productive. Because of this, we recommend to our current students that if they view an animation early in their studies, they should go back to the module at a later time.

For the long-term retention studies, the control group was tested for retention of embryonic folding 16 months after their last review of the material. When these scores were compared with a study group that had last studied the material 4 months prior (Table 3), we found the greatest difference in scores and strongest statistical significance. Their average score of 4.6 was significantly higher than the control

Table 3.

Mean Quiz Scores

	Class 2009 Short-term retention	Class 2010 Short-term retention	Class of 2009 Long-term retention (at 16 months)	Class of 2010 Long-term retention (at 4 months)	Class of 2010 Long-term retention (at 16 months)
Control Group	8.9 ± 2.2 (n=13)	7.6 ± 2.3 (n=25)	3.4 ± 1.4[a] (n=37)	3.4 ± 1.4[a] (n=37)	3.4 ± 1.4[a] (n=37)
Study Group	10.6 ± 1.8[b] (n=16)	8.0 ± 2.1 (n=22)	3.6 ± 1.3 (n=32)	4.6 ± 1.6[b] (n=39)	4.2 ± 1.7[b] (n=22)

Values are given as mean ± standard deviation.
[a]This control group represents Class 2008 tested at 16 months.
[b]indicates statistical significance relative to control group using one-tailed student's T-test ($\alpha = 0.05$).

group ($P = 0.0005$) suggesting that the animation could be helpful in long-term retention. This is to be expected, as the retention period was so much shorter for the study group. Although the scores from this group dropped slightly the following year, 16 months after studying embryonic folding (Table 3), the average was still statistically higher than the long-term average of the control group. This suggests to us that our animation was effective in student comprehension and long-term retention of the material.

It is interesting to note that the students from the previous year did not score significantly higher than the control group when tested 16 months after learning embryonic folding. However, there were students included in the group of Class of 2009 volunteers (tested in May 2007) who had been in the control group when the module was first tested on this group in January 2006. The control group students had been unable to view the animation in conjunction with the lecture, whereas the study group students had been required to view it as part of the study. In addition, there were many students in the Class of 2009 who did not volunteer for the study at all. At the conclusion of the January 2006 study, all students had been granted access to it, if they elected to do so independently. So, the Class of 2009 differed from the Class of 2008 control group in that they all had access to the module whereas Class of 2008 did not. However, in testing the study group, we did not identify who actually had chosen to use the module. When we gave this quiz, we had initially assumed that all students had seen the animation, either during the study or afterward. As this was their second time through the material, it is possible that a significant number of students who already understood the concepts within it never took the time to view it. This could have diluted the significance of the test results comparison.

Therefore, we are more confident of the long-term studies associated with the Class of 2010, because with this study, it is highly likely that everyone in that class had used the animation at some point because they had two exposures to embryonic folding with the animation available to them.

The overall impression is that the module was beneficial to student understanding of the events occurring during embryonic folding, with a positive impact on short-term and long-term quiz scores. The approach to teaching embryonic folding and neural tube development that we have assessed by way of this study is one that we believe will be beneficial to the academic health sciences community. At time of publication, the Embryonic Folding module is currently available as a peer-reviewed publication on HEAL (2008) and MedEdPortal (2008), and we anticipate that the Neural Tube Development module will soon complete the peer review process. We are looking ahead at the possibility of expanding on these two modules with the addition of a module that focuses on cranial nerve nuclei development. We believe that by sharing our modules, as Indiana University and others have done before us, we can create a rich collection from which many can benefit and reduce redundant development efforts.

CONCLUSIONS

Through comments in the formative evaluation process, students expressed appreciation for the way in which the modules presented views on the embryonic development process that could not be presented on paper or via lecture. The vast majority of students expressed that the modules helped them to understand the material above and beyond what they could learn from textbook/lecture.

Test scores over time showed a trend of higher scores for students who used the module as a complement to the material learned in lecture and from textbooks. Additional testing will be required to determine the degree of statistical significance of these results. The data to date is encouraging and fuels our interest in developing additional modules of a similar style to present the more complex processes of embryonic development; we are currently exploring the possibility of working on a module depicting development of cranial nerve nuclei.

The Embryonic Folding module has been accepted as a peer-reviewed publication on both the HEAL (2008) and MedEdPortal (2008) websites. The neural tube development module has been submitted for peer review to these sites as well. Already, according to the MedEdPortal usage report, over 100 individuals from almost as many different institutions have used MedEdPortal to access the Embryonic Folding animation (MedEdPortal, 2008). In addition, we are aware of faculty who participated in our nationwide faculty survey that planned to load the Embryonic Folding module on Local Area Networks.

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