Designing Blended Content Modules as Support to Traditional Face-to-Face Delivery: An Application to Data Analysis, Inferential Statistics, and Simulation Experiments Courses

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Abstract

Due to the boom in technological innovations and the accessibility to web-assisted tools, blended instructional environments have dramatically increased the options for content delivery in non-traditional formats. While several questions have arisen regarding the benefits and pedagogical challenges of blended instructional models, the use of these environments has quickly spread across higher education. Programs have adopted blended learning environments mainly due to three reasons: 1) improved pedagogy, 2) increased access/flexibility, and 3) increased cost effectiveness. The Industrial Engineering Department at Universidad del Norte, a large private university in Colombia, the Engineering Department and the School of Business at Colorado State University – Pueblo, a regional comprehensive university in the United States have been planning on transitioning and incorporating web-assisted tools into their curriculum. This work focuses on the designing stage of blended modules containing theoretical and applied content, common to three statistic courses, in order to support Face-to-Face delivery.

This paper presents the process of designing, including the assessing component, of web-based modules to support the traditional Face-to- Face delivery of the theoretical and applied aspects of two discrete and two continuous distributions. Both are core concepts to the Data Analysis and Simulation Experiments courses taught to juniors in the Bachelor of Science in Industrial Engineering (BSIE) and Inferential Statistics course taught to all sophomores in the School of Business. Once the concepts and theoretical aspects have been introduced to the students, the courses proceed to introduce diverse applications of the distributions by using examples from both manufacturing and service systems. Two of the main students' complaints about the delivery of these concepts are the pace and scope of the Face-to-Face delivery. Furthermore, the failure rate and its implications for statistics courses' scheduling and faculty assignment play an important role at both universities. In this proposed blended format, students on all of the courses will be presented with the concepts and exercises about the mentioned statistical distributions, before the Face-to-Face session in a self-timed delivery mode. In order to assess if this blended format increases the understanding about both the discrete and continuous distributions, three control and three experimental groups at each department/college will be evaluated. The control groups, one on each course, will not have access to the blended modules. Two different groups of outcomes will be assessed in this design: summative and formative outcomes. Summative outcomes, i.e. related to understanding of the concepts will be assessed by using tests and home works while the formative outcomes such as engagement, self-

advocacy, satisfaction with the learning experience, and peer-to-peer collaboration will be assessed by using surveys.

Background

The landscape of education has changed as technology has opened many avenues to facilitate the interactions that traditionally took place in a face-to-face setting. Increasingly, authors are pointing out the advantages of utilizing different approaches to the traditional lecture for college students (See Bishop and Vergler[1], Kellogg[2], and Toto and Nguyen[3]) for instance. These novel methods (flipped classroom, blended instruction, and hybrid instruction) are usually focused on growing student engagement through the use of technology as a platform for the student-content interactions as well as to support peer-to-peer interactions (Heplestone et al.[4] and Sarder[5]). However, it is difficult to establish the optimal "blend" while implementing these student-centered learning strategies (Thai et al.[6]).

While several studies have documented positive results in the use of the aforesaid methods (Alvarez[7], Strayer[8], Ferrari and O'Connor[9]), Frydenberg[10] cautions that these alternatives are not a "one size fits all" solution. Student engagement remains a challenge as it did in the traditional model: when moving the initial student-content interaction outside the classroom (assuming that the artifacts used for this interaction are as effective as they are in the traditional setting (McNeil[11], Zhang et al.[12])), the initiative to engage with the material comes solely from the student (Herreid and Schiller[13]). Furthermore, the student-instructor and student peer-to-peer interactions should be designed in such way students engage at a deeper level with the content (Gannod et al.[14]; Strayer[15]) by establishing meaningful connections of the acquired content when performing tasks proper of the discipline of study (Edgerton[16]). Thus, for these novel approaches to successfully improve the students' learning experience (in terms of attaining learning outcomes, engagement and self-advocacy) they should be deployed guaranteeing an alignment between the use of technology (as a facilitator of the student-content interaction) with face-to-face pedagogies of engagement (Edgerton[16], Ginns and Ellis[17]).

Staker and Horn[18] recognized that these innovative learning models have been defined in a flexible way due to the evolving nature of the field. In other words, there is not universal definition for blended or flipped learning but there have been common elements or factors that have been identified in the literature as being part of the core structure of any instance using a "blended" or "flipped" approach. Furthermore, Carman[19] argues that "some of the best-designed learning experiences draw on a blend of learning theories and philosophies" (Carman[19], p.1), making it unpractical to formulate definitions that are of normative nature. These common elements are presented in Figure 1 (adapted from Carman[19]).

Figure 1. Core pillars of a blended learning process.

When designing a learning experience using a blended approach, these five elements are instanced based on the nature of the skills and content to be mastered; the characteristics of the students; and the context in which learning will take place (Zemke[20]). Staker and Horn[18] provide a taxonomy (see Figure 2) that allows any instantiating of the elements above to be classified in one of four models: rotation, flex, self-blended, enriched-virtual (For more details on these models see Staker and Horn[18]) based on the weight and distinctive activities/artifacts used for each pillar.

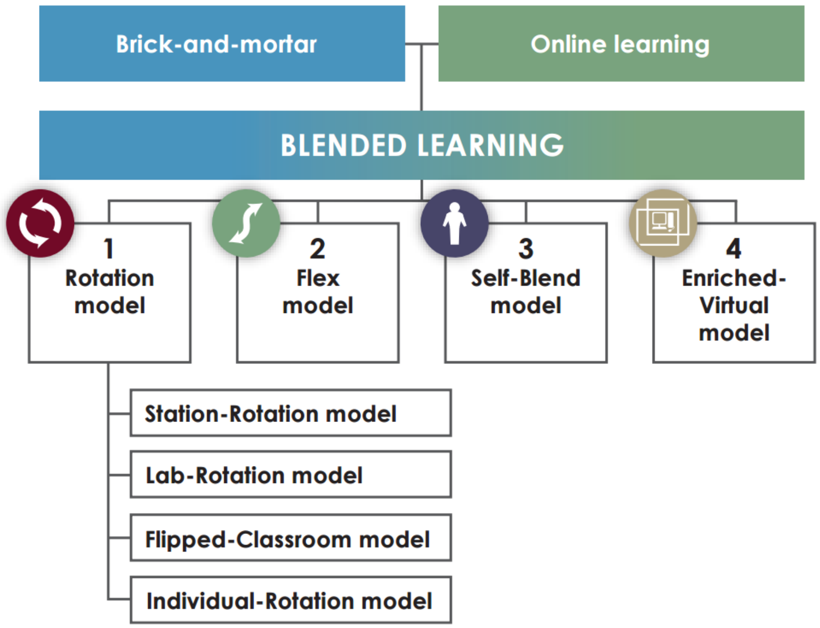

Figure 2. Taxonomy for Blended-Learning (Staker and Horn[18]).

While new technologies have facilitated, improved, and made online education openly available, designing and deploying online education tools are still challenging tasks in both business and engineering. In this paper, a rotation model, using a flipped classroom model is proposed to use jointly for some topics common to business and engineering students.

Next, detail of the design of the modules by using the blended approach will be presented followed by a preliminary discussion about assessment and implementation.

Justification

The Industrial Engineering Department at Universidad del Norte in Colombia and the Engineering Department and the School of Business at Colorado State University – Pueblo in the United States have been planning on steadily transitioning and incorporating blended learning instances mainly due to three reasons: 1) increased access/flexibility, 2) documented enhancement of the learning process, and 3) increased cost effectiveness. In the two engineering departments and the business school, there are courses that are built upon a few core concepts which are then extended and applied to specific contexts within the respective fields.

The Industrial Engineering Department at Universidad del Norte in Colombia made drastic changes in 2008 when they merged Statistics I and II, two courses for all engineering students into a single course called Data Analysis for Engineering I (DAE I). Since then, the trend of students who withdraw from or fail the course (35% in the last 5 years) has gone up. These students might be at a high risk of not being able to maintain academic good standing or of having some delay in their academic progress.

At the college of Business and the Engineering Department at Colorado State University – Pueblo in the United States, students have been complaining about the lack of time during the face-to-face interaction for applied exercises discussing the different distributions. Additionally, the two faculty members at the United States institution have noted a wide level of students' background making difficult to make progress in the face-to-face interaction towards discussing and learning about the different probability distribution (PD).

The problem of consistently poor performance of students in statistics is common and it has been studied before. Research indicates that this problem has multiple predictors related to the multiple factors usually classified into problems associated with the student, the instructor, and the university context (Chang & Beilock[21]).

Faculty at both institutions have identified some potentials causes of the students' struggle and poor academic performance when discussing and learning PD. Such factors include but are not limited to: 1) the content and the pace of teaching; 2) poor development of the reasoning skills required to developing stochastic and probability reasoning; 3) students' attitudes towards statistics courses, among other aspects.

In order to be able to design the different modules, first an analysis of the objectives of each course and their relationship to the student learning outcomes was performed. Both the Industrial Engineering Department at Universidad del Norte in Colombia and the Department of Engineering at Colorado State University – Pueblo in the United States are accredited by the Accreditation Board for Engineering and Technology (ABET), the business college at the United States is accredited by the Association to Advance Collegiate Schools of Business (AACSB). The School of Business at Colorado State University – Pueblo teaches BUSAD 265 Inferential Statistics as a core course that covers part of the quantitative analysis requirements of the AACSB accreditation. The course covers the most commonly used statistical methods in business: sampling, parameter estimation, hypothesis testing, correlation, multiple regression and chi square tests. The only prerequisite for the course is MATH 121 College Algebra hence the course taught is algebra based not calculus based. However, students are introduced to the concept of Probability Density Functions and are expected to recognize and understand the concept. Equations are provided to the students but they are expected to know how to apply them based on the characteristics of the problem or business situation under consideration. The

Department of Industrial Engineering at Universidad del Norte in Colombia teaches DAE I Data Analysis for Engineering which is calculus based. Finally, the Department of Engineering at Colorado State University – Pueblo teaches EN420 Simulation Experiments which reviews the concepts developed on EN375 Stochastic Systems Engineering which is calculus based as well.

Table 1 shows the equivalence of the objectives of each course. The objectives from the course at the Department of Engineering in the United States were used to define the equivalence. Appendix 1 shows the objectives of each course and their corresponding student learning outcomes. In table 1, for instance, course objective 1 from the Department of Engineering, "***1.** You will be able to understand and use the language and mathematics of probability*" is equivalent to objectives 1, 2, and 3 in the college of Business, "***1.** Properly calculate, interpret and communicate the results of using advanced statistical techniques to make business decisions, emphasizing on the limitations, assumptions, constraints and pitfalls associated with the results. **2.** Understand and properly apply statistical terms. **3.** Understand and properly apply visualization techniques to present relevant statistics in diverse business environment.*" and objectives 1, 2, and 17 from the Department of Industrial Engineering in Colombia, "***1.** Identify variables of interest associated with counting and measuring processes to be organized, analyzed, characterized and represented by different types of graphics. **2.** Extract information from qualitative and quantitative data sets that have been grouped (tables or graphs). **17.** Develop statistical techniques (descriptive analysis, estimation, hypothesis testing, regression models, among others) using statistical software.*"

Table 1. Equivalence of the Objectives in the three courses analyzed.

University in the United States		**University in Colombia**
Business	**Engineering**	**Industrial Engineering**
1-3	1	1, 2, 17
3-5, 9	2	1-4, 17
5	3	5-8, 17
4	4	3, 4, 17
6-7	5	9-10, 17
6-7	6	2, 10, 14, 17
8	7	11-13, 17
9-10	8	1-2, 17

In general, the three courses have similar objectives allowing the design of common blended modules. This work focuses on the designing stage of blended modules containing both *theoretical* and *applied* content, common to three courses: Data Analysis for Engineering I, Inferential Statistics and Simulation Experiments across two different countries and two different languages (English and Spanish). The design considers as common instances the Online Content and the summative and formative assessment; the other three pillars (Live Events, Collaboration, and Reference Materials) are tailored to the specific disciplines and courses. From an efficiency perspective, this study attempts to create content based on instances that could be used across disciplines and countries, maximizing the institutional resources to achieve the desired learning outcomes while enhancing the students' experience by increasing their engagement, self-advocacy, satisfaction with the learning experience, and peer-to-peer collaboration.

Design

The present work outlines the design of four group of modules for the three courses that share the Online Learning as well as the summative and formative assessment components, creating instances for the three other pillars of the blended learning process specifically tailored to the disciplines (Collaboration, Reference Materials, Live events). Participants are second year undergraduate business and engineering and third year industrial engineering students. Table 2 shows both the shared and individual instances of the five pillars of the blended learning process including the instructional elements used to create each instance.

Table 2. Instructional elements of the five pillars of the blended learning process.

		Business	Engineering	Measurement		
				Learning Outcomes	Self-advocacy	Engagement
Online Content		You tube videos using teasers and polls				✓
Assessment	Summative	Quiz (multiple choice/short answer/problems)		✓		
	Formative	Mini-challenges using Online applets/simulations of statistical distributions		✓	✓	✓
Live events		Problem-based learning[1]; instantiating per discipline			✓	
Collaboration		Peer-to-peer review of problems; class review of problems; instantiating per discipline			✓	✓
Reference materials		Case studies	Engineering Applications	✓		

[1]These problems are designed using Barrows' 6 features of problem-based learning (Barrows [22]).

At the studied universities, all business (BUS), engineering (EN), and industrial engineering (IE) students are required to take a Probability & Statistics course. At the three programs, the course is a standard introductory statistics class. The class is designed to introduce probability distributions, descriptive statistics, confidence intervals and hypothesis tests to both majors, while laying the foundation for courses in statistical process control and simulation experiments for IE majors and advanced statistics and marketing for BUS and EN majors. The paper reports the designing stage of modules to deliver the concepts of two discrete distributions (Binomial and Poisson) and two continuous distributions (Normal and Exponential) for the first time to the BUS and EN majors and as part of a review for IE majors. BUS and EN major students are expected to take it during the second semester (spring) of their sophomore year and IE majors during the second semester (spring) of their junior year. BUS and IE majors meet two times per week, 80 minutes per class. EN majors meet three times, two times for 110 minutes each and one time during 50 minutes.

In a traditional class setting for all majors, content delivery takes place in the classroom (most typically through lectures and computer exercises) and students solve homework and do other learning activities outside of classroom. In the proposed flipped environment, content delivery still occurs mainly in the class but applied activities such as exercises and home works are done outside of class, most often through online content and reference materials (See Figure 1). Class time is also used for active learning though live events and collaboration such as simple problem solving, case analysis, or problem-based learning activities that are conducted in the presence of the instructor who can intervene where needed to clarify concepts, solve problems, or pose new questions.

In this paper, four modules, one group per distribution, are designed for deployment during the spring semester of 2020 for the university at the United States and during the fall 2019 for the university in Colombia. Each module is composed of three videos, one including a description of each distribution and its properties. Two additional videos, one with basic exercises designed to introduce basic concepts and another one with exercises including examples from the manufacturing and service industries as described in Table 2.

A quasi-experimental research design is carried out to analyze the impact of the use of these modules on students' performance. One control and one experimental group for the engineering students at Universidad del Norte in Colombia and at the business students in the school of business in Colorado State University – Pueblo will be defined in separate courses. A quantitative comparison of performance means will be made using student's grades. Grades reflect, in an objective and faithful way, the result of the student's learning according to objectives of each of the three courses. A grading rubric will be designed by the faculty members both in Spanish and English in order to guarantee the validity of comparisons.

Data required for the quantitative comparison will be collected from students in the three courses analyzed. The EN major students are taught by two faculty members at Universidad del Norte in Colombia and usually are large groups of about 60 students. The same applies for the business students at the school of business in Colorado State University – Pueblo. However, for the engineering students at Colorado State University – Pueblo, the control and experimental group will be selected from the same course since just one session is taught each fall semester and this course is usually medium to small between 10 to 25 students. Students on this course will be randomly assigned to either a control or an experimental group in order to establish the comparison.

Both institutions have defined procedures for research when human subjects are involved. The large private university in Colombia through its Center for Excellence in Teaching (CEDU) has developed a generic research protocol, approved by the university ethics committee, intended to guide researchers in the treatment and use of information coming from human subjects. At the small comprehensive university in the USA, a similar protocol exists and procedures for dealing with human subjects and research involving them is clearly defined. At both institutions, students will be made aware about the research taking place and the treatment of the data obtained from them. Additionally, it will be highlighted that student participation in the study is voluntary.

Further Discussion

While the existing face-to-face delivery of the basic statistics concepts provides business and engineering students with the foundational skills necessary to understand and apply these concepts in both manufacturing and services industries, the modules proposed in this paper will eventually address the pace of the delivery since the students will be responsible to self-time the delivery of the concepts. Moreover, each module will present both basic and applied exercises for students to apply the concepts in different business and engineering environments. The proposed modules are shorter than the interactions in a face-to-face delivery method and they include basic and applied exercises for better collaboration between students. Nevertheless, this paper is a first try to use blended instructional environments as a support to the traditional face-to-face delivery method.

Furthermore, this international partnership will be beneficial for both faculty members and students. Both universities and faculty members are committed to improve academic performance through the implementation of innovative teaching-learning strategies. It is well known that international collaboration promotes advances in applied research in education. The comparison not only between universities but also between programs with the will provide insights regarding both the design and implementation of the proposed non-traditional learning environments.

Several issues arise when implementing blended learning environments. Students' motivation is still an issue. Instructors need to articulate content and activities performed asynchronously with class work and provide feedback to maintain student motivation and engagement high in order for the blended environment to be successful.

Cheating when performing online assessment becomes an issue too. While different technologies can be used to minimize cheating on online assessment this is an area still to be improved. Specifically, sharing information (videos and online evaluations) with the students from control groups needs to be taking into account when designing the materials and activities. To prevent this, instructors may use some available resources in blackboard, such as timers, randomize questions, and log in controls, among other control strategies.

Another important aspect is the pace of students' progress when studying with the online material since some students tend to watch all the material in one day and others tend to do it in a daily basis as a part of their routine of studying. Then, the instructor needs to establish strategies to synchronize the progress of students for the face-to-face encounters in class to accomplish the objectives.

The main contribution of this ongoing research is twofold, first this work proposes the design of theoretical and applied blended modules to be applied to three different statistics courses, two in engineering departments and one in a school of business. Second, it proposes the assessment of those modules based on both summative and formative outcomes. Additionally, the modules will be produced both in English and Spanish in an international collaboration.

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