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Evaluation of Techniques for Eliciting Online Interaction in Systems Engineering Courses

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Abstract

For this study, we ask the question: what circumstances lead to synchronous student interaction in the synchronous online sections of Systems Engineering courses? Observations suggest that formative assessment question and answers, class structure, and technological capabilities can play a role in determining the level of classroom interaction, but these effects have not been quantified to date. In this study, we gather quantitative data on online-student to instructor real-time interactions using the archived recordings of 6 Systems Engineering courses offered in Fall 2015. The presence and participation of the students, and the types of successful interaction elicitation techniques are described for this dataset. The challenges and opportunities of instructing synchronous sections of systems engineering courses are discussed. Results may be used to develop best practices for instructors of Systems Engineering online coursework.

Keywords

Systems Engineering, Distance Education, Graduate Education, Synchronous Online Learning

Introduction

Systems Engineering (SE) is a discipline and a sub-discipline of engineering that experts have identified as a key component of sustaining US competitiveness in the sectors of manufacturing, technology, services, and government. As such, the Colorado State University (CSU) SE graduate program has particular relevance for students engaged in distance, mid-career education. In response to feedback from industrial partners, the Systems Engineering program at CSU has developed a suite of courses that are offered concurrently online and in a classroom setting. The technologies used to broadcast the CSU SE program courses allow for student feedback, question and answer, and synchronous online interaction, but the rates and types of these student interactions varies by course, by instructor, and by semester. This papers seeks to develop a deeper understanding of what techniques for eliciting online interactions are relevant and successful in a Systems Engineering curriculum.

The Systems Engineering program at CSU is a cross-departmental graduate program offering Masters and Doctoral degrees in Systems Engineering, granted by the College of Engineering. The courses are instructed by the faculty of the Systems Engineering program which includes tenure-track faculty, adjuncts, and Professors of Practice. The courses are offered using a flexible format in which students can self-determine whether they would participate in the course through in-class attendance, synchronous online attendance, or asynchronous review of lectures and learning materials. Based on feedback that the SE program has gathered from its industrial advisory boards, the program has made a considerable effort to make the program synchronously accessible to working professionals. As examples of these efforts, the courses are instructed between 5:15pm-8:00pm on weekday evenings, courses can be streamed synchronously through home, work, or mobile devices, and students have the ability to interact synchronously through their computer microphone or through a text-based interface.

The ability for students to synchronously participate in the CSU SE program is one of the key assets of the program, but the degree to which the students are taking advantage of the capabilities of the synchronous online learning environment has not been quantified. The program seeks to understand the number and types of synchronous interaction that our students are engaging in. We seek to improve the students' learning experience by understanding these interactions and the circumstances of classroom, technology, and instruction that correspond to a high degree of synchronous interaction.

Background

Much of the research in the online learning literature is specific to the asynchronous learning environment where the student engages with the coursework through a multi-media website, and with the instructor through text based software. These studies have demonstrated that interaction in courses is a primary predictor of student and instructor satisfaction with asynchronous online courses[1]. Research in asynchronous courses has had the objective of characterizing and achieving deep learning and interaction through the development of student presence[2]. For asynchronous online students, achieving this presence in the classroom consists of carefully cultivating the social phenomena that can simulate student-to-teacher direct, conventional, social, scholarly, and learning interaction[3]. In asynchronous online learning environment, the limitations of computer mediated communication makes these types of interactions slower, with less depth of understanding, and with less social context[4]. .

As a result, synchronous online interaction is often asserted to be the preferred means of communication with learners[5,6]. Synchronous online interaction has benefits associated with preserving instructor verbal and non-verbal immediacy[7,8], enabling informal and student-to-student interaction[9], enabling student praise, and enabling instructional flexibility and formative assessment. Numerous studies document pitfalls associated with synchronous online learning including technological breakdowns, a sense of isolation, and disparities in learning outcomes between situated and online learners[10].

Advancements in audio and visual technologies associated with online synchronous learning have improved the potential for instructor-student and student-student interactions[11], but instruction must be delivered in a way that enables these interactions[12,13]. Instructors must adapt existing practices to enable student success in the synchronous online environment. The literature suggests that the degree of student synchronous interaction can be influenced by technology and interface characteristics, content area experience, student roles and instructional tasks, and information overload[14,15].

Methods

The methodology used for this study was a descriptive analysis of interaction data collected in a set of 6 graduate Systems Engineering courses offered in Fall 2015 at Colorado State University. To develop a dataset to quantify the number and types of online interactions, we observed and coded the online student presence and interactions for a randomly selected subset of the 6 courses offered. In Fall semester, 2015 the following courses were offered (with their face-to-face and distance enrollment):

- ENGR/ECE 501 – *Foundations of Systems Engineering* (88 Face-to-Face, 39 Distance students)
- ENGR/ECE 532 – *Dynamics of Complex Systems* (25 Face-to-Face, 27 Distance students)
- ENGR 530 – *Introduction to Systems Engineering Processes* (9 Face-to-Face, 21 Distance students)
- ENGR 531 – *Engineering Risk Analysis* (6 Face-to-Face, 17 Distance students)
- ENGR 567 – *Systems Engineering Architecture* (6 Face-to-Face, 9 Distance students)
- MECH 501 – *Project and Program Management* (0 Face-to-Face, 11 Distance students)

For each class period, for each of these courses, the audio, video, textual, and speaking interactions are recorded for both the students and instructors. Archives of these courses are saved in *Adobe Connect* format. Of the 88 class periods that were recorded, 24 were randomly selected for detailed review, analysis and coding. Asynchronous interactions including email, message boards, and discussion groups were not considered in this dataset. Instructors varied within and among the courses, as some of the sampled class periods were a combination of both guest lecturer and normal instructor.

Results and Discussion

Results of this study are presented in three primary areas of inquiry. First, we seek to quantify the synchronous student presence and participation relative to the class size, and relative to the class progression. Second, we seek to understand the role of course content and structure in encouraging synchronous student interaction. Finally, we seek to understand some of the the actions of the instructors that are associated with specific synchronous student interactions.

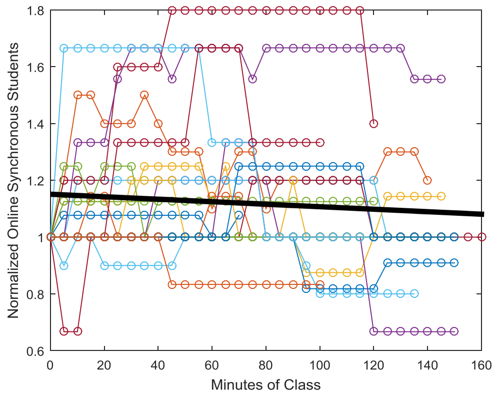

Figure 1. Timeline of synchronous student attendance in the sampled subset of courses (*n*=24, colored lines) with a fitted linear trend line (black) showing small but significant net decrease in student attendance over the class period.

Synchronous student presence and participation - To quantify the synchronous student presence and participation, the number of students who actually synchronously streamed any portion of the course was recorded for each of the sampled class periods (*n*=24). We can calculate that of the 124 distance students enrolled in the 24 class sections in the subset (566 student synchronous participations are therefore possible) students engaged with the synchronous section only 188 times (34% of the possible participations). The other 66% of the time, the online students engaged with the class by asynchronously observing the course (or not watching a lecture). Similarly, we recorded the number of students who were synchronously streaming the course with a 5 minute sampling period. The result was normalized by the number of students who were streaming the course synchronously at the beginning of the class period. As illustrated in Figure 1, the normalized number of students who are synchronously streaming the class varies over the course of the class period. Students can be observed to both join and leave the class "at the top of the hour" (after 60 and 120 minutes). There is a statistically significant trend in students leaving the synchronous environment as a function of time (by linear regression, H_0:dy/dx=0, n=583, p<0.05) although the mean rate of leaving is less than 1 student per 2.5hr class period. Finally, we counted the number and types (text communication, audio communication) of student interactions that happen during a class period. Any technical, social, or procedural interaction that originated with the student was counted as an interaction, as any of these interactions can contribute to collective community-building and culture-building in the classroom. These interactions are presented in Table 1 in the form of the mean number of synchronous interactions per (~2.5hr) class period. Pre-class microphone tests and similar functional troubleshooting were excluded from the number of student interactions. As illustrated in Table 1, some of the courses are characterized by a large number of synchronous interactions with the online students, and some of the class periods have no recorded synchronous interactions with the online students. In our sample set, there were zero interactions where a student interjected/interrupted the instructor spontaneously to ask a question using the synchronous audio. All synchronous audio interactions resulted from being "called on" by the instructor, or being asked for feedback. As a result, the preponderance of online synchronous interactions were performed by text, even in a content management system that allowed for high quality audio interaction.

Table 1. Quantification of synchronous online participation in the sampled subset of class periods

Course Identifier	Sample Mean Synchronous Interactions per Class Period	Course Content by INCOSE Definition
ENGR/ECE 501	3.9	Project Processes
ENGR/ECE 532	25.3	Technical Processes
ENGR 530	6.5	Project Processes
ENGR 531	4.7	Technical Processes
ENGR 567	0.3	Technical Processes
MECH 501	27.0	Project Processes

Systems Engineering Course Content and Structure– In developing an understanding of these discrepancies among courses, we look to whether the course content and structure of the courses influences the amount of synchronous student interaction.

Mastering the SE body of knowledge involves mastering subjects with various degrees of technical content. In CSU's SE curriculum, the student is expected to develop deep expertise in complicated and mathematical subjects (defined in the INCOSE SE Handbook as *technical processes*), as well as in qualitative analysis and soft-skills (defined in the INCOSE SE Handbook as *project, enterprise, and agreement processes*)[16]. Research indicates that in mathematical disciplines, teaching activities are more focused and instructive, with the primary emphasis being on the teacher informing the student. In contrast, teaching and learning activities in "soft" disciplines tend to be more constructive, and reflective[17,18,19]. We had hypothesized that this effect would realize itself in the SE program in that more technical process-derived courses would have fewer synchronous student interactions. As illustrated in Table 1, we do not see these effects in the data a difference in the number of synchronous student interactions between the technical courses (by one-way ANOVA, H_0:μ_T=μ_P, n=6, p=0.85). The course periods that are more technical, more mathematical, and more textbook-centric have neither more nor less online synchronous interaction as do the courses that are project, enterprise, or agreement process oriented. Instead, these results suggest that the instructors' practices have more influence on synchronous student interaction than does course subject matter.

Course structure also varies across the SE program. Some instructors present material through slides, some through writing on the virtual white board, some use class time for guest lecturing and in-class presentations. Research has suggested that the pace of lecture may be important for improving student interaction[20], but in this study we find no significant relation between the number of slides or other media presented per minute during the course periods (a surrogate for course pace), and the number of synchronous interactions (by linear regression, H_0:*slope*=0, n=24, p=0.35). In another example, many of the SE courses involved a midterm or final project whose aim is to test the broad learning objectives of the course. In many of these courses, groups made of up both online and in-class students would present their results in groups synchronously. This type of learning activity was successful in generating high-quality synchronous interactions for a few of the synchronous online students, but in our sample set of course periods there was only 1 case where synchronous students became engaged in subsequent discussions or in question and answer discussions.

Instructor actions driving synchronous student interactions - In developing an understanding of these discrepancies among courses, we look to the actions of the instructors and support staff to develop a culture where synchronous interaction of the online students is encouraged and enabled. We seek out the best practices that enable interactivity from those class periods with high rates of interaction. Many of the instructors have similar practices that are intended to enable and encourage synchronous online interaction. A subset of these are listed:

- Every instructor had some variety of "get to know you" exercise for the online students. These were in the form of a synchronous audial or textual introduction, an introductory written assignment, or similar.
- Every class period began with a formulaic textual note of welcome to the distance students. This always included offers to perform microphone checks and offers of technical assistance. Every class period ended with a formulaic textual note of thanks to the students and an invitation to participate in the next week's class period.
- Every instructor read aloud textual interaction from the synchronous online students if and when they saw the interaction. When the instructor did not see the messages from synchronous online students, an online education technician would get the professors attention and/or read the message aloud.
- In every synchronous student interaction within the subset analyzed here, the synchronous students were treated with respect, were complemented on insightful answers, and were generally included as part of the classroom culture and experience.

As evidenced by the disparities between the rates of synchronous student interaction presented in Table 1, these conditions are necessary but not sufficient for enabling synchronous student interaction. By observing the set of online synchronous interactions within our sample set, we have some analysis and generalizations that are the distinguishing factors between courses that do and do not enable these interactions.

The most successful means to prompt synchronous interactions from the on-site and the online students is for the instructors to ask a question to the class in the form of a formative assessment or variations on Socratic dialogue, then waiting for student response. For example, having completed a conceptual model, the instructor for ENGR 532 asked, "what is wrong with this model?" and awaited a student response by looking out into the classroom of on-site students. In this case, and in the case of 28 other similar questions asked to the students during that class period, the on-site students answered before the synchronous online students could formulate, type and transmit a response. For this one class period, the median time period between asking the question, and the synchronous online answer is 19 seconds. This delay is not due to technology latency or any such technical problem. Instead, I hypothesize that the online students wait for the in-class students to answer, and they then compose and transmit their responses. Alternatively, when that same instructor requests that the question be answered exclusively by the online synchronous students (either by calling on the synchronous online students as a group, or as individuals), he had a 100% success rate in developing synchronous interaction. This course period represented the sampled course period with the highest rate of synchronous online student interaction.

In the sampled course period with the lowest rate of synchronous online student interaction, the professor sought to employ similar methods, but only allowed 6 seconds of "dead time" for students to answer the question, "are there any questions online?" A 6 second wait time is considered long, by in-class standards[21], but by waiting longer to allow online students to collect their thoughts and compose an interjection, the rate of success of synchronous online interaction would be higher.

Conclusions

This study seeks to develop an understanding of the quantity, type, and drivers of synchronous online student interaction in a Systems Engineering context. The results of this work demonstrate that the synchronous online mode of learning is a popular means of engaging with distance learning technology. When prompted through some explicit instructor actions and a culture of inclusivity (regarding prompting, wait time, scheduled presentations), the synchronous online students interact often and with high-quality. This paper demonstrates how a detailed and quantitative assessment may be conducted to inform the course structure and instructor training of a Systems Engineering education program. The approach presented in this paper is structured to develop or re-inform the function of such programs effectively on the basis of information that is readily archived by conventional content management systems.

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