Creating an Enhanced MBSE Learning Environment Using Lego® Mindstorms

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Agenda

• Intro
• Current methodology
• Lego suitability to teaching MBSE Concepts
• Building the course, one brick at a time
• Demonstration
Intro – MBSE

• MBSE is HARD.
• Art as well as science
• Abstract in nature
  - But with massive and real consequences
• No established way to make MBSE tangible in a class

SE alone has masters and doctorate programs
One person’s logical is another’s conceptual.
FMEA’s – Learning only happens on failures
Sports teams use scrimmages to foster learning.
*Why not for MBSE?*

We need to do better at teaching MBSE if it is to be a successful discipline
Intro – Fundamentals of learning

- Understanding the subject matter and the object matter
  - The subject matter are the concepts to be learned
  - The object matter is the context-rich ‘why’

- Concept Encoding
  - Students construct their own version
  - They constantly refine the construct (see below)

- Feedback loop
  - Consequences
  - Coaching/positive feedback

Students need to actively participate in the learning process
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Current Teaching Methodology for MBSE courses

- Textbooks
- White papers/conference presentations
- Formal Classes / Hands-on
- Demonstrations
- Security Camera System (Friedenthal)
- This presentation
- Ski Resorts (Peek) / Multi-Function Printer (PMASE)
- Rovers (Peek)

Providing physical feedback on success and failure of MBSE concepts will speed up mastering and adoption
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Lego suitability to ... concept exploration

- Lego Architecture Set introduced in 2013
- Used by architects to study concepts
- Full disclosure: I own this one
Lego suitability to ... prototyping design

- Lego Mindstorms (ev3) set introduced in 2013
- Education version used by STEM teachers
  - Lego has dedicated and curated curriculum
- FIRST Lego League
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Building the Course: Core Modules

- Introduce problem, generate and model a concept (Concept Exploration)
- Model and analyze the tradespace (Concept/Design Exploration)
- Model the structure and behaviors (Design)
- Build and execute (V&V)
- Competition

Legos provide a medium for these!

Each of these modules could be subdivided, then mixed and matched (like Legos) to keep the days short.
Building the Course: Provided Material

• Starter SysML Model
  - Analytical and pattern libraries
  - Model framework with best practices
  - Example models
  - Programming tutorials

• Lego kits
  - Set of differing pre-built drive trains
  - Set of sensors
  - Set of chassis

Activity diagrams + custom Lego Mindstorms plugin
The challenge: rescue an injured person from a dangerous environment

- Carry an injured person (an egg)
- From point ‘a’ to ‘b’
- In a certain amount of time
- Egg must retain structural integrity
- Optional: retrieve a second egg
- Optional: drop off intel at a second location
How do we know it’s effective?

- Use a study and a control group
  - Study group with Lego, control without

- Written test at end of course of core concepts and competencies

- 6 month later follow-up questionnaire of core concepts and competencies

- Compare results
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Demonstration – programming the robot with SysML
Questions
Backup Slides
Backup: Programming References / Notes

- Currently using a directly-commanded approach with the default ev3 OS.
  - A great starter for programming in Python and Java (although Python is the author’s preferred language)

- Another option for the firmware/OS is the Lejos embedded OS that is based on Java.
  - Earlier efforts chose this path with MD17/18.

- Create a library of Java APIs that can be called from CSM and other modeling tools.
- RESTful not currently researched. Given the embedded nature, likely a challenge.
Sources

11. Lego Mindstorms Ev3 software, tutorial 3