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Formative Evaluation of a Web-based Multimedia Intervention to Support Learning of Statistics

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Abstract: Tailoring information to the needs of the learner is an important strategy in teaching complex concepts. Web-based learning modules informed by multimedia theory for teaching declarative and procedural knowledge (statistical terminology, concepts, and procedures) were introduced to a mathematics course designed to teach undergraduate students. The formative evaluation of these modules was conducted over a period of two trimesters (August to December 2015 and January to April 2016) with a total of 187 students and six instructors. Students' perceptions on the modules' usability features (e.g., pace of audio presentations, ease of navigation, and layout) as well as on cognitive support and effectiveness of the modules were analyzed. Students and instructors' reflections on their experiences with the modules were also gathered and analyzed. Both set of participants were overwhelmingly positive about their online learning and teaching experiences of statistics. Suggestions for improvement included having more multimedia lectures, showing more examples as well as calculator tutorials, and asking more comprehension questions in the modules.

1 INTRODUCTION

Teaching and learning mathematics has often been identified as challenging and a barrier to students' graduation in higher education (Complete College America, 2011). For this reason, a mathematics course was redesigned with the purpose to increase student retention and the number of students receiving passing grades. Also, better support for students whose time schedules prevented them from attending synchronous online sessions needed to be offered.

In face of these challenges, a course re-design was done to a mathematics course offered at a large non-profit private university with a large selection of online courses and programs, named Franklin University for the purpose of this study. The data analysis prior to the re-design revealed that there was a need to better support the needs of undergraduate students taking the course. This conclusion was made based on faculty members' interviews and student course evaluations. Most of students were adult learners who had to juggle work, family responsibilities, and financial commitments along with their academic programs. The majority of the students who took the mathematics course as an online section was not even able to attend the live synchronous sessions because of schedule conflicts. To better address the needs of these students, a series of web-based learning modules (refereed here as Software) was created. It consisted of weekly web-based multimedia interactive lectures and aimed to help students synthesize the statistical knowledge and check their understanding of terminology, concepts, and procedures. An example can be viewed at http://video.franklin.edu/Franklin/statistics/1a/story.html

This proposal focuses on the evaluative efforts to judge the learning value of the Software. It describes the two rounds of formative evaluation conducted between August 2015 and April 2016.

2 LEARNING OF STATISTICS AND COMPUTER ASSISTED LEARNING

Repetitive practice through carefully selected and managed examples is considered an important way of learning statistics. It allows students to construct generalizations and see patterns (Petty, 2012). The

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efficient way of engaging students in repetitive practice is using auto-graded assignments that can be provided by a textbook publisher or an in-house system.

Larwin and Larwin (2011), in their meta-analysis study found that Computer Assisted Instruction (CAI) has a moderate impact on student achievement. Some researchers emphasized that technology needs to be used not only for computing numbers but for concept exploration (Moore, 1997; Garfield et al., 2000). Others stated that technology has the potential to expand the range of visualization techniques that can help learners understand concepts (Chance et al., 2007). Including embedded comprehension questions in CAI can be considered as an additional benefit (Sklar and Zwick, 2009). Also, animated presentations of statistical concepts can help non-statistical majors learn statistics (Sklar and Zwick, 2009). Wender and Muehlboeck (2003) found that computer-animated graphics were more effective than static images in teaching statistics and the use of computer-animated graphics resulted in better students understanding of statistical concepts and retention of the material.

Kirschner et al., (2006) advocated a strong emphasis on guidance of the student learning process. The Cognitive Theory of Multimedia Learning describes the cognitive process that occur when exposed to multimedia learning (Moreno and Mayer, 2000). Using both of the auditory and visual channels, student learning through multimedia instruction can be enhanced as information is presented. Keller's attention, relevance, confidence, and satisfaction (ARCS) model features enhancing and sustaining motivation strategies. Instructional designers can build into the software interface a menu-driven program structure, which enhances learners' confidence by providing control access to different parts of courseware (Song and Keller, 2001).

3 METHODS

3.1 The Intervention

According to the report from Complete College America (2011), for part-time students, the chances of graduation with a 4-year bachelor's degree within 8 years is 24.3%. Moreover, graduation rates are especially low for poor, older students (Complete College America, 2011). Since Franklin University undergraduate students largely fall into the above categories, it was important to count success of every student. Most Franklin University students are first generation college students who work part-time and balance work, classes and family responsibilities. The majority of them are financial aid recipients. Student average age is 33.27 years. Table 1 summarizes the average statistics of undergraduate student population at Franklin University.

Table 1: Statistics of Undergraduate Student Population at Franklin University.

Category	Percentage
Race	Caucasians - 66.7% African Americans - 21.6% Asians - 3.2% Hispanic - 3.2% Others - 5.3%
Student Status	Full time - 33.6% Part time – 66.4%
Financial Aid Recipients	70 %
Gender	Males – 43.5% Females – 56.5%

3.2 The Software

Twenty-eight web-based multimedia modules were created targeting the weekly learning outcomes. Topics included sampling, types of data, graphs, variance and standard deviation, percentiles, rules of probabilities, confidence intervals, hypothesis testing, tests with qualitative data, correlation coefficient and least-squares regression.

The Software were not only designed to provide additional information but rather to increase students' understanding of key concepts through the use of multimedia instruction and periodic checks of student comprehension. At Franklin University the Software targeted students in both sections of the mathematics course, online and face-to-face. Details on the design of the Software are described in Alpay et al, 2014.

3.3 Study Design

This study explores students' and instructor perceptions of the benefit and value of the Software. Students' perceptions and instructors' feedback of the intervention were collected over the period of two trimesters (August to December 2015 and January to April 2016) at Franklin University.

The focus of the first formative evaluation was to collect preliminary information on the Software effectiveness and usability. It took place between August and December of 2015. The instrument for collecting student perceptions consisted of four parts, as follows:

Part 1: a table for reporting any bugs that students

could potentially encounter in any of the modules was made available.

Part 2: students were asked to rate 14 statements (see Table 3) on the rating scale of 5 (5-strongly agree; 1-strongly disagree) about the Software assigned for their review. Students were asked to evaluate:

1. three usability features, such as pace of the audio presentations, ease of navigation, and layout of the Software.
2. overall experience with the Software.
3. sufficiency of cognitive support provided by the Software.
4. helpfulness of Software features, such as:
   a. explanations
   b. real-life examples
   c. summary slides
   d. transcript of lectures
   e. self-assessment questions
   f. supplemental content (tips for how to use a calculator, topic videos, etc.)
   g. program feedback to self-assessment questions

Part 3: students answered two open-ended questions about what they liked about the Software and what changes they would like to make, if any.

Part 4: students were asked to write a paragraph about their learning experience with the Software and provide examples to illustrate which specific program features and/or instructional strategies helped/did not help them learn the new material.

The second round of formative evaluation evaluated the Software after minor bugs were fixed.

The examples of the bugs: (1) a few buttons on some screens did not work the way it was expected; (2) a few pop-up windows did not work the way it was expected. Since no major problems with software design were found in the first round, the data collection instruments to seek additional student feedback on the value of the Software remained the same in the second round. Thus, the design of the second round of the evaluation in the second trimester (January to April 2016) did not change.

On both rounds of formative evaluation, instructors' feedback was collected through an anonymous online survey on Survey Monkey. The instructors answered six open-ended questions focused on how the Software was used in the course by students and instructors.

3.4 Data Collection Process

The data was collected from four sources: (1) students' responses to two open-ended questions, (2) students' survey ratings of the Software features, (3) student reflections on their experiences and, (4) instructors' responses to six open-ended questions via online survey.

Data were analyzed for recurring themes related to the helpfulness of the Software features and instructional strategies used in the mathematics course. The data were triangulated to ensure the reliability and validity of the instruments. The data collection instruments corresponding to the research questions are presented in Table 2.

Table 2: Research Questions and Data Collection Instruments.

Research questions	Data collection instruments
1. What were the students' perceptions of how the Software supported their cognitive processing of the target concepts? 2. What was the overall student experience with the Software? 3. What unanticipated problems did students and instructors experience with the Software? 4. Which features and instructional strategies implemented in the Software were the most and least helpful to students and instructors?	Online survey consisting of 14 statements, 2 open-ended questions and a reflection summary. Students could take the survey at their convenience within the allocated time for response. Students rated their experience with the Software using a rating scale of 5 (5-strongly agree, 1-strongly disagree).
5. What were the instructors' perceptions of student use of the Software? 6. What was the instructor's overall experience with the use of the Software in this course? 7. What effect did Software have on the role of the instructor and the effectiveness of instruction in the course?	Online survey consisting of six open-ended questions. Instructors could take the survey at their convenience within the allocated time for response.

Franklin University Institutional Review Board approved this study. An informed consent was obtained from instructors before they completed an anonymous online survey. Students who participated in the study were given bonus credits. Students who did not participated were given alternative course activities to gain equivalent number of credits.

After reviewing the modules, student-participants would fill out the survey form. Since students would be sending the signed consent forms to the research assistant in a random fashion, this would ensure the fact that the research assistant could assign modules to students sequentially with a goal of having the same proportion of evaluations for each

module. This task assignment schema guaranteed that the multimedia modules were assigned to students in a random fashion. The research assistant kept track of the assigned/unassigned multimedia lectures, the students' responses, their bonus points and survey results.

3.5 Participants

All students of Franklin University who were enrolled in the mathematics course were eligible to participate in the study. Out of 236 students enrolled in the course between August and December of 2015, 147 students (62%) took the course online and 89 students (38%) were enrolled in the face to face section. Eighty-six of the enrolled students (36%) agreed to participate in the first round of formative evaluation of the Software. From January to April of 2016, out of the 209 students enrolled in the course, 131 (63%) took it in online and 78 (37%) in a face to face format. Eighty-one students (39%) agreed to participate in the second round of the formative evaluation.

Six instructors out of 13 (46%) participated in the study between August and December of 2015, two of them taught face to face sections and another four taught online sections.

Six instructors out of 13 (46%) participated in the study between January and April of 2016 three of them taught face to face sections and another three taught online sections.

4 RESULTS

4.1 Summary of Students' Quantitative Data

As reflected in Table 3 below, students' experiences with the Software were overwhelmingly positive.

Students rated the usability of the Software very high. The majority of the formative evaluation participants strongly agreed that they liked the layout, navigation, and pace of the instruction. See items 1, 2, 9 in Table 3. Most participants strongly agreed that the Software design supported their cognitive processing of the new information. See items 6, 7, 8 in Table 3.

The vast majority of the students found the Check Your Learning questions embedded in the Software helpful. Also, they highly valued the program feedback providing the explanation of correct answers, and they found the feedback sufficient. See items 10, 11 in Table 3.

Table 3: Students' experiences with the Software.

Survey question #	Aug-Dec 2015 **Mean (SD)**	Jan-Apr 2016 **Mean (SD)**
1.	4.7 (0.83)	4.7 (0.59)
2.	4.7 (0.73)	4.7 (0.53)
3.	4.6 (1.2)	4.7 (0.67)
4.	4.5 (0.94)	4.5 (0.76)
5.	4.1 (1.06)	4.3 (0.89)
6.	4.6 (0.79)	4.7 (0.55)
7.	4.4 (0.79)	4.5 (0.71)
8.	4.5 (0.85)	4.4 (0.69)
9.	4.5 (1.35)	4.5 (0.78)
10.	4.5(0.72)	4.6 (0.73)
11.	4.3 (0.79)	4.4 (0.91)
12.	4.3 (0.96)	4.4 (0.84)
13.	4.6 (0.72)	4.7 (0.62)
14.	4.5 (0.84)	4.6 (0.61)

Survey questions (5-strongly agree; 1-strongly disagree): 1. I liked the layout of the sections in the lecture; 2. I liked the navigation in the sections in the lecture; 3. I liked the explanation and the examples used in the informational slides of the lecture sections; 4. I liked the summary slides used throughout the sections; 5. I found the transcript option useful; 6. The sections helped me understand this week's material, 7. The section design helped me retain the new information; 8. The section design helped me maintain my attention; 9. I found the self-assessment feature (Check Your Learning questions) helpful; 10. The answer feedback to the Check Your Learning questions (explanations of the correct answers) were helpful; 11. The answer feedback to the Check Your Learning questions was sufficient; 12. I liked the supplemental content (if any), such as calculator tips and topic videos; 13. The pace of the content was good; 14. I enjoyed my experience using the lectures.

Such features as access to audio transcripts and supplemental materials (for example, help on how to use the calculator for accomplishing specific tasks) were highly valued by some students, but not by all of them. See items 5, 12 in in Table 3. This can be attributed to the difference in student prior knowledge of the topics. Transcripts allowed students with high prior knowledge to briefly go over familiar material. For example, the calculator help was used only by those students who needed it.

The overwhelming majority of the study participants enjoyed their experience with the Software. See item 14 in in Table 3.

4.2 Summary of Students' Qualitative Data

Thematic content analysis was used for summarizing themes from student reflections on their learning experiences with the Software supported by illustrative examples. The themes fell under 4 categories:

- Effectiveness of multimedia design - software usability and visual design
- Effectiveness of multimedia instructional design – helpfulness of software features
- Effectiveness of support for cognitive processing of information provided by the Software
- Overall satisfaction with the Software

"Composite" responses that reflected the content of all the responses in each category were created and tabulated. The most frequent themes are presented at the top of the list. Eighty-six students provided their comments. Some students commented on more than one theme. The results are presented in Tables 4 to 7.

Table 4: The themes from students' comments about effectiveness of multimedia design.

Theme	Aug-Dec 2015 **# comments**	Jan-Apr 2016 **# comments**
Supports well self-paced learning	25	30
The pace is appropriate	17	26
The quality of narration is appropriate	14	12
Easy to navigate	44	39
Colors are visually appealing	10	24
Color coding supports the information processing	7	10
The length of mini lectures was appropriate	16	25

Overall, there were no negative comments, only positive ones. Students were happy with all aspects of the Software. They thought that the lectures gave a classroom feel to a non-classroom approach to learning. Students found that the lectures were very user-friendly and supported cognitive processing of the new information effectively.

Table 5: The themes from students' comments about effectiveness of multimedia instructional design – helpfulness of software features.

Theme	Aug-Dec 2015 **# comments**	Jan-Apr 2016 **# comments**
Summary slides are helpful	25	36
Real-life examples are helpful	23	17
Explanations are helpful to guide student learning	34	32
Self-assessments at the end of each chapter reinforce student learning	39	44
Program feedback on student answers to quiz questions is helpful and sufficient	46	50
Supplemental materials were helpful	24	21
The calculator tutorial was helpful	19	25
Inclusion of audio transcripts is helpful	20	21
Graphics and tables were helpful	18	12
Animated examples helped understand concepts	20	11

Students used the Software as preparation for doing homework assignments (27 comments) and preparation for exams (9 comments). Also, students highly recommended building similar lectures for other courses in which complex concepts are taught.

Table 6: The themes from students' comments about effectiveness of support for cognitive processing of information provided by the multimedia lectures.

Theme	Aug-Dec 2015 **# comments**	Jan-Apr2016 **# comments**
Helped students understand the material	32	34
Helped students remember the material	37	23
Theme	Aug-Dec 2015 **# comments**	Jan-Apr2016 **# comments**
Helped students maintain their attention	24	37
Helped students organize information for encoding into long-term memory	13	6

There were a few suggestions for improvement. Twenty students asked that more self-assessment questions be included in the Software. Nine students recommended three tries instead of two tries on the self-assessment questions. Four students would like to have a section containing all the videos teaching how to use calculators in one single place. Four students would like to have a reference to the specific page in the textbook. This last suggestion would help

Table 7: The themes from students' comments about overall satisfaction.

Theme	Aug-Dec 2015 **# comments**	Jan-Apr2016 **# comments**
Reduces phobia of math	7	6
Recommendation to build similar lectures for other courses	10	12
Satisfaction with the Software	25	32

students go to the textbook, if extra study is required without spending time searching it.

Based on the bugs report, students' suggestions for corrections were collected. Students' suggestions were tabulated by the research assistant and corrected by the multimedia designer.

During the second trimester (January to April 2016), most of the themes that came from students' comments remained the same compared to the first trimester (August to December 2015). The major new theme that emerged was about having student experiences with the Software graded. One of the students, wrote the following comment:

"Because these interactive lectures were not mandatory, I did not complete them for every section. When I felt like I was stuck on a problem or having a hard time remembering the material, I would use these lectures. I wish I had gone about the class differently and used these lectures each week. My reasoning was that because the amount of work in this class is so large, on top of the other classes I was taking, and my personal life, I did not have time to complete something if it was not part of the grade. It would be nice if these lectures counted for a portion of our grade."

4.3 Instructors' Feedback

As to instructor participants, all of them (two face to face instructors and four online instructors in August to December 2015 and three face to face instructors and three online instructors in January to April 2016) provided favorable comments about the Software. Most of them recommended that their students should use the Software before they come to class or during synchronous online sessions. All the instructors believed that the Software was a good resource for helping students understand complex statistical concepts. Half of the instructors considered the Software as a tool that provided helpful ideas for teaching statistical concepts. Composite responses that reflected the content of all the instructor responses in each category were created and tabulated (see Table 8).

Table 8: Instructor comments about their perceived effectiveness of the Software.

Areas of inquiry based on research questions	Composite responses	# instructors comments
The use of the Software by the instructor for teaching the course	The web-based multimedia modules were highly recommended for students to watch before class	6
Effect of the software on the instructor role, if any	It frees instructor time for discussing and clarifying complex concepts in class and during synchronous online sessions. Good addition to the course.	6
The use of the Software during online synchronous sessions or in class, if any	a) Some screens in the Software were used during the synchronous online sessions to help students visualize complex concepts; b) Played the videos in the Software instead of lecturing. This was not a very successful experience because the instructor lost students' interest.	5 1
Perceived student reactions to the Software	Positive comments from students because it helps clarify the weekly material	6
Perceived effect of the software on student understanding of the topics	Excellent resource, supports understanding of the material because it is chunked down into easy to understand pieces.	6
The use of the Software for professional development, if any	a) The software provides helpful suggestions to the instructor on how to help students understand the concepts; b) The Software did not have any impact on professional development	3 3

5 DISCUSSION AND CONCLUSIONS

Most of the students who participated in the evaluation of the Software found it highly valuable for their learning. The web-based multimedia modules provided invaluable instructional support for online students, as well as face to face students. Students favored self-paced instruction, dual coding of information supported by multimedia lectures, systematic instruction of complex subject matter for online students, the opportunity to review the material at a later time, clear, concise and effective instruction, multiple examples, comprehension questions with explanatory program feedback and many other aspects of the Software.

Interestingly, students used the Software in additional ways that their instructors did not anticipate. It was not only used as initial learning before classroom instruction, but also served for reviewing the course material and for test preparation.

Surprisingly, one of the most valuable features in the Software appeared to be comprehension questions augmented with explanatory feedback. Also, several students mentioned that they would like to have similar instruction in other courses. Others regretted that student experience with the software was not part of their course grade. They thought that if the Software experience were graded, more students would be using it for their benefit. One of the unanticipated consequences of the formative evaluation study was that by exposing students to the Software, the number of students who started using it on a regular basis increased because they realized that this was a more effective and efficient way of learning statistics.

The following comments were chosen as the best representations of student experience with the Software. They are:

- "I have done much with online classes and various interactive programs such as Pearson Math XL, Webassign, and McGrawHill Math connect. The interactive lectures on the Franklin course site are far better than any of the others I have used."
- "I really enjoy the interactive lectures. I think it gives a classroom feel to a non-classroom approach to learning."
- "At the beginning of the math course, I didn't look at the interactive lecture and opted to read the book and assist the SLA meetings on Thursdays. One day I decided to listen to the interactive lecture to see if it was helpful. I really liked it because I was able to hear someone explain the course and give concrete examples I could relate to. It really helped me understand the idea behind each chapter and what each formula and equation was used for."
- "My experiences with this interactive were completely positive. Having this experience with the interactive lectures really helped bring the lesson plan alive; in class the professor can go over and show example but with the interactive series it allows you to stop and replay whichever sections you may not understand."

5.1 Suggestions for Improvement

The major suggestions for improvement were about building additional interactive multimedia lectures for this course and similar resources for other math courses. Some students wanted to have more multimedia presentation of the new material, more examples, more calculator tutorials, and more comprehension questions in the Software.

5.2 Study Strengths and Limitations

Only 36% and 39 % of the students enrolled in the course between August 2015 and April 2016 participated in the evaluation. Thus, it is likely that the respondents were those who potentially might benefit from the Software use. Although not representative of the entire cohort of students, this formative evaluation provides useful information for the design and development of multimedia educational materials to teach statistics and support the needs of online students. The results of the study demonstrated that students valued the principles of sound educational practices applied to both online and face to face instruction. Also, student comments provided preliminary evidence of the effectiveness of web-based multimedia modules. This study benefits the field of multimedia instructional design by reporting on specific strategies employed to produce effective instructional solutions.

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