Work in Progress: Aligning a Professional Development Program with Industry Needs

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Introduction

Model-based systems engineering (MBSE) is being widely discussed, and by some, vigorously pursued, as a replacement for the standard paper-based approach to system/production engineering, which is costly and slow. MBSE provides a methodical approach to build a holistic model in a digital space that elucidates functional, physical, and behavioral interdependencies and guides the entire product life-cycle development and engineering. Thus, MBSE allows companies to bring new processes, production systems, and products to the market more quickly and at a competitive cost. However, this holistic approach requires that all employees who work in the digital space become familiar with MBSE. Our project is designed to help address this need for professional development for current and future employees of organizations transitioning to MBSE.

A multidisciplinary team of eighteen faculty, staff, and students at Purdue University is preparing online instructional materials on model-based systems engineering. (Fentiman et al., 2020) The suite of modules is targeted for current and potential employees of organizations that are either transitioning to MBSE for production engineering or planning to do so in the near future. Our goal is to design, develop, deploy, and evaluate the suite of instructional modules and make them as effective and flexible as possible for employees with a wide variety of education, experience, and job responsibilities. In addition, we want to design the modules so that they can be adapted for use in 2-year and 4-year degree programs, helping prepare future employees to work in an organization that utilizes MBSE. It is essential for us to prepare materials that are well-aligned with the needs of organizations whose employees will be working in the digital environment using MBSE.

This research and professional development project, which is funded by the National Science Foundation, requires that the instructional materials be online and widely available. At this stage of the project, modules are offered through Purdue Online – College of Engineering division to industry and government agency employees who are interested in learning the foundations of MBSE. Learners who successfully complete a module by earning a score of 80% or higher on all assignments receive a certificate of completion. They can also receive continuing education units (CEUs). The complete instructional suite consists of seven modules, each of which contains a variety of components such as short instructional videos, case studies, team projects, quizzes, and guided discussions. Each module requires 10-15 hours of active participation. Members of the instructional staff interact with the learners, monitoring discussions, and answering questions. The individual modules are not currently offered for university credit, although they can be incorporated into selected existing university courses taken by students enrolled in 2-year, 4-year, or graduate degree programs.

The first step in designing the instructional modules was to understand the needs of organizations transitioning to MBSE. The purpose of this paper is to describe the actions we have taken to align our instructional modules with employers' needs and to discuss the lessons we have learned so far.

Tools for Aligning Instructional Module Content with Industry Needs

We have used five different, but coordinated, approaches to align the content of our MBSE instructional modules with the needs of industry and government agencies as well as their employees. We have considered not only whether the modules' technical content is appropriate but also whether the pedagogy makes the modules engaging and effective instructional tools for current and future employees with a wide variety of technical and cultural backgrounds. After we complete a module and verify that it is aligned with employers' and employees' needs, we work with university faculty and administrators to identify ways to make the modules or portions of modules available to students (potential future employees of organizations utilizing MBSE) through existing university courses and programs. That process is just getting underway.

The five ways we have attempted to align our modules with employers' needs are:

1. Hold an hour-long discussion with a group of MBSE experts or proponents from a corporation or government agency that wants to transition to MBSE. We held eleven such discussions at the beginning of the project. The discussions were guided by a set of questions designed to elicit information necessary to design the instructional modules.
2. Review the results of the 2020 MBSE Maturity Survey as reported in the Systems Engineering Research Center's Technical Report SERC-2020-SR-001, "Benchmarking the Benefits and Current Maturity of Model-Based Systems Engineering across the Enterprise," (McDermott et al., 2020) with the goal of identifying barriers to adopting MBSE.
3. Form and utilize an Advisory Board to provide ongoing advice on development and deployment of the instructional modules.
4. Obtain external reviews of each module by MBSE experts from industry, government, and professional societies to confirm content validity.
5. Conduct pilot offerings of each module for employees of organizations represented on the advisory board or other interested organizations and solicit feedback from the learners as well as study their performance on quizzes and other assignments.

In the remainder of this section, additional information is provided on each of these five approaches.

Discussions with MBSE experts

Several members of our project team from Purdue University have industry and government contacts through previous projects related to model-based systems engineering or through alumni

of the university. They were able to identify a number of corporations and government agencies with a strong interest in transitioning to model-based systems engineering and asked their contacts at those organizations whether they would be willing to talk with our project team about the need for instructional materials related to MBSE. In total, 25 professionals representing 11 companies and government agencies participated in these discussions. Those 25 professionals held different roles in their organizations, and as a result, they brought different prior experiences with, and viewpoints of, MBSE to the conversation.

The discussions were guided by a series of questions, but each organization's representatives had opportunities to steer the conversation to topics they thought were most important. Some of the questions that elicited the most helpful responses were:

- What categories of employees (job titles) would you like to receive training in MBSE?
- How would each of those types of employees use the information?
- What topics do you think are essential to include in the MBSE instructional materials?
- In what ways do existing MBSE courses or programs fail to meet your needs?
- For current employees in the categories identified above, what types of online instruction on MBSE are you seeking (e.g., credit or non-credit, full courses, short courses, or continuing education workshops)?
- What, if any, formal certification do you require for people who have completed the training?
- What technology will your employees have available to them to take the MBSE modules?
- In your organization, is training done on company time or on personal time?

The interview responses helped identify expected audiences and relevant MBSE topics that were deemed necessary by the organizations. Our team used the insights gained from these interviews to structure the MBSE educational modules and create content. For example, interviewees from 9 out of 11 organizations explicitly stated the need to educate senior management and leadership on benefits of MBSE because management support is viewed as a key to enable MBSE adoption. Moreover, a majority of respondents emphasized the importance of hands-on applications of MBSE tools which may be lacking in a theory-based instruction.

Review of SERC's 2020 MBSE Maturity Survey

An introductory paragraph of the executive summary of the SERC report says

> "In 2019-2020, the National Defense Industrial Association Systems Engineering Division (NDIA-SED) and the International Council on Systems Engineering (INCOSE) collaborated with the Systems Engineering Research Center (SERC) at the Stevens Institute of Technology to benchmark the current state of Digital Engineering (DE) and Model-Based Systems Engineering (MBSE) across government, industry, and academia. The team developed and executed a survey of the systems engineering community to broadly assess the maturity of system engineering's "digital transformation", identify specific benefits of MBSE and associated metrics, identify enablers and obstacles to DE

and MBSE adoption across the enterprise, and understand evolving and necessary shifts in the systems engineering (SE) workforce."

Our team was particularly interested in obstacles to adoption of MBSE and workforce development needs. By the time we reviewed the SERC report, our team had prepared a preliminary outline of the content of the seven instructional modules. Team members mapped the obstacles to MBSE adoption and workforce development needs to the seven modules and adjusted content as necessary to address as many of the obstacles and needs as possible. Often the needs could be addressed with the addition of a short instructional video or case study or revision of a discussion prompt.

Formation of and Interactions with an Advisory Board

The MBSE project's Advisory Board consists of approximately a dozen members from industry (mainly large manufacturing corporations) and government agencies plus half a dozen faculty members and administrators from academic institutions that have an interest in incorporating instructional materials on MBSE into their curricula. Most of the industry and government agency members are from organizations with which we had discussions at the beginning of the project. Many of the members, including those from academia, wrote letters of support for our proposal to the NSF, so they have been involved in the project since its inception and have a strong interest in its success.

The Advisory Board has been extremely valuable not only by helping us define the technical content of the modules but also by providing insights into how professional development training is typically done in their organizations. For example, they have told us how much time employees are able to devote to professional development in a typical month or year and how they are accustomed to interacting with the training, e.g., in person or online, in large or small chunks of time. In addition, they have told us what instruction the employees and employers value and the best way to make employers and employees aware that a professional development opportunity exists. That information has helped us design, deliver, and advertise our instructional modules in ways that meet learners' and employers' needs.

Two virtual, 2-hour Advisory Board meetings are scheduled each year. The agenda for a meeting is typically a combination of updates on our progress and discussions of topics on which we would like to have Advisory Board members' counsel. Discussion topics to date have included

- Will the proposed content of a specific module be valuable to some of your employees, and if not, how should it be modified?
- What MBSE-related skills do organizations expect of new hires into entry level positions?
- Who would be the best people to pilot an instructional module and provide feedback on both content and pedagogy?
- How do employers determine the value of a professional development program?
- Which categories of employees should take which modules (not everyone needs all of them)?

- How could employers and universities coordinate efforts to encourage college students to learn about MBSE?
- Do you have corporate partners or suppliers that interface closely with your organization and will also need to understand the fundamentals of MBSE?

External reviews by experts

Many members of our Advisory Board have expertise in MBSE and have volunteered to provide feedback on modules they felt qualified to review. For each module, we prefer to have feedback from at least three people. Sometimes Board members are not able to do the review themselves but will identify a person in their organization who would be willing to provide feedback.

External reviews are guided by a set of questions. Reviewers are asked to answer each question "yes" or "no," rate that particular aspect of the module as "exceptional," "good," "needs improvement," or "poor," and then provide comments on any aspects they choose.

Some aspects of the modules that reviewers were asked to evaluate were:

- Are learning objectives clear?
- Does the content align with business goals?
- Is the content timely and relevant?
- Is the content organized logically and coherently?
- Is the content accurate?
- Does the content grab learners' attention?
- Is the content presented in a real-word context?
- Does the module activate prior knowledge?
- Does the module give learners a chance to practice and apply skills?
- Are graphics and text integrated?
- Is the module presented in a conversational style?
- Is feedback located close to practice answers?
- Does the module have a "fun" factor?
- What is the level of "stickiness," i.e., does the information stay with learners?

Instead of providing numerical ratings, some reviewers chose to go through the entire module and provide detailed comments on specific components such as instructional videos, quizzes, case studies, team assignments, and so on. That is also very helpful.

Pilot offerings of the modules

After project team members believe that the modules are sufficiently refined, we provide a pilot offering to employees of organizations represented on our Advisory Board at a reduced price in exchange for feedback from the learners. The initial pilots intentionally have a small group of learners, approximately 10. Each module is available online through the university's online engineering unit on a standard learning management system platform. Two Qualtrics surveys (pre-module and post-module) are embedded in the module. In addition, researchers with proper certifications are able to see student performance on quizzes to help them understand what

concepts students mastered and which ones were not clear – or alternatively, which quiz questions were clearly written and which were not. Pre-module questions were designed to gather information useful in forming project teams. Post-module questions were actually statements to be rated on a scale of 1-6 with the meaning of each number defined as (1) strongly disagree, (2) disagree, (3) slightly disagree, (4) slightly agree, (5) agree, and (6) strongly agree. Some statements on the survey were:

- I understood the instructions for all assignments and activities.
- The topic was covered at a depth that met my expectations.
- The videos and readings provided clear information for learning the topic.
- The course activities are valuable to learning the content.
- I can learn the content of this course.
- I value the subject material of this course.
- This course requires too much time

Learners were given an opportunity to provide additional information such as which instructions were unclear, what additional information should be included, or what information was unhelpful.

The first module, Introduction to Systems Engineering (SE) and Model-Based Systems Engineering (MBSE) for Production Systems, is designed for people with little or no background in systems engineering. It is also being piloted in graduate and undergraduate courses to gauge its effectiveness as instructional material for future employees who are expected to work in a digital environment. Additional modules will be piloted as well. Students are being asked to provide feedback somewhat similar to that requested of current employees taking the modules. All seven modules are listed below, and descriptions can be found on the Purdue Online – College of Engineering website under professional courses.

- Introduction to Systems Engineering (SE) and Model-Based Systems Engineering (MBSE) for Production Systems
- Engineering a System with SysML
- SysML Implementation and Applications
- Quantitative Statistical Methods Supporting MBSE
- Production Engineering and MBSE Applications
- Digital Engineering and the Model-Based Enterprise
- MBSE Capstone Project.

We are still exploring options for integrating the modules, or components of them, into 2-year and 4-year degree programs. The most common way to use the modules seems to be incorporating one or more of them, or components of them, into an existing course. A detailed list of topics, sub-topics, and talking points along with copies of the visual aids used in the videos and links to selected resource materials will be available at no cost to faculty members who want to incorporate the modules into their courses and are willing to agree to provide data and feedback to our team. Because this is a research project as well as a workforce development project, we need to collect data on student reactions to and performance on the instructional

materials, which we will seek through an agreement or memorandum of understanding with faculty using the materials.

What We Have Learned so Far

This section briefly summarizes what we have learned to date about aligning our instructional modules on MBSE with the needs of organizations transitioning to, or planning to adopt, model-based systems engineering. While the five coordinated approaches to alignment that were outlined in the previous section were applied, in our case, to MBSE, they seem to be generally applicable for many efforts to design, deploy, and evaluate instructional materials with technical content.

In discussions with representatives of organizations, industry and government, either using MBSE or transitioning to a digital environment, we learned, of course, more about the specific MBSE-related knowledge, skills, and abilities organizations expect of their employees. We also learned that it is not just the engineers constructing and utilizing the digital models who will need an introduction to MBSE. Changing to a digital environment involves a change in culture, and everyone in the organization needs to understand the new environment and how they will interact with it.

The Advisory Board provided insights into how much time people in industry can reasonably devote to professional development. Ten hours of active participation in training on one topic seems to be the limit. Potential learners want to know the start and end dates of a module and exactly what they will be expected to do. Most of them must find time for the module outside of normal working hours. Because we needed to schedule instructors for each module, it was also important for us to know how much calendar time should be allocated for learners to complete a module requiring 10 hours of participation. We initially tried two weeks, and that was not enough. Three weeks was comfortable for most participants.

We were fortunate to have the Systems Engineering Research Center's 2020 report on the MBSE Maturity Survey which gave us insights into obstacles to the adoption of MBSE and needs for professional development in that field. It is worthwhile to look for similar studies to inform the design of professional development materials in other fields. Results of that survey helped us to focus module content and identify places where the training is most needed.

While the value of having an advisory board is common knowledge, we found that establishing an expectation for active engagement from the start was essential to reap the benefits of a well-qualified board. Using team members' networks to identify potential advisory board members was important. It helped to ensure that board members were interested in the project and prepared to contribute.

Detailed comments on the "final product" from external reviewers who have expertise on not only the concepts being taught but also how they are used in the "real world" are invaluable. It is important to say, and to show through reactions to comments, that all comments, including very negative ones are welcome. Some of the most direct and critical comments force the team to

rethink and revise or re-confirm the very foundations of the project such as its purpose and intended audience.

Finally, soliciting honest comments from the learners participating in the pilots is essential. Access to some demographic data associated with the survey responses is helpful because it allows module designers to know the background, including education and experience levels, of the respondents when modifying the modules.

Concluding Remarks

Since this is a work in progress, we are not yet in a position to draw conclusions about the instructional materials, how well they will be received, or how widely they will be utilized. We can say, however, that the contributions made by the members of our Advisory Board and the practicing engineers, faculty, and students who have reviewed or piloted the instructional modules have been invaluable in shaping those materials. They have helped us to align the materials with the needs of employers and employees transitioning to model-based systems engineering, and we sincerely appreciate their efforts.

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