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Online Resource Utilization in a Hybrid Course in Engineering Graphics

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ABSTRACT

This presentation focuses on an ongoing instructional innovation research and development project centered around the development of a blended, online and face-to-face introductory engineering graphics course. The work presented here is an in-depth analysis of how students make use of the online resources to supplement the instructional support they receive in class. The researchers were particularly interested in answering questions concerning not only *what* resources were accessed, but *in what order*, and whether there is any statistical correlation to *learning outcomes*. In this study, the focus was on resources related to the textbook materials and quizzes and tests associated with this material. The data being analyzed was collected from 180 students taught by two different instructors over one semester. Background on the project, analysis of Moodle log file data, along with recommendations for further refinement of instructional strategies will be presented.

Keywords: blended instruction, online assessments, log file analysis.

INTRODUCTION

The movement to online education using computer-based systems has been well underway for over 10 years [1]. Among other reasons, higher education administration has sensed the potential of budgetary savings in the delivery of material online that has historically been delivered in lectures [2]. More importantly, the use of information-computer technologies (ICT) as a means to broaden participation on higher education and support 21st century skills [3] has only accelerated the pace of development of online learning opportunities in post-secondary education. Not surprisingly, engineering education has been among the areas pursuing online course offerings even though

practitioners and researchers have also noted the particular challenges of providing online instruction for curriculum that has a large laboratory component [4].

To address some of the difficulties of repurposing all of a course's content online, a method chosen by many engineering instructors is a blended, or hybrid, style of course offering where some of the course material that was originally delivered in a traditional face-to-face setting is instead delivered online [5]. Some of the course content, however, continues to be provided in a face-to-face model of instruction. In such an approach, lab-based material that is hard to transform into online content can continue to be taught in a face-to-face, synchronous manner. A hybrid format provides flexibility in delivery and format that at times can be hard to match with comparable traditional methods [6]. The asynchronous nature of web-based materials means that much of it can be viewed anytime, anyplace, and as many times as desired [7]. It follows that students often express a preference for this style of delivery [8]. In addition to distributing instructional content between online and face-to-face modes, a hybrid course can also provide a layered approach where the same material is delivered in different modes—both online and face-to-face [2].

One of the reasons for moving course content online is the potential for making use of a learning management systems (LMS). These software-based systems can not only display web-based content, but serve to manage and automate many of the administrative functions of a course [9]. This automation of administrative functions lowers the barriers to using ongoing formative and summative assessments where the grading is partially or completely automated by the system [10, 11]. As such, textbook or lecture content that was previously only assessed at a mid-term or final exam can now be reinforced though ongoing formative assessments in the form of weekly quizzes. For many of the reasons listed above, both students and teachers have indicated the perceived value of the learning tools made available in online courses [12].

In summary, newer web-based LMS systems have provided flexible options for componentized delivery of engineering course resources in the media and format that best suits learning outcomes and student acceptance, especially the delivery of material that was historically provided in a lecture setting. A hybrid course can, ideally, offer the best of face-to-face and online by selecting the delivery method best tuned for the learning goals and preferences of the students [13, 14]. A recent, large scale meta-analysis of educational research studies of online instruction [15] noted that, overall, instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction. It also noted that this difference may not be necessarily rooted in the media used per se, but instead may reflect differences in a combination of content, pedagogy and learning time. That is, what is important is not only *what* is provided to students and *how* it was structured in the learning environment, but also *how much time* the students spent with it.

This finding points up the fact that online learning can be enhanced by giving learners control of their interactions with media, prompting learner reflection. Studies [15] indicate that manipulations that trigger more learner engagement through learner reflection and self-monitoring of understanding are effective when students pursue online learning as individuals. However, the meta-analysis by Means and colleagues [15] goes on say that elements such as video or online quizzes are not necessarily utilized as much as one would hope. The practice of providing online quizzes, in and of itself, does not seem to be more effective than other tactics such as assigning homework.

Findings by Means and others raises interesting questions concerning how best to determine what resources to provide to students in a hybrid course and how to structure them so they will be utilized effectively in learning. Clearly, for instructional materials to support learning, they have to be used by students. It is not surprising that DeNeui and Dodge [16] found a significant positive partial correlation between overall LMS usage and student exam scores. A study by Hensley [10], in a comparison of purely online, hybrid, and face-to-face versions of the same pair of courses, showed significantly higher final grades for a purely online course over both the face-to-face and hybrid. However, the differences may have been the result of the removal of some of the motivating factors to make use of the online resources in the hybrid format compared to when all of the material could only be accessed online. Previous work by the authors [17] has shown that, when used, online materials such as weekly assessments provided motivation to study the textbook material.

The Graphic Communications faculty at North Carolina State University began offering a blended or hybrid version of their introductory engineering graphics course in the Fall 2007 semester [18, 19]. The move was made in response to both budgetary pressures and a desire to provide a richer, more consistent presentation of what had traditionally been the lecture component of the course. The move to a hybrid format also provided the opportunity to provide a richer set of formative assessment opportunities and a centralized repository for online tutorials that were used in the lab component of the course. This move meant that one, two-hour meeting per week (primarily devoted to lecture on the textbook material) "went online." The online portion of the course consisted of units (Figure 1) where students could watch streaming media of textbook lectures (Figure 2), solid modeling demonstrations (Figure 3), and sketching demonstrations (Figure 4). The online units also included weekly quizzes on the textbook material (Figure 5). This hybrid format still included a two-hour face-to-face meeting each week where faculty introduce the main concepts for the unit, answer questions about solid modeling and sketching activities, and check some homework.

In order to better understand the impact of this marked change in course structure, a design-based study [20, 21] was instituted as part of an ongoing continuous improvement of instruction [22]. The goal was to carefully and systematically study student learning outcomes and attempt to understand how changes in course structure (and resulting instructor and student behaviors)

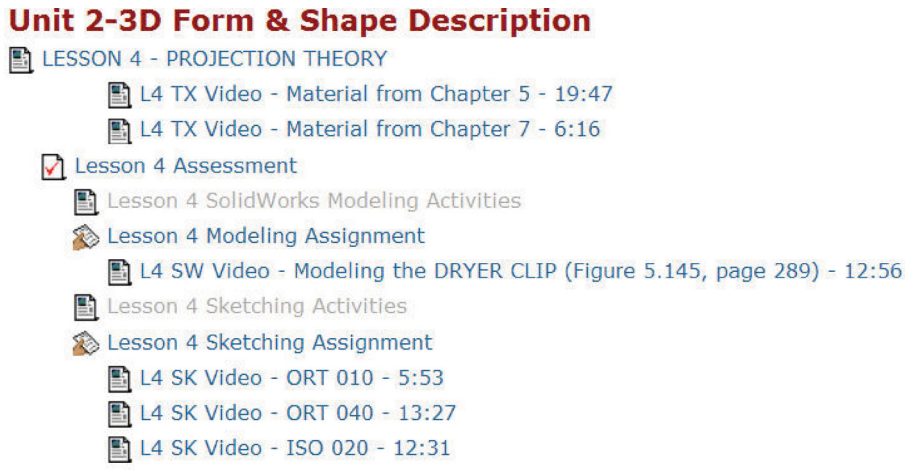

Figure 1: Example of an Online Unit for the Course.

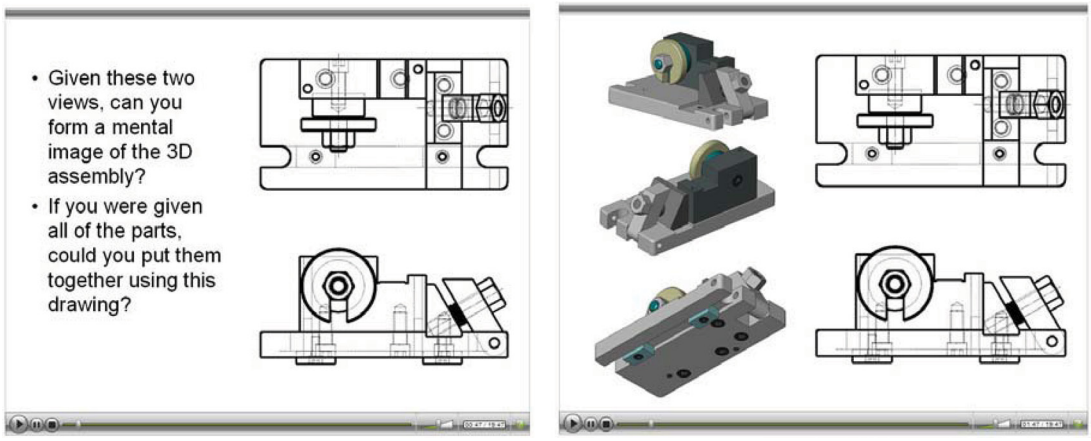

Figure 2: Examples of Online Lecture Media.

were linked to these outcomes. As is the nature of design-based research, this process is iterative with the analytic outcomes from each semester feeding into modifications of the course for the upcoming semester.

Self-report data collected in the Fall 2007 and Fall 2008 semesters indicated general satisfaction with new course design. In addition, the collected data showed a correlation between performance on these weekly assessments and the final course grade as well as providing motivation to study

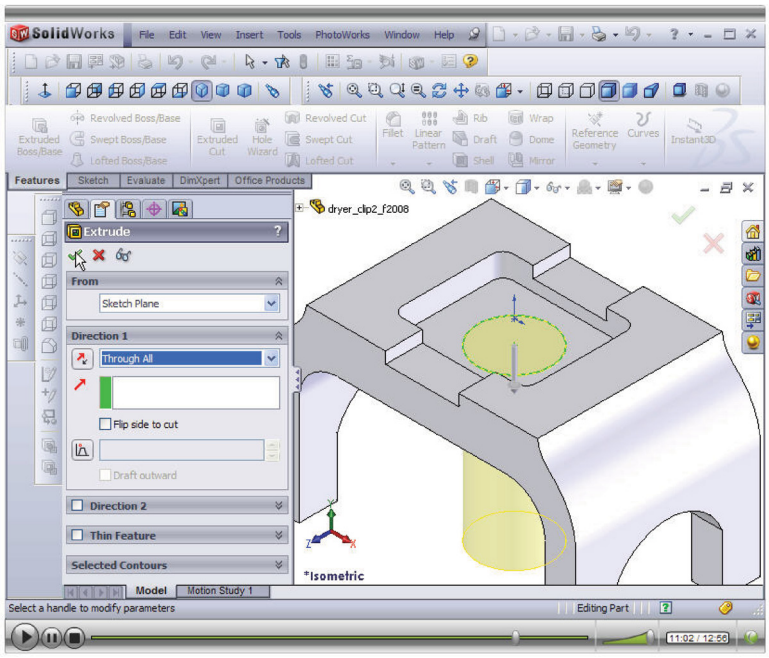

Figure 3: Example of Online Solid Modeling Demonstration.

the textbook material [17]. One interesting finding from this initial research was self-report data on how the online resources were being utilized by the students. Streaming media presentations of the textbook material, solid modeling demonstrations, and sketching demonstrations were organized on course web pages. Students could navigate through the pages in any order. Each week students also were asked to complete an online assessment or quiz in the LMS. Post-course surveys were used to get feedback from students about how they used the online materials. In the Fall 2007 classes, students reported 19 different resource utilization sequence strategies for completing the material related to the textbook.

For the spring 2009 semester, all online materials were moved to the Moodle LMS. By placing materials within Moodle, the authors could better track how students were navigating through the course. While the self-report data from students on how they used the online materials collected in our previous studies was insightful, it still suffered from students needing to accurately recall what instructional resources they used and in what order. While students may have been able to recall how they were making use of the instructional resources at the end of the semester, there were questions as to whether they could accurately recall what their pattern of use at the beginning of the semester. In addition, the survey did not attempt to gather information on whether this pattern

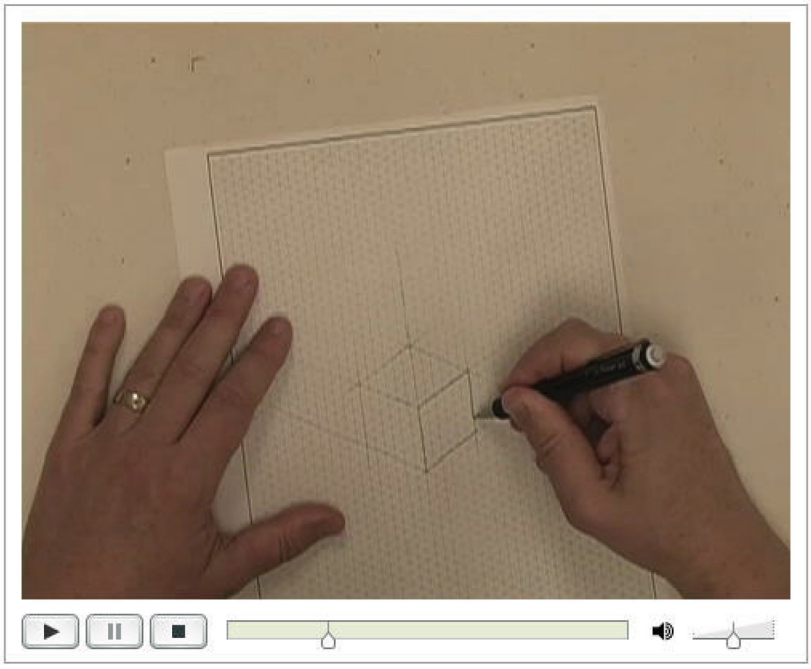

Figure 4: Example of an Online Sketching Demonstration.

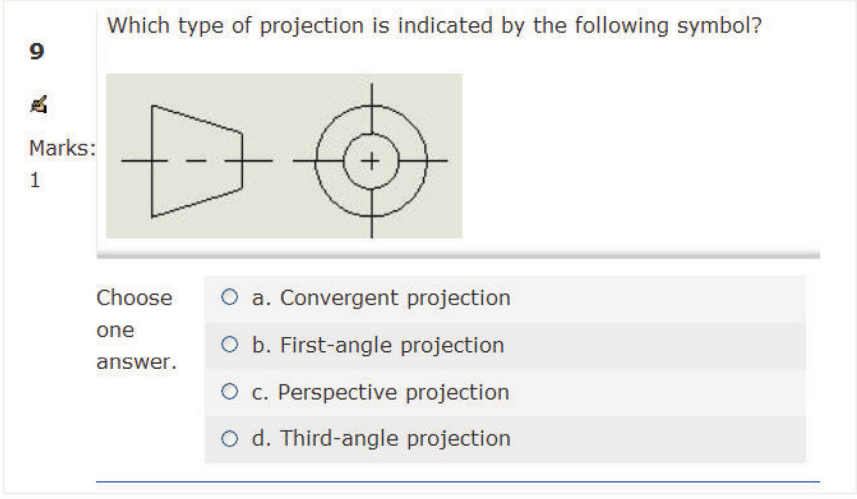

Figure 5: Example of an Online Assessment Item in the Course.

of use changed over the course of the semester. The online logging capabilities of Moodle allows the accurate tracking of the online resources students accessed and how these patterns may have changed over the course of the semester. [23]. Online usage logs have been used in other studies [23–25] to better understand how online resources were being used and how these usage patterns might relate to learning outcomes. Of continued interest was whether the resources provided to the students for reviewing the textbook content—formatively assessing their knowledge, and therefore reflect on their understanding—was being used and what the relationship was between their use and exam scores (the summative assessment for the course). This type of analysis would provide greater insight as to the role of online resources in supporting student learning over of the course of the semester.

In the design of the hybrid course, suppositions were made both as to what online resources would be of use to students in learning the course content and how these materials would be used. These suppositions were arrived at both from the prior research noted above and from our ongoing design-based study with this course. We were interested in testing these suppositions by looking at the use of the video-based PowerPoints™ (called Video in our analysis) and online quizzes (called Quiz) and whether there was a relationship between this usage and their final exam (called Exam). These suppositions were:

1. Students should be reading the assigned textbook materials, reviewing the materials with the Video presentations and then testing their knowledge with the Quizzes.
2. The Quizzes serve as a formative assessment of how well they have retained key concepts and terms. Since they can take the Quiz twice, they can also use the Quizzes to help cement material and to point to gaps that they can then review.
3. Since the Quizzes count for 10% of their grade, there is an incentive to review materials (textbook and/or Video) prior to taking the quiz.
4. The Video is arguably a better way to enhance learning of textbook material than the quizzes, and watching the Video then taking the Quiz is best.
5. Ongoing use of Video and Quizzes will help prepare students for the summative assessment (final exam).
6. With a total of nine possible units with Video and Quiz combinations, examining material from Units 1, 5 and 9 would give us a good look at student instructional resource usage behaviors at the beginning, middle, and end of the semester.
7. Students use of resources would change over time, with the highest level of conformance to the ideal (using all available resources) being at the beginning of the semester and then tailing off as the semester progressed.

Using these suppositions, the following research questions and hypotheses were explored:

Q1: What is the relationship between the number of quiz attempts and final exam score?
H1: Number of units in which there was at least one quiz attempt will correlate with the final exam score.

Q2: What is the relationship between the accessed and used resources (video, quizzes) and final exam score?
H2a: Use of the Video in Units 1, 5, 9 would predict Exam score
H2b: Use of the Video and then taking the Quiz in Units 1, 5, 9 would predict Exam score

Q3: How does access and use of resources change over time?
H3a: Use of the Video would change between Units 1, 5, 9
H3b: Use of the Video and then taking the Quiz would change between Units 1, 5, 9

METHODOLOGY

During the fall 2009 semester, three blended learning sections of GC120 were studied. All online materials were accessed only through Moodle. An additional difference in these sections from previous semesters was the enrollment for each section was set at a maximum of 60 students instead of 24 in previous semesters. Tables 1–3 display the demographic data of the students in the blended sections of the course.

As in previous semesters, students were required to view and complete online materials on a weekly basis. Materials were organized into 12 weekly online units. Each unit consisted of streaming media presentations of the textbook material, streaming media SolidWorks™ demonstrations, and streaming media sketching demonstrations. Students also had to complete a 10–20 question Quiz in Units 1 through 5 and 8 through 11 as a check of their textbook knowledge (Units 6, 7 and 12 did not have assigned textbook material). They were given two attempts at each assessment, if needed.

Section	Frequency	Percent
003	55	34%
004	56	34%
005	53	32%
TOTAL	164	100%

Table 1: Enrollment Per Blended Section of GC120.

Year	Frequency	Percent
Freshmen	4	2%
Sophomore	115	70%
Junior	29	18%
Senior	16	10%
TOTAL	164	100%

Table 2: Academic Year.

Major	Frequency	Percent
Aerospace Engineering	17	10%
Civil Engineering / Construction Management	45	27%
Mechanical Engineering	44	27%
Other Engineering Majors	29	18%
Education	7	4%
First Year College	8	5%
Other Majors	14	9%
TOTAL	164	100%

Table 3: Academic Major.

For each assessment, there was paired a streaming video of a voiced-over PowerPoint™ presentation of the key concepts of the required textbook readings for the week (the Video).

Moodle logging tools were used to record when each of these resources were accessed for each student. Data was extracted from the logs for each student enrolled in the course. A purposeful sample of Moodle units was examined, with data for Units 1, 5 and 9 used for this study. Students who did not take the final exam in the course were excluded from the sample.

RESULTS

Tables 4–6 display the order in which students completed the Videos and the Quizzes for these three units. Because students could take the Quizzes twice, access the Video as many times as they wanted, and use both these resources in any order they wanted, there were a number of possible permutations of how students accessed these materials.

During Unit 1 the most popular strategy for students was viewing the streaming media video and then taking the online assessment twice (38%). As stated earlier, students were allowed a maximum of

Order of Activities	Frequency	Percent
VQQ	63	38%
VQ	52	32%
V	16	10%
QQ	11	7%
Q	7	4%
VQVQ	7	4%
Did not view media or complete assessment	5	3%
QQV	2	1%
VQV	1	1%
TOTAL	164	100%

Q: Attempt at online assessment/quiz.
V: Viewed streaming media video of textbook material.

Table 4: Order Students Completed Moodle Activities in Unit 1.

Order of Activities	Frequency	Percent
Q	45	28%
VQQ	42	26%
QQ	35	21%
VQVQ	13	8%
Did not view media or complete assessment	11	7%
VQ	10	6%
V	4	2%
QVQ	4	2%
TOTAL	164	100%

Table 5: Order Students Completed Moodle Activities in Unit 5.

two attempts at each assessment. The second most popular strategy in Unit 1 was viewing the streaming media video and then taking the online assessment once (32%), followed by only viewing the video (10%). In Unit 5 the most common strategies for students were taking the online quiz without viewing the streaming media video (28%), viewing the streaming media video and then taking the online assessment twice (26%), and taking the assessment twice without viewing the streaming media video (21%). The top three strategies used in Unit 9 were viewing the streaming media video and then taking the online assessment twice (27%), taking the assessment twice without viewing the streaming media video (23%), and taking the assessment once without viewing the streaming media video (20%). Tables 4–6 revealed a total of ten different possible sequences:

Order of Activities	Frequency	Percent
VQQ	44	27%
QQ	38	23%
Q	32	20%
Did not view media or complete assessment	25	15%
VQ	12	7%
V	5	3%
VQVQ	4	2%
QQV	3	2%
QVQ	1	1%
TOTAL	164	100%

Table 6: Order Students Completed Moodle Activities in Unit 9.

Watched Video (Vyes)?	Sequences
No (0)	Q, QQ, Nothing
Yes (1)	V, VQ, VQQ, VQV, VQVQ, QQV, QVQ

Table 7: Sequence Grouping based on Watching the Video.

Watched Video and took Quiz? (VQyes)	Sequences
No (0)	Q, QQ, V, QQV, Nothing
Yes (1)	VQ, VQQ, VQVQ, VQV, QVQ

Table 8: Sequence Grouping based on Watching the Video and Taking the Quiz.

Mean	81.76
Std. Deviation	8.76
Minimum	54
Maximum	98

Table 9: Exam Score Descriptive Statistics.

			Total Quiz Attempts	Exam Score
Spearman's rho	Total Quiz Attempts	Correlation Coefficient	1.000	.181*
		Sig. (1-tailed)	.	.012
		N	164	156
	Exam Score	Correlation Coefficient	.181*	1.000
		Sig. (1-tailed)	.012	.
		N	156	156

*. Correlation is significant at the 0.05 level (1-tailed).

Table 10: Correlations – Total Quiz Attempts × Exam Score.

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.213	.045	.039	8.603	.045	7.319	1	154	.008	
2	.223	.050	.037	8.610	.005	.729	1	153	.395	
3	.237	.056	.037	8.610	.006	.997	1	152	.320	1.950

Model 1 - Predictors: (Constant), Vyes5

Model 2 - Predictors: (Constant), Vyes5, Vyes9

Model 3 - Predictors: (Constant), Vyes5, Vyes9, Vyes1

Dependent variable for all models: Exam

Table 11: Vyes X Exam Regression Model Summary[d].

1. V
2. VQ
3. VQQ
4. VQV
5. VQVQ
6. QQV
7. QVQ
8. Q
9. QQ
10. Nothing

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	541.605	1	541.605	7.319	.008
	Residual	11396.620	154	74.004		
	Total	11938.224	155			
2	Regression	595.623	2	297.811	4.017	.020
	Residual	11342.602	153	74.135		
	Total	11938.224	155			
3	Regression	669.570	3	223.190	3.011	.032
	Residual	11268.654	152	74.136		
	Total	11938.224	155			

Model 1 - Predictors: (Constant), Vyes5

Model 2 - Predictors: (Constant), Vyes5, Vyes9

Model 3 - Predictors: (Constant), Vyes5, Vyes9, Vyes1

Dependent variable for all models: Exam

Table 12: Vyes X Exam ANOVA[d].

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.204	.042	.035	8.619	.042	6.699	1	154	.011	
2	.226	.051	.039	8.605	.009	1.513	1	153	.221	
3	.228	.052	.033	8.630	.001	.123	1	152	.726	1.949

Model 1 - Predictors: (Constant), Vyes5

Model 2 - Predictors: (Constant), Vyes5, Vyes9

Model 3 - Predictors: (Constant), Vyes5, Vyes9, Vyes1

Dependent variable for all models: Exam

Table 13: VQyes X Exam Regression Model Summary[d].

These sequences can be organized into two groups based on whether the sequence included watching the Video (Vyes) (Table 7).

A second way is to group those sequences that included both watching the Video (at least once) before taking the Quiz (at least once)—called VQyes (Table 8):

This method of organizing the possible sequences of instructional resource utilization provides a means for answering the previously posed research questions and paired hypotheses. Answering

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	497.640	1	497.640	6.699	.011
	Residual	11440.585	154	74.290		
	Total	11938.224	155			
2	Regression	609.665	2	304.833	4.117	.018
	Residual	11328.559	153	74.043		
	Total	11938.224	155			
3	Regression	618.835	3	206.278	2.770	.044
	Residual	11319.389	152	74.470		
	Total	11938.224	155			

Model 1 - Predictors: (Constant), Vyes5

Model 2 - Predictors: (Constant), Vyes5, Vyes9

Model 3 - Predictors: (Constant), Vyes5, Vyes9, Vyes1

Dependent variable for all models: Exam

Table 14: VQyes X Exam ANOVA[d].

	Value	
	No (0)	Yes (1)
Vyes1	23	141
Vyes5	91	73
Vyes9	95	69

Table 15: Frequency Counts for Vyes.

	Value	
	No (0)	Yes (1)
VQyes1	41	123
VQyes5	95	69
VQyes9	103	61

Table 16: Frequency Counts for VQyes.

these research questions, then, provides a means of comparing our suppositions about optimal usage of the resources against actual usage. The research hypotheses are used to organize the quantitative results, with these results relative to the research questions synthesized in the Discussion. Students' final exam score (Exam) is used as part of analyses for all of the research hypotheses. The Exam variable descriptive statistics are provided in Table 9

H1: Number of units in which there was at least one Quiz attempt will correlate with the final Exam score.

A Kolmogorov-Smirnov test of normality showed that the distribution of number of quiz attempts was non-normal ($p < .001$), therefore a Spearman correlation was used (Table 10). There was a significant correlation ($rho = .181$, $p < .05$) between the number of quiz attempts and final exam score.

H2a: Use of the Video (Vyes) in Units 1, 5, 9 would predict Exam score

H2b: Use of the Video and then taking the Quiz (VQyes) in Units 1, 5, 9 would predict Exam score

Initial analysis of Vyes indicated that Video use in Unit 5 had the highest correlation with Exam, with Unit 9 next and then Unit 1. Therefore a forward step-wise regression was modeled, adding Units 5, 9 , and 1 in that order (Tables 11 and 12). The model shows that Vyes5 was the best predictor of Exam score and that Vyes9 and Vyes1 did not add anything to the prediction. Results of Durbin-Watson test, tolerance and VIF indicate that assumptions of residual independence and collinearity were not violated.

A parallel examination of Video plus Quiz (VQyes) revealed very similar results, with VQyes5 being the best predictor and VQyes9 and VQyes1 adding very little to the model (Tables 13 and 14).

H3a: Use of the Video (Vyes) would change between Units 1, 5, 9

H3b: Use of the Video and then taking the Quiz (VQyes) would change between Units 1, 5, 9

Since Vyes and VQyes can be considered repeated measures and that these measures can also be considered bivariate categorical data, a Cochran's Q test was conducted to test the null hypothesis that there was no change in the categorical variable (Vyes or VQyes) over time (Units 1, 5, and 9). Separate tests were run for Vyes (Table 15) and VQyes (Table 16). Both tests for both Vyes ($Q = 101.28$; $p < .001$) and VQyes ($Q = 74.17$; $p < .001$) were significant. Examination of the counts showed that a majority of students conformed to the ideals (view the Video then take the Quiz) at the beginning of the semester (Unit 1) but that this pattern reversed by Unit 5, dropping off slightly more by Unit 9.

DISCUSSION

This study was part of an ongoing design-based study examining how the move to a hybrid course format impacted engineering graphics students' learning. Confirming the self-report findings in previous studies of our online course, students used a diversity of approaches to making use of the online resources. While a number of students followed the explicitly recommended order of material use (i.e., view the streaming video before attempting the quiz), many students took alternate approaches to usage and usage order. Research Question 1 was focused on whether use of the formative assessment resource, the online quizzes, was positively correlated with performance on the final exam (the summative assessment of the same course content). The results seem to indicate that the instructors had done a good job aligning the formative and summative components and that usage of this formative assessment resource was associated with higher scores on the final exam.

With the weekly online quiz assessments only worth a total of 10% of students' final grade and the midterm and final worth collectively 40% of the grade, it was our assumption that students primarily saw the value in the weekly assessments as a reflection tool preparing them for the larger summative assessments of the midterm and final. The data collected seem to support the conclusion that those students who attempted more weekly assessments (and/or made use of the streaming videos) did better on the final exam.

Research Question 2 explored the supposition that use of the video-based PowerPoint™ presentations, in combination with the online quizzes, would predict the final exam score. Models exploring the Video only and the Video in conjunction with the Quiz showed themselves significant but rather modest predictors of final exam scores. Interestingly, it was the Quiz taken just before the midterm (Unit 5) that had the highest predictive power. Perhaps that during the first week of class (Unit 1), students all conformed more or less to expectations articulated by the instructor. By the end of the course (Unit 9), there were usual pressures related to the end of the semester. These different external pressures at the beginning and the end of the semester may have altered the relationship between resource usage and exam score.

Findings related to Research Question 3 also support the role of external pressures that seem to weigh on students at different points in the semester. Students did conform most closely to the ideal as articulated by the instructors at the beginning of the semester, but fell off significantly in their use of these resources by the end of the semester. Interestingly, this fall-off was already evident by mid-semester. While students may have determined themselves that the Video and Quizzes were not of enough value to spend time on them, the results of the correlational and regression analyses seems to indicate that they are of value in improving performance on the final exam. It may be

instead, that building pressures on a student's time more than a conscious decision to forgo these resources led the students to stop using them.

The findings from this study have a number of implications for other instructors implementing purely online or hybrid engineering courses. The flexibility provided by LMSs means that students can be given great latitude as to when they access materials and how they use them as part of their overall learning strategy for the course. Our studies show that when provided flexible access, students will use the resources (or not) in a wide variety of sequences to serve what they perceive is their learning needs. Our current study also demonstrates that how a student accesses these resources changes over the course of the semester, probably due both to their ongoing experience with the course and the changing time pressures that normally build over the course of an academic semester. We clearly saw a drop-off in the use of resources over the course of the semester. It may be that if the weekly quizzes were worth more of the final grade, they would have been taken more seriously. However, the higher percentage weighting on the quizzes would have made them less of a formative, self-study tool for the students and more of a high-stakes mini-summative assessment. If an instructor has a strong preference as to the sequence in which resources are accessed, they may want to investigate the tools available in their particular LMS to control the order in which materials are accessed. Similarly, "time window" tools can be used to control when items are available. For the course in this study, weekly quizzes were only available for a few days during the week of that particular lesson, preventing students from cramming for multiple quizzes closer to exam time. All of this needs to balanced against the general student preference for flexibility in making use of instructional resources.

CONCLUSION

Probably the most important finding of this study is that the logging tools provided in Moodle provides a powerful way for instructors to gather and analyze data on how students make use of the resources provided online. Future work will include exploration with new ways these tools can be deployed to support course development, teaching and learning. The researchers found it much easier to chart student trends and performance in a more accurate way than in past incarnations of this course. This provides instructors with better information to use in the redesign of course materials for the future with the desire to aid the students more in learning the material. Since the production of the multimedia learning resources is a labor-intensive practice, this formative data for the instructor provides valuable evidence as to whether such material is being used by students and whether it provides real educational value. Another possible avenue for research would be to

see if demographic variables, such as year in school or gender, predict different patterns of usage. Just as usage patterns of course resources seem to vary over time, they may also vary between different student sub-populations. In the short-term, resource (especially quiz) utilization monitoring can help alert instructors to students whose use of the course materials may have changed markedly during the course of the semester.

One of the limitations of this study was the granularity of the log data. The researchers were able to identify if a resource, like a video, was accessed but not how long it was viewed, or if segments were replayed. Future research work will look at developing methods for more fine-grained analysis of log data. This work would include more data points over the semester to better understand trends, analysis of first versus second tries on quizzes, and the use of SCORM-compliant learning resources [26] in conjunction with Moodle that allow richer data collection usage (e.g., how long did they view a video and how many times did they stop and start it). In addition, this work will also move into analyzing resources related to the laboratory portion of the course. This study also had the general limitation as to how both formative and summative assessments were conducted—that is, primarily through multiple choice questions. While the lab portion of the course created CAD files of student work that provided insight into learning the applied portion of the course, we are continuing to look for assessment tools to use in conjunction with the textbook content that provide richer data. Again, log data—in this case, how students might interact with queries and probes provided by the LMS—may help provide a mechanism for this.

In conclusion, this study demonstrated that LMSs like Moodle both provide expanded flexibility in the types of learning resources provided to students and the tools provided to instructors for monitoring their use. An important finding of this study was that use of these resources changed over the course of the semester and that monitoring these patterns of change may help alert instructors to emerging learning patterns, which may impact students' mastery of course content. Further research in this area that might enhance the power of this monitoring would be to focus both on increasing the granularity of the log data collected on resource utilization and expanding the types of assessments used to assess student learning.

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