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FROM WATERFALL TO COLLABORATIVE: HOW THE COURSE DESIGN PROCESS EVOLVES ALONG WITH RELATIONSHIP BUILDING

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This paper discusses the instructional design experiences and processes shared by a multi-disciplinary group—including more than a dozen faculty, staff, and students—while developing a series of online courses on Model-based Systems Engineering (MBSE) for professional engineers, a project sponsored by the National Science Foundation. The team size, the complexity and uniqueness of the subject matter, the targeted learners, and the pre-determined research questions created a rare situation in which the team members collaborated and/or negotiated outside the realm of the traditional instructional design process. Over time the team went through two different types of instructional design processes, beginning with a waterfall-type process where the communication between the subject matter experts (SME) and the design team was somewhat limited and finally evolving to a collaborative process where the interaction between the two teams was more direct and immediate. The evolution of the design process and the dynamics between the SMEs and the design team resulted in several major design revisions implemented to improve the quality of the online courses.

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INTRODUCTION

This Model-based Systems Engineering (MBSE) project was funded by the National Science Foundation (NSF) with the goal of developing a series of online learning modules to address an industry-identified need for practicing engineering professionals to have the knowledge and skills of MBSE, defined as "[t]he formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (Hart, 2015). Based on the needs assessment from our industry partners, we focused on the MBSE-related skillset needed by engineers who work with MBSE engineers. From the higher education perspective, more and more companies are moving into MBSE, and engineers who work in those organizations need to have a level of exposure to work effectively. Thus, there is a need to include MBSE in the engineering curriculum so that engineering students are prepared to work in the digital environment, even if they do not become MBSE specialists in the organization.

There were two main goals we hoped to achieve through this project.

- **GOAL 1.** To develop a series of MBSE modules that provided authentic, collaborative learning experiences focused on key concepts and skills of MBSE. And the *learning content* needed to be appropriate for the target learners—professional engineers either with or without any systems engineering background.
- **GOAL 2.** To examine educational research questions included in the NSF grant proposal. Specifically, the

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SUB-GROUP	PERSONNEL
Project management	PI: Full Professor in the School of Engineering Education
The subject matter expert (SME) team	Co-PI 1: Full Professor in the School of Aeronautics and Astronautics. Expertise: Systems engineering Co-PI 2: Department Chair and Full Professor in the School of Environmental and Ecological Engineering Expertise: Manufacturing engineering Co-PI 3: Associate Professor in the Polytechnic Institute Expertise: Computer graphics technology Post-doctoral fellows, graduate students, and undergraduate students who work closely with these three Co-PIs
The program assessment and research team	Co-PI 4: Assistant Professor in the School of Engineering Education Expertise: Online course assessment Doctoral students in Engineering Education advised by Co-PI 4
The instructional design team	A senior instructional designer from the Teaching and Learning Technologies Department who is also an adjunct faculty member at the university A faculty member in the Learning Design and Technology Program in the College of Education
The program evaluation team	Two faculty members in the Learning Design and Technology Program in the College of Education

TABLE 1. MBSE Members, Expertise, and Responsibilities.

researchers asked: *to what extent an instructional design approach, based on the community of inquiry, social learning theory, and experiential learning, could create a learning environment that instilled in learners from many demographic groups a sense of belonging and promoted deep levels of learning*.

A group of experts was recruited by the PI to achieve the two goals. The members were from three different colleges within the same university and six different programs. Table 1 provides information on their roles and professional backgrounds. Prior to this project, some of the team members had worked together, but most of them had not.

It is important to note that this project began in January 2020 with the group intending to meet in person regularly. To keep the team on track and help the team members communicate with each other, the PI scheduled weekly meetings. The group had five in-person meetings prior to March 2020 when the pandemic started. Afterward, all activities were conducted virtually.

The PI and Co-PIs identified a series of learning modules based on the information obtained from a thorough needs assessment. The needs assessment consisted of interviewing corporate partners who are using or plan to use MBSE, as well as market analysis. The SME team then divided the topics into groups and took on topics based on their expertise. Overall, there are seven modules. Co-PI 1 led the design of Module 1, Module 2A, and Module 2B. Co-PI 2 led the design of Module 3 and Module 4. Co-PI 3 led the design of Module 5 and Module 6 (Capstone project). The first four modules (1, 2A, 2B, and 3) were officially offered as non-credit courses to a small group of professional engineers through the university's online program in Fall 2021. The remainder of the series was offered in Spring 2022.

The design process started with a model resembling a waterfall process model including five steps: (a) Needs assessment; (b) Content design; (c) Content development; (d) Content review; (e) First Module 1 pilot—with each step leading into the next and little to no interaction or iteration between the steps (see Figure 1). It is important to point out that the instructional design team was more involved in the development step and less in the early design process. After the first pilot of Module 1, the design process was transformed gradually to a more collaborative process in which the instructional design team and the SME team worked closely and collaboratively (see Figure 4). This paper will discuss the journey the team took from the beginning of the project to

its present status and our reflections on that process. What does this process imply from a holistic perspective? What could we have done to avoid the unintentional disconnection among the team members?

THE DESIGN PROCESS

While we had two clear goals before we embarked on our journey, there were unknowns. We did not fully know what topics we needed to include in our modules nor how well the potential learners would respond to our design. Strategies that we developed to solve these two challenges were: 1) Conducting a needs assessment with corporate partners; 2) Conducting external reviews and piloting the learning modules with target learners. We started by conducting a needs assessment to answer the clearest and present question—what should be included in the learning modules?

A Prolonged Needs Assessment

Prior to generating the learning content, we conducted a needs assessment, described by Dick et al. (2022) as "discrepancy analysis" and a part of the front-end analysis to identify instructional goals. The goal was to understand what the potential learners would need to be prepared to work in an environment where MBSE was used.

Since our target learners were professional engineers, the PI and Co-PIs identified individuals from 11 different companies who were experts in MBSE and/or held managerial positions that enabled them to understand what knowledge and skills professional engineers would need to apply MBSE at work. Multiple interviews were conducted by the team members including the PI, Co-PIs, the design team, and the program evaluation team. Some were held with groups of experts and others with a single individual. Each interview lasted approximately one hour. To supplement the interviews, two team members conducted a market analysis to identify MBSE related professional development programs already available in the market. They compiled a list of existing programs from other institutions (e.g., certificates, master's degree programs, etc.) and the topics included in these programs.

The team spent approximately six months completing the overall needs assessment. This prolonged needs assessment is unique compared to other instructional design processes. However, it allowed the team to develop a more holistic picture of what would truly benefit professional engineers in organizations moving toward digital systems engineering. The series of learning modules identified by the PI and Co-PIs after the needs assessment is shown in Table 2.

The thorough needs assessment also enabled us to create more specific and clear portraits of our target learners and determine what specific learning modules would be beneficial to these potential learners. Co-PI 1 who has content expertise in MBSE and decades of professional experience in MBSE, created a list of personas that could benefit from or might be interested in a specific subset of the seven modules (see Table 3).

MODULE	TITLE
1	Introduction to Systems Engineering (SE) and Model-Based Systems Engineering (MBSE) for Production Systems
2A	Engineering a System with SysML
2B	SysML Implementation & Applications
3	Quantitative Statistical Methods Supporting MBSE
4	Production Engineering & MBSE
5	Digital Engineering & the Model-based Enterprise
6	MBSE Capstone Project

TABLE 2. MBSE Modules. There are two submodules for Module 2 because Module 2A introduces the theories of Systems Modeling Language (SysML) whereas Module 2B demonstrates the applications of SysML and introduces tools that can be used to implement SysML

PERSONAS	MODULES
Systems engineer in need of upskilling to obtain MBSE skills	1,2A,2B,3-6
Mechanical design engineer in need of language and skills to participate on a systems engineering team	1,2A,2B,3-6
Production systems engineer who needs to know how MBSE can be applied to production systems (and how MBSE shapes the products)	1,2A,4-6
Supply chain manager who is struggling to understand SE-oriented requirements that customers are placing on products related to evidence for product reliability	1,2A,4,5
A marketing/sales professional who needs to understand the essential approach his/her firm uses to design and produce the products being sold	1,2A,4,5

TABLE 3. Five Profiles of Industry Personas with Mapping to the MBSE Modules.

Round 1—Content Design & Development

Immediately after the module topics were chosen, the team began the content design phase for Module 1. As shown in Figure 1, this step involved the SME collaborating with the

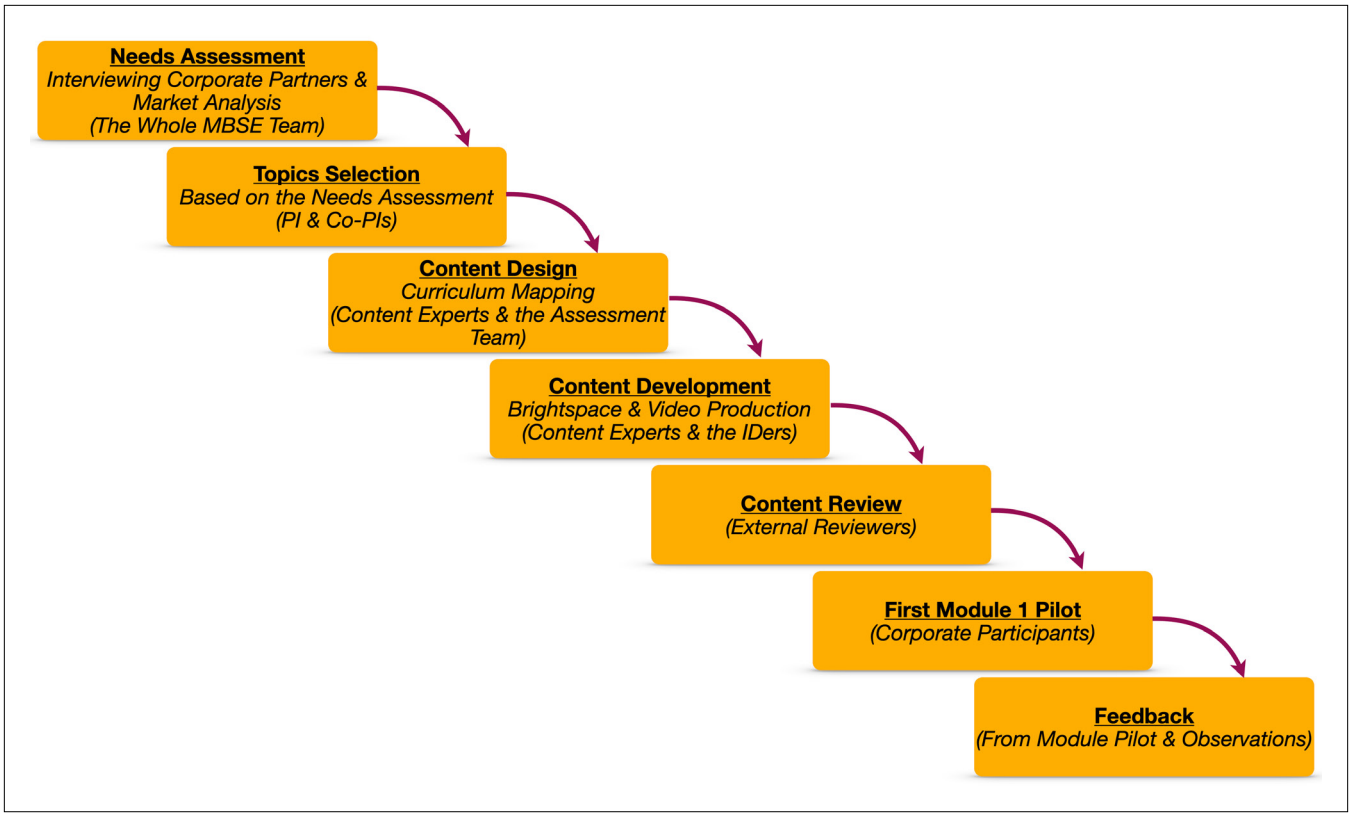


FIGURE 1. Round One: MBSE Module 1 Design & Development Process.

assessment and research team to create a curriculum map. More specifically, they worked together to:

- Determine the overarching learning goals of each module based on the needs assessment.
- Develop a series of learning objectives that encompassed a variety of cognitive skills in Bloom's taxonomy.
- Embed social interactions in the assessments by implementing a group assignment in the form of a case study and discussion questions.
- Design a group assignment suitable for the target professional learners.
- Align the design of the module with the learning goals, assessments, and pedagogies used.

This first step was critical to the process as it ensured (a) the topics identified based on the needs assessments were included; (b) appropriate instructional strategies were incorporated in the module design (e.g., group project) to enable us to collect relevant data to answer the proposed research questions; and (c) the learning topics, objectives, and assessments were aligned.

It is notable that the instructional designers were not involved in the content design process. This was because the focus of this phase was to structure the module design to answer the research questions in the grant proposal. Therefore, the assessment and research team led this effort.

The content development step centered around the implementation of the module in Brightspace. During this time, the designers played the roles of graphic designers, instructional technologists, and liaisons between the video production team and the content experts. They were less involved in conversations related to instruction and pedagogies. Much of their time was spent answering questions related to Brightspace and/or Kaltura, the video streaming platform supported by the university

Challenges & Solutions

The challenges encountered during the design phase of Module 1 can be categorized into three areas: learning content, assumptions about target learners, and perceptions of online learning. These three elements were interconnected and closely related to the second goal of the NSF funded project, which was to investigate the effectiveness of an online learning design approach that motivated collaborative problem-solving, experiential learning, etc. One common instructional strategy for enhancing social interaction and motivating knowledge exchange among learners is to include a group project in the module. As the team explored the possibility of implementing this strategy, challenges surfaced gradually like a ripple effect. Although the challenges and their solutions were unique, examined together they influenced the entire module design and delivery. Additionally, the combination of challenges and solutions

drove a continuous conversation about online teaching and learning among the team members.

Challenge 1: Learning content—group project design

When conceptualizing the design of group projects, one recommendation was for learners to share their own projects or discuss what they do at work with other learners. We thought that learners would benefit from having opportunities to discuss how the concepts covered in the module related directly to their everyday work and to share their experiences with each other. These presumed advantages, to directly connect the concepts to on-the-job work, quickly became less feasible when industry partners pointed out that issues of intellectual property, proprietary knowledge, etc. would prevent learners from sharing their experiences with others. To address these concerns, we identified three publicly available case studies and incorporated them into the modules instead of requiring the learners to bring their own MBSE projects to the discussion. Alternatively, they could choose to share a real-world experience. This approach provided the learners with a space to collaborate and share their own experiences in a more authentic manner. The case studies introduced the importance of MBSE in various industries. Therefore, we focused on finding cases where MBSE allowed for more efficient ways of reducing errors for complex systems and where major failures happened, in part, due to a lack of MBSE considerations. Three case studies were added: Samsung Galaxy Note 7, Hubble Space Telescope, and Airbus A380. While the cases might not be as closely related to the learners as their own projects, this design method enabled us to provide the learners with a space to collaborate and discuss real-world experiences while maintaining their professional boundaries.

Challenge 2: Assumptions about the target learners

There was a constant tension between the desire to create an authentic and meaningful learning experience (where professional learners had opportunities to engage with content at a depth that would enable application) and the acknowledgment that professional learners work full-time with limited availability. To address this challenge, we designed the modules to be fully asynchronous with both individual and group assignments. There were no synchronous learning activities in which learners were required to participate. Further, when a group project assignment was integrated into one of the modules, the team developed a grouping strategy to ensure the group project could be implemented smoothly for the learners. A pre-learning module survey was developed to gather information about each learner (e.g., professional position, years of experience in MBSE). When possible, we grouped learners according to their availability to connect with other learners, as well as their previous experiences with MBSE, and their employers. The intention was for learners from the same corporation to interact because they could more freely discuss projects directly related to their own organization. Our method addressed scheduling conflicts and prevented the intellectual challenge described previously.

Challenge 3: Meaningful online interaction

Team members had different and somewhat conflicting ideas on two issues: the value of social discourse and what constituted meaningful interaction in an online course for professional engineers. As the team began to discuss the need for including multiple forms of social interaction and learner collaboration (e.g., discussions, group projects) in the module, some of the SME/Co-PIs expressed concern that professional learners would not want to work in teams or interact with peers. They shared concerns that discussion boards are often viewed as "busy work" in online courses and that learners may write something to satisfy the course requirement that does not contribute to actual learning. Considering the educational research questions were centered around social constructivism, the concerns raised by the SME needed to be addressed when developing the modules. The PI and Co-PI 4 recommended conducting a workshop on online course design and delivery for the entire team. The assessment research team and the instructional design team delivered the training to nurture buy-in from all members of the team on the value of social interaction to the overall learning opportunity. The workshop focused on providing evidence-based online teaching strategies and discussing the feasibility of incorporating collaborative learning activities. Team members were encouraged to discuss how the strategies shared could be applied or adapted in their own module. While the workshop was well received by some, anecdotally, the uncertainty over incorporating learner interaction activities (e.g., group projects) in online learning modules remained for others. It became clear that some team members had deeply held beliefs that some learners would question the value of collaboration and social discourse. It is understandable that this challenge was beyond the scope of this project as it was more related to each individual's online teaching expectations and experiences, etc. Nevertheless, there was an intentional effort, encouraged and led by the PI and other team members, to formally and informally share their own online teaching experiences and online professional development learning experiences to broaden team members' perceptions of online teaching and learning.

In retrospect, there seemed to be an unintentional shift of attention to the more familiar content creation activities for some team members as soon as the team began to design and develop the learning module. The focus became developing individual learners' MBSE knowledge and skills while relying on others to address the previously agreed upon research goal of this project—examining collaborative learning and experiential learning in online professional

WEEK	TOPIC	LEARNING CONTENT	LEARNER ENGAGEMENT	KNOWLEDGE CHECK
Week 1	Topic 1: Motivation for Systems	Lecture Video	• Topic 1 Discussion • Topic 2 Discussion • Topic 3 Discussion • Final Group Project	• Final Quiz • Final Group Project Note: A final quiz and a final group project were used to evaluate learners' level of knowledge of module content in weeks 1 and 2. Both assessments were implemented in week 2.
	Case Study 1: Hubble Space Telescope	Lecture Video		
	Topic 2: Systems	Lecture Video		
	Topic 3: Systems Thinking	Lecture Video		
Week 2	Topic 4: Models	Lecture Video	• Topic 4 Discussion • Topic 5 Discussion • Topic 6 Discussion • Final Group Project	
	Case Study 2: Samsung Galaxy Note 7	Lecture Video		
	Topic 5: Systems Engineering	Lecture Video		
	Case Study 3: Airbus A380	Lecture Video		
	Topic 6: How to Practice Systems Engineering	Lecture Video		
	Final Group Project	N/A	• Final Group Project	• Final Group Project

TABLE 4. The First Iteration of Module 1.

development modules. These challenges reminded us that there was a need for the team to revisit the goals of the project from time to time.

This project intentionally brought together individuals with very different expertise and experiences with online learning. Our team consisted of educational researchers, instructional designers, and engineering faculty, along with graduate students. While a strength of our project is the different perspectives that members bring, it also meant that each person came to the project with previous experiences and ideas about what "high-quality" online learning practically means. Each team member was committed to the goal of providing excellence, yet members held very different ideas about what learning opportunities should be included. Considering the team members hold different ideas of online teaching and learning, early in the project these ideas could have been discussed explicitly and then negotiated. In addition, having continuous and authentic exchanges about the course design and delivery would have been helpful to guide the team toward pursuing shared goals.

The First Iteration of Module 1

Module 1 had six videos, each lasting approximately 20 minutes. As the first module in the series, Module 1 focused on laying the groundwork for deeper topics by introducing the basic concepts of Systems Engineering (SE), models, and systems thinking. In terms of the learning activities, Module 1 included a group assignment, which asked learners to apply the knowledge in Module 1 to a real-world system. Learners could choose one of the case studies included in the module, or they could identify a system of their own. Other activities included individual end-of-lecture quizzes and discussion board questions. The total estimated time to finish this module was 10 hours. See Table 4 for the first iteration of Module 1.

Experiential Description of the Design

To understand the background of learners in the course, learners completed a pre-module survey with questions about their previous experience in SE and MBSE. Learners were then grouped to work together with others of similar proficiency. Three real-world case studies were prepared for the learners to pick from. Each learner viewed the case study options and then as a group, they decided which case they would work on. Learners worked in these groups to complete case studies that were akin to examples they would encounter in their professional work. Learners worked in these groups throughout the module in the communication mode/s (synchronous or asynchronous—text or real-time) that the group decided.

Pilot & Round 2—Content Design & Development

To test our design and gather learner feedback, we conducted two pilot runs of the module which informed revisions. The first was facilitated by two members from the SME team. We recruited eight pilot learners from our industrial partners. The learners were separated into two groups for the group projects, based on their previous experience in MBSE for the group projects. This pilot lasted two weeks.

DESIRED STATUS	-	ACTUAL STATUS	=	NEED
1. Learners are able to complete all learning activities within two weeks.	-	Most learners did not complete the learning activities within two weeks.	=	Extend the timeline.
2. Learners have the opportunity to evaluate their understanding of the topics throughout the module.	-	There was only one knowledge-check activity implemented in this module which was the final quiz.	=	Create knowledge check activities for each topic.
3. Learners participate and interact with each other in topic discussions.	-	Most learners posted their initial responses to the topic discussion prompts. However, peer interactions within the discussions were minimal.	=	Decrease the number of the discussion activities throughout the module. Revise the discussion prompts to encourage peer interactions.
4. Learners collaborate to complete the group project.	-	Only one group completed the final project.	=	Enhance learner—learner interaction within the module Scaffold the final project throughout the module.
5. Learners receive feedback from the instructor (in a timely manner).	-	Learners received feedback from the instructor for the final project two weeks after it was submitted.	=	Enhance teaching presence and instructor presence.

TABLE 5. Gap Analysis after the First Module 1 Pilot. The gap analysis was conducted based on the equation of needs assessment, "Desired status—Actual status = Need," described in Dick et al. (2022, p. 28).

NEED	INSTRUCTIONAL INTERVENTION
1. Timeline	• Participants need three weeks to complete the module. We changed the timeline for the learning module from two weeks to three weeks. The learning materials were then reorganized accordingly.
2. Final Project	• Instead of requesting the learners complete the final project at the end of the module, we divided the final project into three parts and the learners worked together to complete one part each week. • The final project became a scaffolded project that enabled the learners to complete the tasks in sequence throughout the module.
3. Discussion board assignments	• Instead of having multiple discussion tasks each week, we developed weekly discussion tasks to make the discussion more focused and less time consuming. Additionally, the three weekly discussions aligned with the final project prompts. This gives the participants the opportunity to work on the final project each week.
4. Knowledge-check opportunity for each topic	• In addition to the final quiz, we created individual topic quizzes to assess learning outcomes.
5. Instructor Presence	• The instructional design team shared online teaching best practices with the facilitator for the second pilot. They also assisted the facilitator in being more present throughout the pilot by crafting the welcome messages and weekly announcements to the pilot participants so that the facilitator could intentionally establish their teaching presence in the module.

TABLE 6. Instructional Interventions Based on the Gap Analysis.

During the pilot, in addition to obtaining feedback from the learners through the module survey, the PI also asked the facilitators of the module and the instructional design team to share the progress of the module at the weekly MBSE team meetings to report on progress and issues. The instructional design team took the initiative to document the observations and feedback from the facilitators during meetings. As a result, we had not only the participants' feedback but also the observations we documented from other stakeholders throughout the two-week pilot to inform our redesign.

After the pilot, the instructional design team created a gap analysis based on the participants' feedback and facilitators' feedback as well as their own observations (see Table 5). They worked with the SME team to redesign the module based on the gap analysis. See Table 6 for the instructional interventions designed to address learners' needs

The Second Iteration of Module 1 & Learners' Feedback

Table 7 shows the second iteration of Module 1. We extended the completion time of the learning module to three weeks when we conducted the second pilot to provide learners with more appropriate and sufficient time to complete the module. In this iteration, the final group project was restructured to be a scaffolded project that enabled the learners to complete the project throughout the three-week timeframe. We also redesigned the discussions completely to complement the final group project to provide learners with weekly opportunities to communicate and collaborate with each other on the final project. As a result, the discussions were changed from multiple discussion topics each week

WEEK	TOPIC	LEARNING ACTIVITY	LEARNER ENGAGEMENT	KNOWLEDGE-CHECK
Week 1	Topic 1: Motivation for Systems	Lecture Video	New: • Week 1 Discussion • Final Group Project—Part 1	New: • Topic 1 Quiz • Topic 2 Quiz • Final Group Project—Part 1 Retain: • Final Quiz (the final quiz was implemented in week 3)
	Case Study 1 Hubble	Lecture Video		
	Case Study 2 Samsung Galaxy Note 7	Lecture Video		
	Case Study 3 Airbus A380	Lecture Video		
	Topic 2: Systems	Lecture Video		
Week 2	Topic 3: Systems Thinking	Lecture Video	New: • Week 2 Discussion • Final Group Project—Part 2	New: • Topic 3 Quiz • Topic 4 Quiz • Topic 5 Quiz • Final Group Project—Part 2 Retain: • Final Quiz (the final quiz was implemented in week 3)
	Topic 4: Models	Lecture Video		
	Topic 5: Systems Engineering	Lecture Video		
Week 3	Topic 6: How to Practice Systems Engineering	Lecture Video	New: • Week 3 Discussion • Final Group Project—Part 3	New: • Topic 6 Quiz Retain: • Final Quiz (the final quiz was implemented in week 3)
	Final Project	N/A	• Final Group Project (Parts 1-3)	New: • Restructured the Final Group Project into three parts.

TABLE 7. The Second Iteration of Module 1.

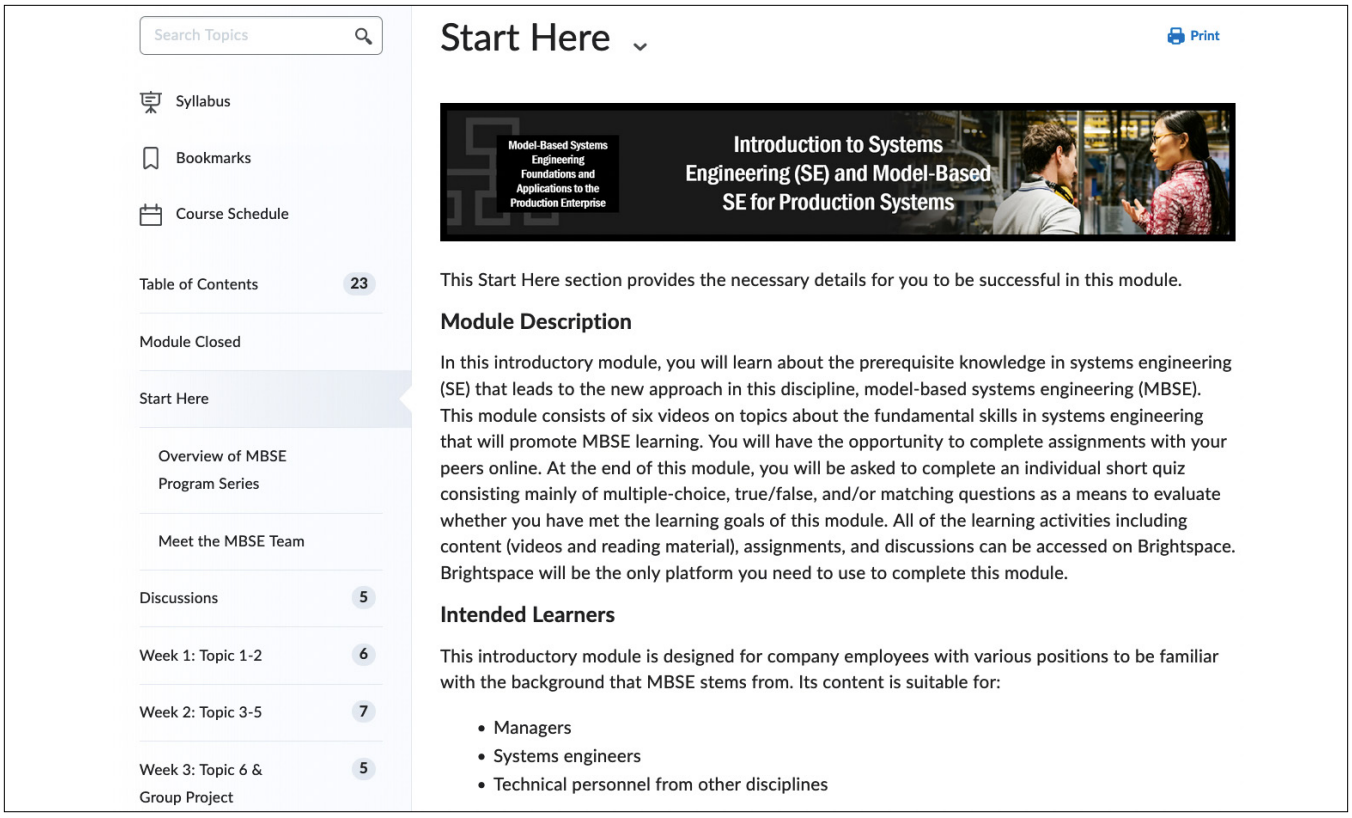
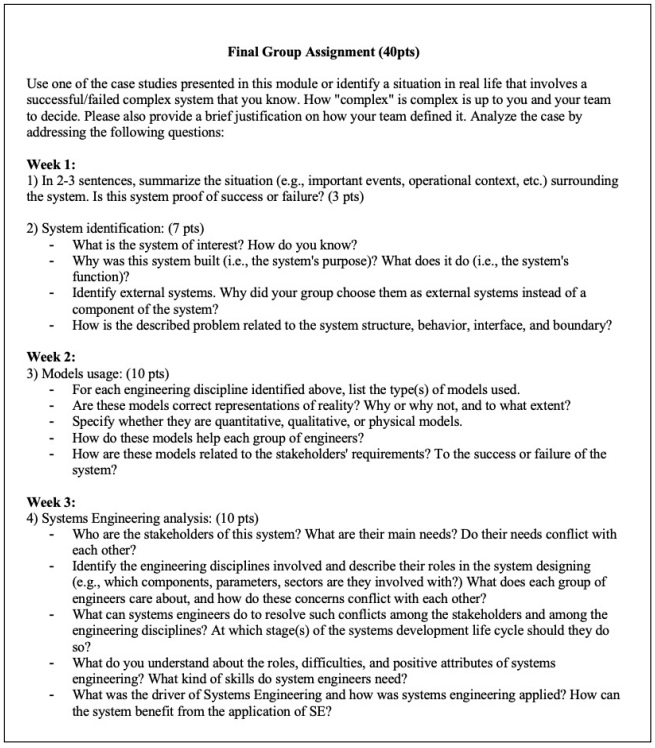


FIGURE 2. A Screenshot of Module 1 Navigation Panel and Topic 1 Introductory Page.



Final Group Assignment (40pts)

Use one of the case studies presented in this module or identify a situation in real life that involves a successful/failed complex system that you know. How "complex" is complex is up to you and your team to decide. Please also provide a brief justification on how your team defined it. Analyze the case by addressing the following questions:

Week 1:
1) In 2-3 sentences, summarize the situation (e.g., important events, operational context, etc.) surrounding the system. Is this system proof of success or failure? (3 pts)

2) System identification: (7 pts)
- What is the system of interest? How do you know?
- Why was this system built (i.e., the system's purpose)? What does it do (i.e., the system's function)?
- Identify external systems. Why did your group choose them as external systems instead of a component of the system?
- How is the described problem related to the system structure, behavior, interface, and boundary?

Week 2:
3) Models usage: (10 pts)
- For each engineering discipline identified above, list the type(s) of models used.
- Are these models correct representations of reality? Why or why not, and to what extent?
- Specify whether they are quantitative, qualitative, or physical models.
- How do these models help each group of engineers?
- How are these models related to the stakeholders' requirements? To the success or failure of the system?

Week 3:
4) Systems Engineering analysis: (10 pts)
- Who are the stakeholders of this system? What are their main needs? Do their needs conflict with each other?
- Identify the engineering disciplines involved and describe their roles in the system designing (e.g., which components, parameters, sectors are they involved with?) What does each group of engineers care about, and how do these concerns conflict with each other?
- What can systems engineers do to resolve such conflicts among the stakeholders and among the engineering disciplines? At which stage(s) of the systems development life cycle should they do so?
- What do you understand about the roles, difficulties, and positive attributes of systems engineering? What kind of skills do system engineers need?
- What was the driver of Systems Engineering and how was systems engineering applied? How can the system benefit from the application of SE?

FIGURE 3. A Screenshot of the Final Project Instructions.

to one single discussion topic each week. Finally, six brand new individual topic quizzes were added. Figures 2 and 3 show the interface of Module 1, the topic introductory page layout, and part of the final project descriptions.

The second pilot was conducted with four professional engineers from one of our corporate partners and was led by the SME who also facilitated the first Module 1 pilot. We implemented surveys to obtain learner feedback, but we also took the opportunity to conduct a focus group interview with the four pilot participants to expand our understanding of their learning experiences.

The redesign of Module 1 was well received. The length and pacing of the whole module were considered appropriate for professional engineers. The four pilot participants were able to complete all graded assignments within the timeframe. It was noted that they did not utilize the discussion space in the learning module to exchange their ideas for the final project. When asked, they indicated since they were from the same company and knew each other they decided to work on the final project outside of the learning module using a communication tool provided by their company. This suggested that our design, which provided space for the learners within the module and enabled them to determine their communication methods, was appropriate. It also confirmed that grouping learners based on their professional affiliation would increase their participation and success in completing the learning module.

It is essential to share that even though the participants did not use the discussion space, it did not mean they did not appreciate the discussions in the module. On the contrary, learners shared that they appreciated having discussions in the online learning modules. Drawing from their other online professional development experiences, they indicated it was valuable to be able to ask for suggestions or brainstorm with engineers outside of their company or from other countries. One of them mentioned that even just reading other learners' discussions, was helpful and valuable to him because he was learning from others through their posts. He further shared that he wished he could have had more time to participate in the discussions himself. We were not expecting the pilot participants to highly value having discussions in online learning courses. In fact, they valued this interaction so much that they recommended having graded discussion assignments to encourage learner participation.

Based on the feedback from the participants and our observations, it was determined that the design of Module 1 was solid and was ready for official offering. The final product is a non-credit, professional development course available through the university's online learning platform. The structure of Module 1 is like the online courses offered by the university, with a start date and an end date by which learners need to complete all related learning activities. When using our module, learners can access the learning materials and engage in learning asynchronously for tasks such as watching videos and completing homework assignments. They can engage in discussion collectively by starting and replying to discussion threads. Lastly, they can work on the final project of the module collaboratively. The instructor does not require them to set up a regular meeting time and work on the project together, though this approach is encouraged. Thus, learners can choose how to collaborate—either speaking synchronously or collaborating in other ways such as working together in a Google Doc asynchronously or through a messaging application.

Reflection on the Round 2—Design Process Transformation

During the first pilot of Module 1, there was a noticeable change in how the SME team and the instructional design team interacted with each other. Because they were the two groups who worked directly with the pilot learners to either provide feedback or technical support, they began to communicate with each other more regularly and frequently to ensure that the pilot was running smoothly and that technical and instructional issues were resolved quickly. In addition, as indicated in the previous section, they were also asked to share their observations on participants' progress in the module during the weekly MBSE team meetings. All these interactions provided these two teams more opportunities to share their thoughts about the design and what could be done to improve the module.

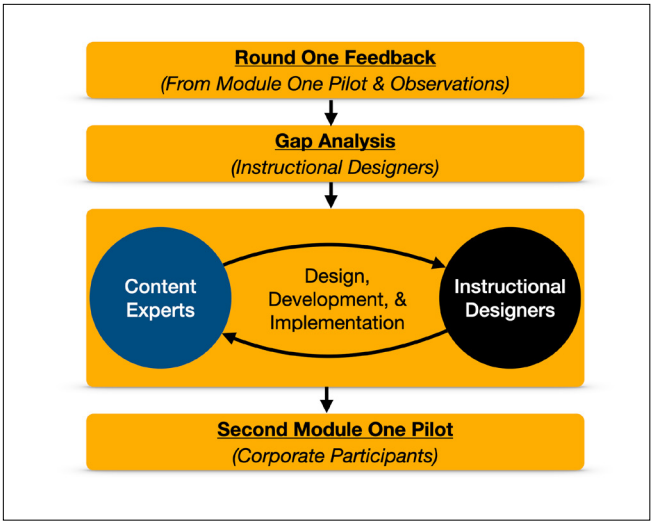


FIGURE 4. Round Two: MBSE Module 1 Design & Development Process.

It was through those communications that both teams were able to understand each other's expertise on a deeper level and further strengthen their relationships. It was probably not known to the SME team that both instructional designers were professors at the university and had years of face-to-face and online teaching experiences in higher education until the first pilot. At that point, they took notice when the designers began to offer suggestions to the instructors on how to facilitate online learning. During the pilot, their conversations went beyond the scope of how the technology worked (e.g., grading in Brightspace). Rather, they discussed pedagogical topics such as how to engage learners, best practices for providing feedback, etc.

As a result, round two of the design process revealed a more interactive relationship between the SME team and the instructional design team (see Figure 4). The instructional design team participated in the SME team's weekly meetings and provided pedagogical suggestions when needed. This approach enabled the designers to offer just-in-time instructional design and technology support for the content experts and further enhanced the collaboration between these two teams. As the relationships between the designers and the content experts grew, the designers began to offer suggestions beyond instructional design and development. For example, they recommended teaching strategies to be used for the implementation of the modules.

SURPRISES

One revelation we encountered related to the timeline of the project. It was adjusted several times for a variety of reasons. The development time for Module 1 was expanded by three months because the content was not developed as quickly as we expected. For context, Module 1 was developed by a postdoctoral fellow and a graduate student who was

pursuing a master's degree in engineering. Both were under the guidance of one of the Co-PIs to develop the content. Their activities included content development, review, revision, confirmation, and implementation. Although this method prolonged the development time, it ensured the production of high-quality and robust learning content. Additionally, this process nurtured talent—a well-established expert in MBSE guiding two individuals to enhance their expertise in the subject matter.

Another surprise that we did not anticipate was an issue with copyright related to Module 2A. It was communicated at several meetings at the beginning of the course development process that the team needed to comply with the university's copyright policy and obtain proper permissions to use copyrighted materials for the learning modules. However, the design team was not closely working with the SME team to review the slides created for the lecture videos. They later found that the expert team used many graphics from a copyrighted resource. This was a mistake that could have been avoided at the beginning of the process. Rather than assuming all team members would be able to incorporate instructional materials that comply with the copyright policy, we could have invited the university's copyright office director to give the team a workshop on the copyright policy for instructional materials. Additionally, the designers should have reviewed more components of the slides—not only the layout of the slides but also the additional materials (e.g., diagrams, graphics) included within them.

This copyright issue was a challenge that could not be addressed easily. To comply with copyright regulations, Module 2A needed to be redesigned. Ultimately, this surprise became an advantage as it provided the team an opportunity to create a set of diagrams that were used in both Modules 2A and 2B, providing a sense of continuity.

In addition, Module 2A did not have a group project, which our research confirmed as an essential element for MBSE. The decision to omit a group project was partially due to the revisions that the SME team needed to make within the given timeframe. Although failing to include a group project could seem like a disadvantage given that learners need these experiences for authentic learning, Module 2A still provides opportunities to address the same needs in other ways such as creating discussions for the learners to share more experiences. Once learner feedback is collected, a group project may be added if needed.

REFLECTION & NEXT STEPS

The team has now entered the last year of the project. Multiple modules have been developed and feedback from the external reviewers and learners has been received, reviewed, and incorporated numerous times to improve the quality of our design. The design process has evolved through time from the waterfall model (see Figure 1) to the collaborative model (see Figure 4). The relationships among the team members have grown and strengthened. Reassessing the process revealed that some of the obstacles could have been prevented or mitigated had some strategies been implemented initially and intentionally throughout the process. In retrospect, our team members to some extent cooperated based on their assigned roles/titles at the beginning of the project, as suggested by the waterfall model. The SME team worked with the assessment and research team to develop learning objectives and assessments and then moved on to the next step working with the instructional design team separately to implement the design into the learning management system. As the team's relationships grew beyond their assigned roles/titles, through formal and informal conversations, a shift in how the team interacted occurred as shown in Figure 4. Arguably the most significant change was that the instructional design team became more involved in the conversations relevant to assessments, pedagogy, and online teaching—contributing their holistic expertise in instructional design. The shift did not occur immediately. It happened incrementally with support from the PI and Co-PI 4, who knew the instructional designers through previous professional collaborations. They were able to highlight the instructional designers' expertise to other team members and identified opportunities for them to fully engage in the process. Some of the team members are planning to collaborate on additional grants in the future. Based on our experiences in this project, we are planning to have a more in-depth team-building activity when we first begin the project. We hope the activity will help the team members to get to know each other beyond their names and assigned roles on the team.

REFERENCES

Dick, W., Carey, L., & Carey, J. (2022). *The Systematic Design of Instruction* (9th ed.). Upper Saddle River, NJ: Pearson.

Hart, L. E. (2015, July). *Introduction to model-based system engineering (MBSE) and SysML*. INCOSE Chapter Meeting 2015, Mount Laurel, NJ, United States.