Enhancing the learning experience of students in reproductive science with multimedia platforms
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Abstract
Understanding how information is processed is key to effective communication. Furthermore, available digital technology provides an opportunity to enhance the learning process in a shorter period of time. This paper will highlight research that utilizes instructional design principles in a multimedia platform to teach complex concepts in reproductive science.

Keywords: Student learning, multimedia, teaching, reproductive science

Introduction
Most of us who teach in the field of reproductive science, whether it be basic reproductive physiology, theriogenology, obstetrics and gynecology or various social services such as Planned Parenthood, district health centers, etc., have had little, if any formal training in cognitive psychology and/or how to apply documented instructional design principles to concepts that are very important for people to understand. Almost all of us have learned to teach by mimicking our peers or former mentors.

During the past eight years, we have been developing strategies for using multimedia to enhance the learning experience of students and explain concepts in reproductive science. We have learned that a solid understanding of multimedia instructional design principles is invaluable to developing strong, day-in and day-out instructional designs in our classes and presentations. We have produced various multimedia prototypes and tested these in 11 land grant universities using over 1,500 undergraduate reproductive science students. The U.S. Department of Education through the Small Business Innovation Research (SBIR) program has funded much of this effort.

Students are relying on mobile devices such as cell phones, tablets and laptops to access information at an accelerated rate. Student behavior using these devices are ideally suited for multimedia teaching/learning and a promising opportunity exits. They are embracing nontraditional learning opportunities that can occur anytime and anywhere.

The development of multimedia approaches that explain concepts in reproductive science could significantly reduce the time for learning. Further, multimedia approaches using technology that students already embrace (and that is constantly improving) would potentially result in an equal or better learning experience than traditional approaches. The purpose of this paper is to describe and summarize the possible uses of multimedia as a method to enhance understanding of important concepts in reproductive science.

The specific objectives are as follows:
- describe some of the most important principles of multimedia instructional design
- identify how these principles can be put into practice,
- demonstrate some research outcomes that support the power of a multimedia approach, and
- discuss the outcomes of Beta tests to evaluate presentation of online content units in reproductive science.

Overview of multimedia principles
Understanding concepts in reproductive science require the integration of anatomical, hormonal and behavioral changes over time. Understanding these concepts is obligatory for proper implementation
of reproductive management and reproductive health interventions. A problem that impedes understanding is that as complexity of a concept increases, cognitive load increases. In other words, the amount of cognitive resources needed to process information increases as complexity increases.¹ To minimize cognitive load so that maximum learning potential occurs, instructional design principles must be utilized, especially in a multimedia presentation.² Multimedia is defined as the combination of words (written or spoken) and pictures, and can be applied to something as simple as a book or elaborate as an online course.² Five foundational multimedia principles for instructional design and how they can be utilized are presented below:

- **The modality principle** incorporates both the visual and auditory sensory channels when presenting information to expand working memory capacity and increase learning.³⁻⁶ We incorporated graphics (visual) and narration (auditory) to maximize information processing in our multimedia presentations.

- **The spatial and temporal contiguity principles** provides explanations or easily-identifiable key words at the same time as information is presented.⁵⁻⁶ Our multimedia presentations synchronize the narration with the animation. Therefore, explanations describe events as they are happening. Also, labels linked to anatomy or processes are provided, rather than simply showing an anatomical section with numbers or letters that requires students to actively search for the key to understand. In other words, students do not have to search for names and functions to understand the anatomy. Much of the printed literature in reproductive science makes it very inconvenient for students and instructors alike.

- **The signaling principle** directs the learner’s focus by emphasizing or highlighting specific points of a concept.⁷⁻⁸ For example, inserting an arrow on a graphic guides the learner’s attention to the specific segment so that the narration of that particular concept can be understood without the learner guessing what he/she should be paying attention to.

- **The personalization principle** indicates that explanations in a conversational format are more effective than explanations presented in a formal format.⁹⁻¹⁰ Multimedia presentations with the narration including “I” and “you” personalizes the communication and builds a social connection between the instructor and the learner. For example, a new topic can be introduced by saying “next, you will learn the stages of the estrous cycle” rather than “the stages of the estrous cycle will be described next”.

- **The Coherence Principle** states that concise explanations without extraneous information are most effective for minimizing cognitive load.¹¹⁻¹² Extraneous information can include ancillary videos, background music, sound effects and supplementary written material that do not pertain to the core information. Extraneous information almost always distracts the learner and decreases learning because the learner is trying to sort the information into relevant and not relevant categories rather than focusing directly on the topic. In reproductive science, there are many differences among species. The instructor might try to embed the differences within the core concepts. This significantly increases the cognitive load and often confuses students.

We have applied these principles in the development of multimedia presentations that describe complex concepts in reproductive physiology. Our research and development pathway is presented in Figure 1. The pathway is divided into two sections: 1) single concept (~10-15 min) development and experimentation; and, 2) multiple concept (~60 min) development. The single concept experiments built upon short-term presentations with an immediate measure of knowledge gains. Details of these results are published elsewhere.¹³⁻¹⁵ The multiple concept development phase focuses on longer multimedia programs incorporated into an online setting.
Review of single concept research/development

During the single concept phase, we have shown that learning is increased when instructional design principles were employed to describe several concepts in reproductive science. These topics were: “Mammalian Follicular Dynamics”, “The Physiology of Parturition”, “The Menstrual Cycle and Oral Contraception”, “Assisted Reproductive Technology” and “Lactation and Nursing” (access to multimedia programs are available upon request). All multimedia presentations include the following features:

- 2-D and 3-D animations (animation principle\textsuperscript{16,17})
- Synchronized narration (personalization\textsuperscript{9,10} and temporal contiguity principles\textsuperscript{5,6})
- On-screen labels (spatial contiguity principle\textsuperscript{5}) and,
- No extraneous information (coherence principle\textsuperscript{11,12})

Overall, the single concept research phase included over 1,400 students from six land grant universities and 122 patients at an OB-GYN clinic. A summary of experimental outcomes is described below.

Multimedia components

Our first research effort compared test scores after students viewed either a multimedia presentation of mammalian follicular dynamics or a traditional lecture captured on video.\textsuperscript{13} Students who viewed the multimedia presentation scored 15.5% higher \( (p < 0.05) \) on tests of the material than students who viewed the videoed lecture (78% and 62.5%, respectively). Furthermore, the multimedia presentation required one-half the time of that for the video lecture. The second experiment (using “Mammalian Follicular Dynamics” as the topic) isolated the effect of 3-D animation on student learning.\textsuperscript{13} Again, the results of test scores favored \( (p < 0.10) \) the 3-D component of the multimedia presentation.

Two experiments were then conducted to examine the impact of animation type and narration length on student learning.\textsuperscript{14} Students in the animation study were randomly assigned to one of three groups and viewed a presentation on “The Menstrual Cycle and Oral Contraception” with no animation, 2-D only animation, or 3-D animation. Type of animation did not influence test scores, indicating that some concepts (like learning the basics of the menstrual cycle and oral contraception) do not require 3-D animation to successfully transfer information. However, some concepts like follicular dynamics 

Figure 1. Pathway of multimedia experiments using multiple reproductive physiology topics. The pathway is divided into two phases (single concept and multiple concepts).
appeared to be dependent on 3-D animation for the learner to successfully process and assimilate the information.

Next, students were randomly assigned to view a presentation describing “The Physiology of Parturition” to compare narration length (short narration-14 min vs. long narration-24 min). There was no difference between student test scores for narration length; indicating that students can learn effectively when explanations are concise, even in a short time period. Explanations that are longer than necessary are inefficient for both the instructor and the student.

Knowledge retention

The next research question was, “does a multimedia presentation extend knowledge retention when compared to a traditional lecture”? An experiment was conducted with university students (n = 46) that measured test scores immediately after viewing, one week later, and one month after viewing the presentation. Students did not know when the second and third tests would be given so that they did not have an opportunity to study prior to the tests. Again, students in the multimedia group significantly outperformed (p < 0.05) students viewing the traditional lecture captured on video. Furthermore, there was a significant (p < 0.05) effect for time after viewing. Mean test scores (out of a possible 25 questions) for the multimedia group were 64.32%, 56.52% and 64.52% correct; whereas mean test scores for the traditional video lecture group were 56.88%, 49.56% and 53.40%, respectively, for students tested immediately after viewing, one week later, and one month after viewing each type of presentation. As expected, test scores declined over time, indicating that consistent studying is necessary to maintain knowledge. Interestingly, when the resident professor gave a review session between the second and third test, students in the multimedia group had test scores similar to that of just having watched the presentation. In contrast, the test scores in the traditional lecture video did not return to the original test score, indicating that a brief review of the material following a multimedia presentation is an efficient method for teaching and learning.

Educational background of audience

Another study was conducted to determine if the instructional design used for university students would be effective to people who are not students of reproductive physiology. Pregnant women (n = 122, with various ages, parity and educational levels) at Northwest OB-GYN clinic in Spokane, WA were asked to view the presentation, “The Physiology of Parturition” or read a booklet containing the same graphics and descriptions and complete a short multiple-choice quiz. Women in the multimedia group significantly outperformed (p < 0.05) women in the booklet group. Although not a direct comparison, 15 test items on this test were identical to a previous test given to university students. The university multimedia group’s score was 88%, while the patient group’s score was 83%, indicating that proper instructional design of complex information can be used to teach a wide variety of people, especially when the concepts are applicable on a personal level.

Multiple concept development

During the fall of 2013, we conducted a Beta test with three content units that consisted of multiple concepts at three universities (North Carolina State University, South Dakota University and Montana State University; see Tables 1, 2 and 3). The objectives of this qualitative study were to: 1) test the online platform delivery to determine functionality limitations; 2) determine student reactions and feedback to platform use and instructional design; and, 3) measure student learning and navigational behavior within each content unit. The online platform was developed by SchooX (www.schoox.com; access to the content units available upon request). The platform allowed students to access information at their own pace and monitor their progress in each content unit (i.e., how many segments completed and quiz score/attempts). All professors required the textbook, Pathways to pregnancy and parturition-3rd ed in their classrooms.

The content units were: “Male Reproductive Anatomy and Function” (NCSU, n = 47), “Reproductive Cyclicity: Terminology and Basic Concepts” (SDSU, n = 76), and “Reproductive
Cyclicty: The Follicular Phase” (MSU, n = 65). Each content unit consisted of multimedia presentations containing Powerpoint® presentations and illustrations using Bamboo® software. Each multimedia section was synchronized with narration describing each concept. After viewing the multimedia sections in the content unit, students completed a quiz and brief survey. Students were allowed to take the quiz as many times as they wished. Participating instructors agreed to not lecture on the content unit prior to the Beta test. Quiz scores counted towards their overall course grades. Students from NCSU accessed the online content during the second week of the semester, SDSU students participated during the seventh week of the semester and MSU students accessed the online content during the eighth week of the semester. A summary of outcomes is provided below.

- Quiz performance was high (see Table 4):
  - 57.3% of the students scored a 90% or above
  - 16.8% scored 80-89%
  - 5.6% scored 70-79%, and
  - 20.6% scored 60% or below

- Features of the online content unit were ranked according to perceived importance by the students:
  - Over 50% of the students ranked ease of access, self-paced learning and the fact that the content was linked to the textbook as the most important factors
  - Synchronized narration and practice tests were ranked lower in importance

- Overall experience accessing the content units was positive (see Tables 5 and 6):
  - 84.7% of the students ranked the content units as “good to exceptional” (of which, 56.1% ranked the content as “great or exceptional”)
  - 14.6% ranked the content unit as fair
  - 30% ranked their content unit as poor

Results from the Beta test are quite encouraging but certainly require further testing for accuracy and precision. Future efforts will include determining: 1) better testing/grading features; 2) a “Frequently Asked Questions” section; and, 3) improved student behavior monitoring to easily identify problem areas within each content section.

**Beta test discussion**

**Quiz scores**

Quiz scores were exceptionally high and probably reflected the fact that students could engage the quiz as many times as they liked until a satisfactory score was achieved. In addition, the motivation for obtaining as many points as possible to help with their overall course grade cannot be separated from other factors. Many students ranked the practice quizzes lower in the content unit because they found the answers to be very unforgiving. For example, if students typed in a correct answer that was not in the test bank or spelled words incorrectly, then these were marked as incorrect answers. More possible correct answer combinations will need to be incorporated into the quiz bank for future use to eliminate this problem. This is one limitation of a software-based testing system compared to an instructor personally grading each answer and interpreting what the student meant.

**Student navigation behavior**

Another advantage to using an online platform to deliver information is the ability to track each student’s navigational behavior, something that one cannot do in the classroom. For example, some students might prefer to take the practice quiz first and then access content unit sections only to fill knowledge gaps, while other students might view an entire section and then answer the quiz questions. Each type of behavior might result in increased learning for individual students.

When using the quiz feature, many students accessed the corresponding content several times as they answered the quiz questions, using the multimedia sections as an “open book resource”. Only a few
students accessed the content minimally and focused on practicing with the quiz rather than revisiting the content. Some students did not access the multimedia sections at all and instead, chose to read the book and then answer the questions. Student navigational behavior can be used to modify content delivery and platform compatibility so that different studying styles can be automatically accommodated. However, more research and development is needed to determine which features of this type of platform will function the best in an online setting.

Conclusion and future implications

Updated versions of the platform will be built so that the instructional team can better understand where, and perhaps why, students have difficulty understanding. Specific sections of the multimedia presentations that are reviewed repeatedly and correspond to related quiz questions can be pinpointed to isolate “trouble spots” and improve the delivery so that a more thorough understanding is achieved. Additionally, quiz responses can be collected over time to determine which incorrect answer is marked the most and review the corresponding content unit section to determine why students are confused or missed the point. Then the instructor can effectively modify the explanation or test items to reduce confusion and misunderstanding in the future. Our ultimate research and development goal is to validate the components of online delivery that will enable implementation of a highly accurate and efficient multimedia delivery platform to maximize a student’s learning experience and understanding of complex processes in reproductive science.

References

### Table 1. Participation

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>University enrollment</td>
<td>54</td>
<td>76</td>
<td>67</td>
<td>197</td>
</tr>
<tr>
<td>Online enrollment</td>
<td>49</td>
<td>76</td>
<td>67</td>
<td>192 (97.5%)</td>
</tr>
<tr>
<td>Online quiz</td>
<td>47</td>
<td>76</td>
<td>65</td>
<td>188 (95.4%)</td>
</tr>
<tr>
<td>Online survey</td>
<td>48</td>
<td>59</td>
<td>45</td>
<td>152 (77.1%)</td>
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</tbody>
</table>

### Table 2. Demographics - Class Rank (% Responses)

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>0.0</td>
<td>1.8</td>
<td>0.0</td>
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<tr>
<td>Sophomore</td>
<td>8.3</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Junior</td>
<td>58.3</td>
<td>7.1</td>
<td>51.1</td>
</tr>
<tr>
<td>Senior</td>
<td>29.7</td>
<td>91.1</td>
<td>46.7</td>
</tr>
</tbody>
</table>

### Table 3. Demographics - Animal Experience (% of Responses*)

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grew up on commercial farm, animal business</td>
<td>20.8</td>
<td>58.9</td>
<td>37.8</td>
</tr>
<tr>
<td>Worked for commercial farm</td>
<td>29.2</td>
<td>39.3</td>
<td>40.0</td>
</tr>
<tr>
<td>4-H/FFA</td>
<td>25.0</td>
<td>53.6</td>
<td>64.4</td>
</tr>
<tr>
<td>Limited to pets</td>
<td>50.0</td>
<td>23.2</td>
<td>33.3</td>
</tr>
<tr>
<td>Worked for veterinarian</td>
<td>68.8</td>
<td>30.4</td>
<td>48.9</td>
</tr>
<tr>
<td>No experience</td>
<td>4.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*responses are greater than 100% because students checked all applicable categories

### Table 4. Test Performance (% of Students and Mean # of Quiz Attempts)

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Students</td>
<td># attempts</td>
<td>% students</td>
<td># attempts</td>
<td>% students</td>
</tr>
<tr>
<td>A (90%)</td>
<td>39.6</td>
<td>3.5</td>
<td>80.3</td>
<td>3.5</td>
</tr>
<tr>
<td>B (80%)</td>
<td>10.4</td>
<td>1.3</td>
<td>17.1</td>
<td>2.8</td>
</tr>
<tr>
<td>C (70%)</td>
<td>6.3</td>
<td>2.0</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>D (60%)</td>
<td>8.3</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>F (&lt;60%)</td>
<td>35.4</td>
<td>1.7</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*mean number of attempts skewed as one student took the quiz 12 times

### Table 5. Would You Recommend This Content Unit to Other Students?

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>40</td>
<td>96.4</td>
<td>82.2</td>
<td>72.9</td>
</tr>
<tr>
<td>No</td>
<td>60</td>
<td>3.6</td>
<td>17.8</td>
<td>27.1</td>
</tr>
</tbody>
</table>

### Table 6. Overall Experience Ranking

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good-Exceptional</td>
<td>54.2</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Fair</td>
<td>14.6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Poor</td>
<td>30.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

% Rank of Exceptional or Great

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>SDSU</th>
<th>MSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCSU</td>
<td>31.3</td>
<td>68.4</td>
<td>68.5</td>
</tr>
</tbody>
</table>