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Plug-and-play adaptive approach to integrating model-based systems engineering concepts into academic curriculum

Overview

In this presentation, we will go over:

- Introduction
- Background
- Objectives
- Methods
- Results
- Discussion
- Conclusions and future work

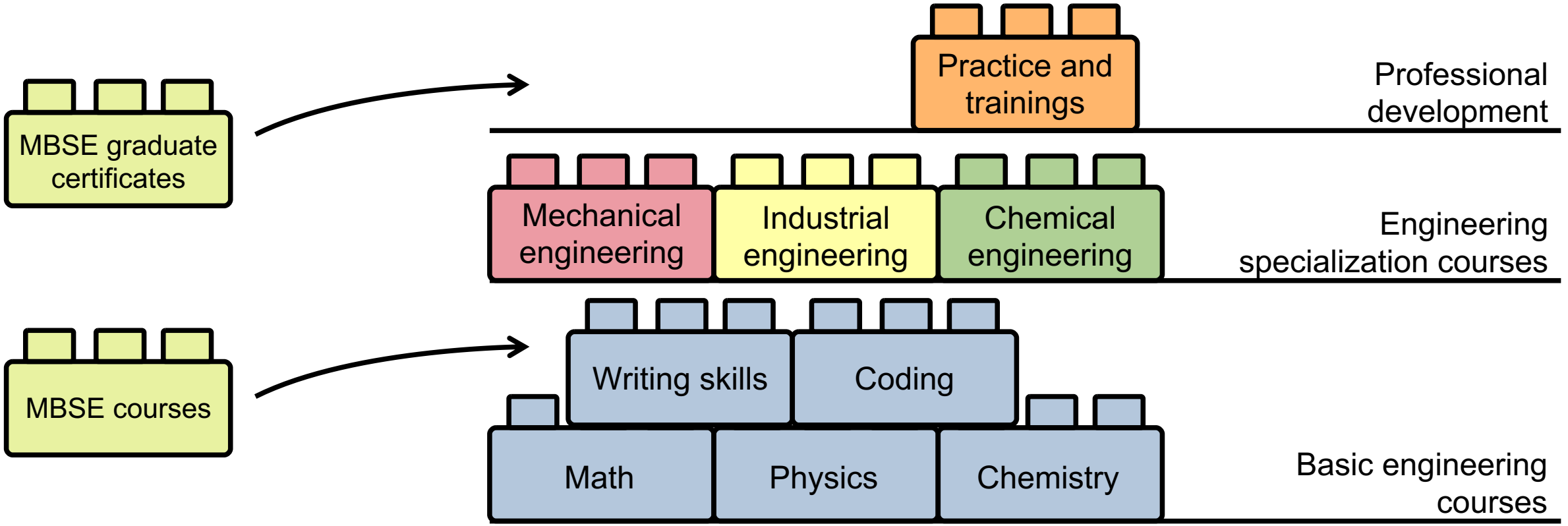
Introduction

Motivation for this work:

- Demand for graduates knowledgeable in MBSE increasing in the manufacturing industry
  - There is a demand for people that can communicate effectively with systems engineers in the workplace.
- Engineering programs are already packed with content
- Teaching new topics requires new expertise
- Plug-and-play modules can support instructors

Introduction

Existing solutions:

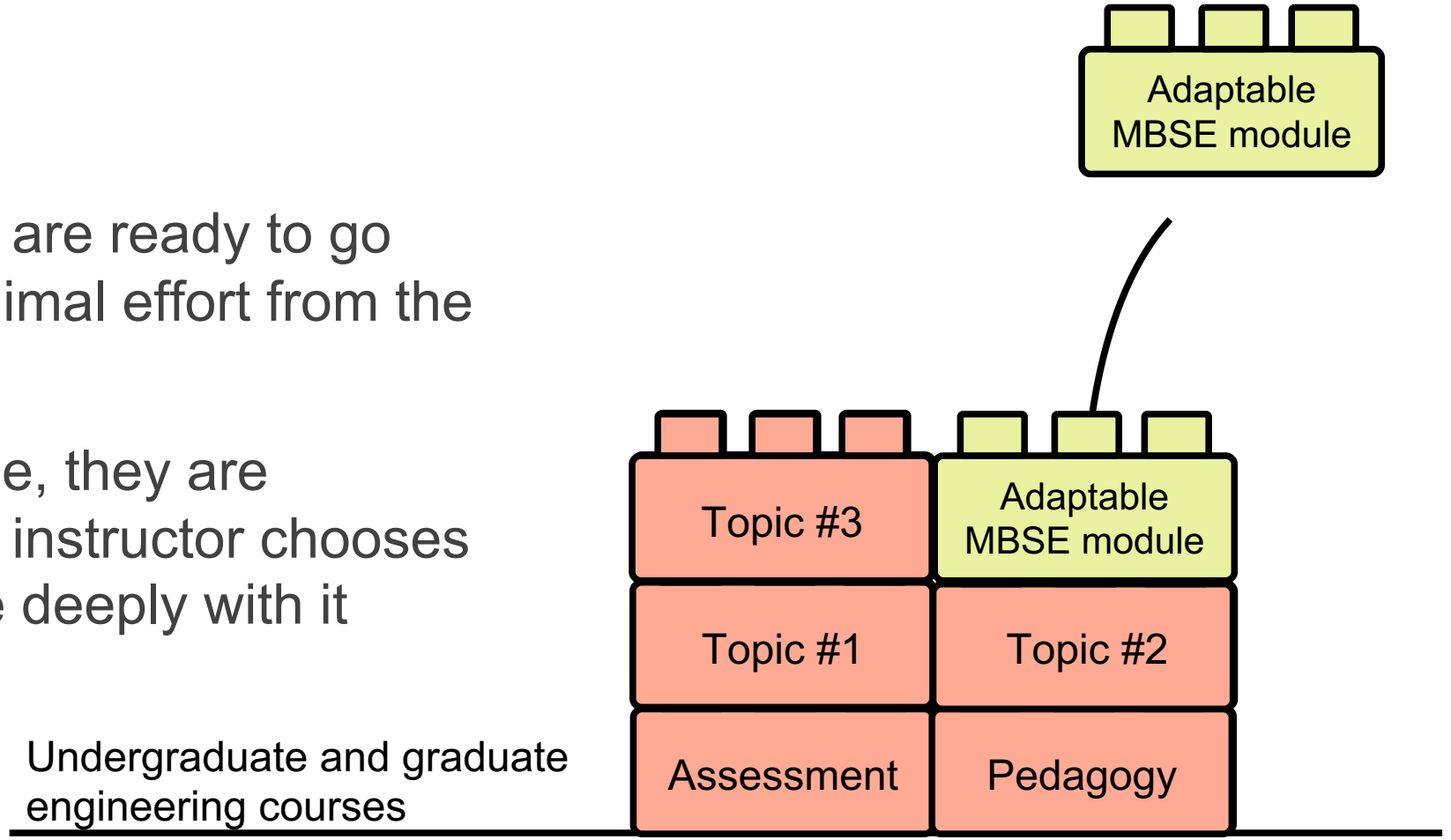


The building blocks of an engineer's education path starting in college

Introduction

Our approach

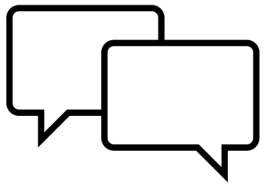
- These modules are ready to go and require minimal effort from the instructors
- At the same time, they are adaptable if the instructor chooses to engage more deeply with it



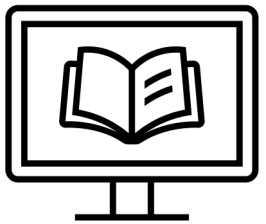
Background

Development of the modules: Content

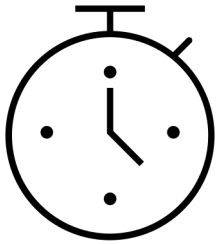
Key aspects of the needs assessment:



Interviews with industry partners about SE and MBSE skills



Analysis of the structure of existing MBSE online programs



Time requirements discussed with industry partners

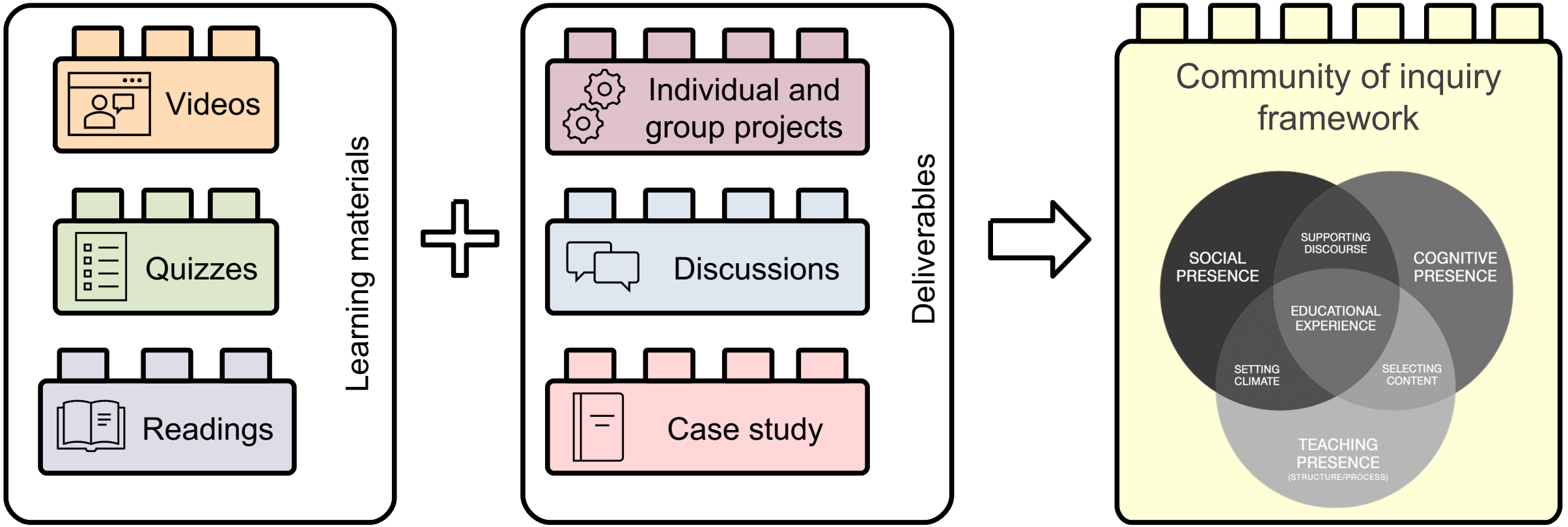
Background

Development of the modules: Content

#	Name	Systems engineers	Managers and other engineers
1	Introduction to SE and MBSE for production systems	✓	✓
2A	Engineering a system with SysML	✓	✓
2B	SysML implementations and applications	✓	
3	Quantitative methods supporting MBSE	✓	
4	Production engineering and MBSE	✓	✓
5	Digital engineering and the model-based enterprise	✓	✓
6	MBSE capstone project	✓	

Background

Development of the modules: Instructional design



Objectives

Understand how one of the modules is received in a graduate-level engineering course

Research question:
How do students react to the design of a preexisting MBSE unit of curriculum when it is implemented into a graduate-level system-of-systems modeling course?

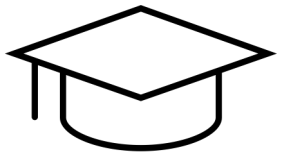
Objectives

Module 1: Introduction to SE and MBSE for production systems

- Motivation for learning SE and MBSE
- Systems (definition, characteristics, properties)
- Systems thinking and its importance in engineering
- Models (definition, types, purposes)
- Systems engineering and how to practice it

Methods

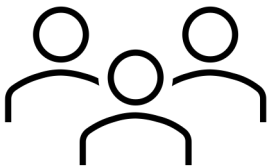
Collecting and analyzing student data:



Module 1 adapted for a graduate-level course

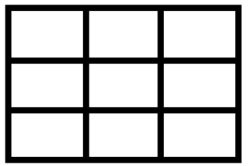
Study conditions

Survey with Likert-type items and open-ended questions

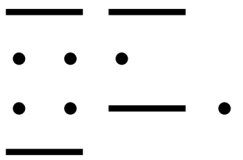


Responses that had completed over 50% of the survey (n=81)

Data collection



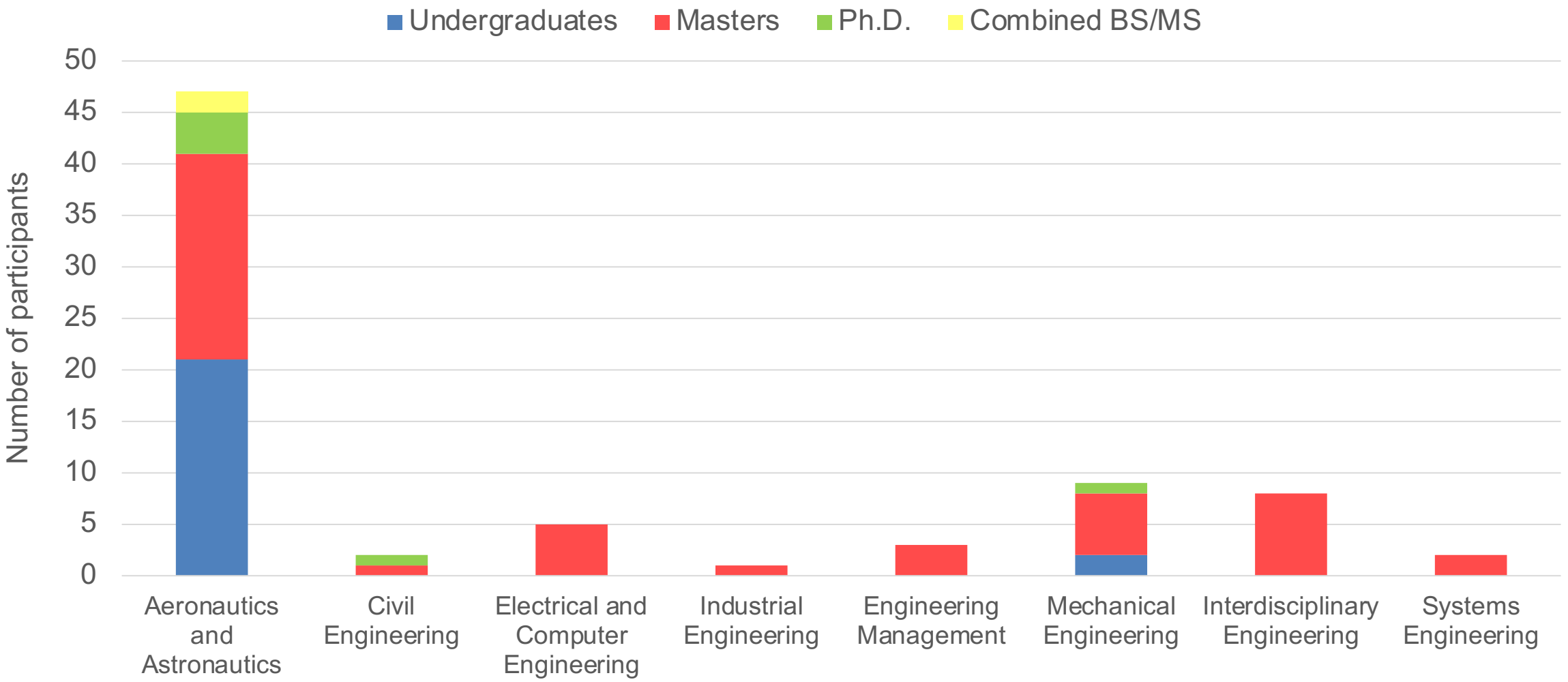
Descriptive statistics for Likert-type items



Inductive and latent coding for open-ended questions

Data analysis

Methods – study participants



Results

Likert-type questions – Module design

Overall positive reactions to the design of the modules.

Item	*M*	*Mdn*	*SD*	*n*
I understood the instructions for all assignments and activities	5.09	5	0.87	81
The topics were covered at a depth that met my expectations	4.72	5	0.95	81
The breadth of information provided on the topics met my expectations	4.73	5	0.97	81
The topics of the module were presented in an effective order	4.99	5	1.09	81
The videos provided clear information for learning the topic	4.74	5	0.97	81

Scale of 1 (strongly disagree) to 6 (strongly agree).

Results

Likert-type questions - Assessment

High SD values and more neutral reactions to questions related to the quiz.

Item	*M*	*Mdn*	*SD*	*n*
This module provided the knowledge for me to be successful in the quiz	3.58	4	1.44	77
The quiz was beneficial for learning the topic	3.64	4	1.44	81
The quiz questions effectively assessed the content in the module	3.52	3	1.44	81
The quiz was within reasonable length	5.23	5	0.81	81
There was busywork in this module*	2.95	3	1.34	81

Scale of 1 (strongly disagree) to 6 (strongly agree).
*Note that in this case, a lower number indicates a more positive outcome.

Results

Likert-type questions – Learner satisfaction

Again, the quiz proved to be viewed more negatively.

Item	*M*	*Mdn*	*SD*	*n*
Overall module	3.75	4	0.71	77
Videos	4.23	4	0.71	77
Quiz	2.70	2	1.15	77

Scale of 1 (highly unsatisfied) to 5 (extremely satisfied).

Results

Thematic analysis

Question	Recurring theme	*n*
Additional topics	Real Life Examples	9
	Curiosity for methodologies and tools	14
	Connections between application and knowledge	4
Challenging concepts	Ambiguous quiz	13
	Unclear definitions	37
	Relating to the real world	6

"Loved the real-world examples—more of these would be great!"

"The most challenging concept was understanding the distinct[ion] between different categories of things. Such as parts of a system description (function, purpose, behavior)."

Results

Thematic analysis

Question	Recurring theme	*n*
What they liked	Real-life examples	24
	Good structure of topics	32
	Engaging	8
Improvements to the module	Disconnect between quiz and knowledge	18
	Ambiguous quiz questions	16
	Lack of examples	16
	Instructional materials	10

"The presentation format was engaging and the information was well structured."

"The quizzes seemed to have about 2 or 3 relevant questions to the material and the other 2 or 3 were completely left field or much more specific than the information provided."

Discussion

Learning experience – learning materials

- Learners wanted more in-depth knowledge about MBSE. Two interpretations:
  - Motivation to learn more about MBSE
  - Previous experience with MBSE
- Examples were a highlight for students
  - This aligns with experiential learning theory (Gadola & Chidamo 2019)
- The instructor incorporated the module without the case study
  - It is expected that the case study would have further contributed to students' learning

Discussion

Learning experience – learning assessment

- Instructor only incorporated quiz as part of the learning assessment
- Students lacked assessments that provided authentic experiences
  - Case study not incorporated can provide such experiences
  - Team will consider developing other authentic learning assessments
- More opportunities to get feedback from the instructor
  - Teaching presence as defined by the community of inquiry framework

Discussion

Perceived learning outcomes

- Difficulties with abstract concepts of systems engineering
- According to Muller & Bonnema (2013), SE might be challenging for inexperienced learners because of its:
  - Broad scope
  - Multidisciplinary nature
  - Ill-defined problems
- Systems thinking is primarily developed through experiential learning

Conclusions

- Plug-and-play approach is well received by students
- Our team will revise quiz and authentic learning experiences

Future studies

- Use of the modules in other settings (e.g., undergraduate engineering and engineering technology programs)
- Investigate the other modules by themselves and as a set

Acknowledgments

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Thank you!

PURDUE UNIVERSITY

Question for the audience

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How do we effectively communicate this trail?