POOLkits: Applying Object-Oriented Principles from Software Engineering to Physics Object-Oriented Learning

THE OHIO STATE UNIVERSITY Physics Education Research Group

Thomas James Kassebaum - Byrd Polar Research Center - The Ohio State University - Columbus, Ohio
Gordon J. Aubrecht, II - Physics Department - The Ohio State University - Columbus and Marion, Ohio

Key Background Points

Parallel Object-oriented Software Engineering (OOSE) for Physics Object-Oriented Learning Kit (POOLkit)

- To build physics concepts from first principles in small digestible chunks of knowledge
- To bridge comparmentalized knowledge from physics to software development
- Ultimately, to provide meaningful learning defined as a learner's ability to interpret and use knowledge in situations other than in the initial situation.

The main advantage of object-oriented design and modeling is its ability to describe effectively complex systems and transfer the model to an object-oriented computer code without major changes.

Object / Class Properties (OOSE)

- Software Objects
  - Data
  - Functions
    - Public (accessible from outside the object)
    - Private (accessible only within the object)
- Inheritance
- Operator Overloading (polymorphism)

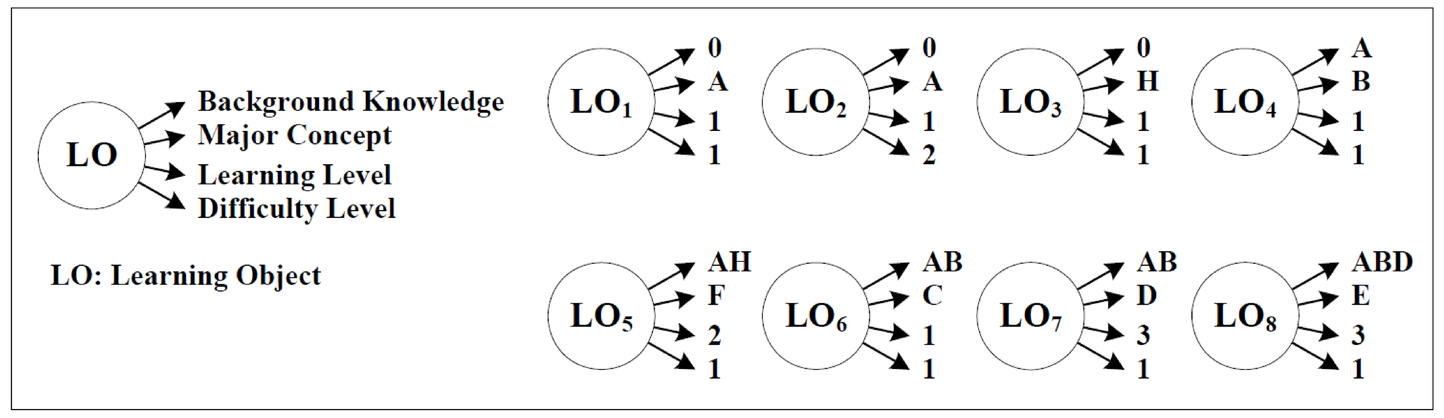


Figure 6. Illustrative example of eight learning objects
Figure from Tseng (2008)

Definitions of Object-oriented Terms

Class -- a template for an object that contains the data elements and associated functions that operate on the data.

Encapsulation -- the binding of data and functions into a class

Inheritance -- the property that allows for the creation of derived classes from base classes while possibly redefining or adding new variables and functions. Also known as extending a class.

Instance -- a manifestation of a class. Also called an **object**.

Method -- a member function of a class that operates on the data within the class.

Polymorphism (overloading) -- the ability to re-use function names within a class heirarchy such that the function operates in the appropriate way for each class.

Object Oriented Physics Definition

Each Learning Object represents a discrete unit of learning resources based on agreed standards:

- Content
  - Physics Object
    - Physical properties
    - Forces
      - External (public)
      - Internal (private)
    - Energy
- Assessment

The assessment of each learning object takes the form of a series of multiple choice questions based on the concepts present within the learning object. The results of the assessment determine mastery. These questions can be derived from well-established conceptual assessments such as the Force Concept Inventory (FCI).

Object Oriented Physics Example

Physical Properties
  Position (x, y, z)
  Time (t)
  Mass (m)

Methods
  Distance(x_1, x_2)
  Distance((x_1, y_1, z_1), (x_2, y_2, z_2))

  Acceleration(x, t)

  Force(m, a)

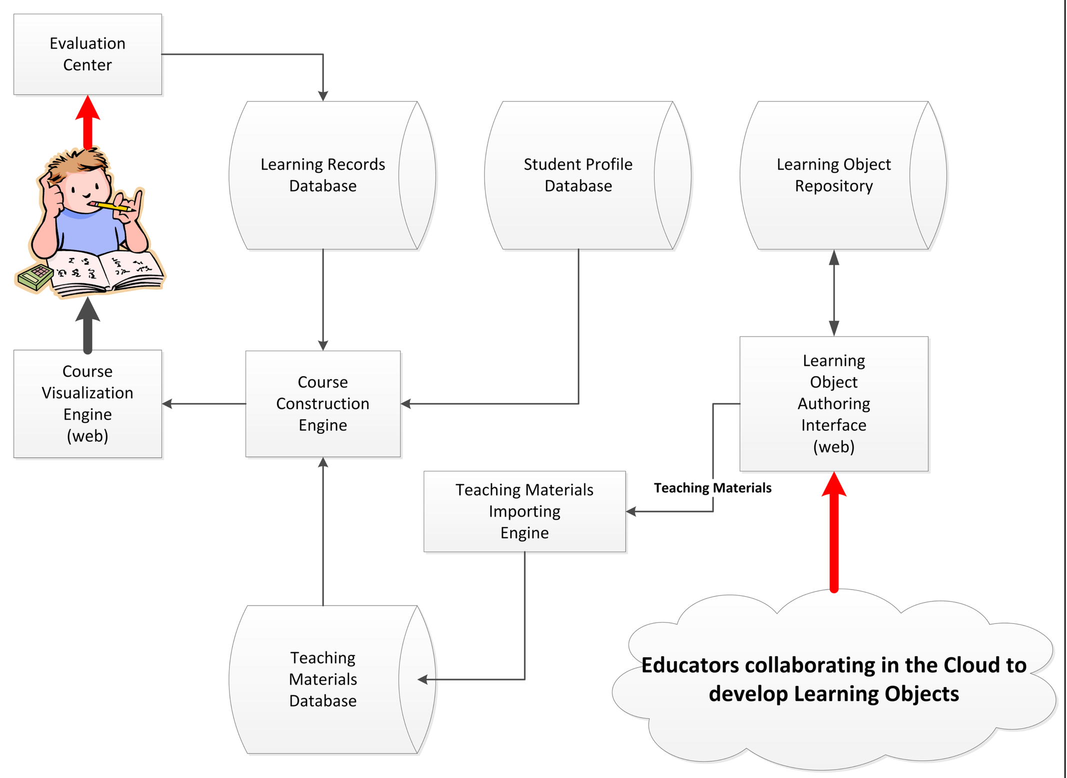
Assessment
  Use appropriate concept questions from PER for force.

Modular Adaptive Learning System

The learning objects for this system use the Shareable Content Object Reference Model (SCORM) standard for the modular learning objects. A proposed learning path is generated by linking these learning objects based on the student's profile and learning evaluation. Each of these learning objects contains a Background Knowledge descriptor, a Major Concept descriptor, a Learning Level descriptor and a Difficulty Level descriptor to assist in the design of the learning session. These descriptors assist in adapting each learning session to fit the abilities of each student -- challenging the brightest students and reinforcing the basics of the struggling students. (See Figure 6 taken from Tseng (2008) for a simple illustration of the learning objects).

Unlike a traditional linear course framework, the object-oriented framework builds each section from self-contained learning objects. Each learning object includes content and assessment, thereby allowing for a learning session to be developed and evaluated based upon the strengths and weaknesses of each individual. The adaptive system easily reconfigures the learning session based upon student feedback and assessment, with the possibility of inserting additional learning objects for the same topic to reinforce the concept, as necessary.

Each learning object will be standards-based and peer-reviewed utilizing the current PER results to guide the development.



Architecture of a modular adaptive learning system as defined by Tseng (2008).

Learning Object XML Example

```
<manifest identifier="LearningObjectManifest" version="n.n">
  <metadata />
  <organizations />
  <resources>
    <resource identifier="LO1" type="webcontent" href="LO1.html">
      <metadata>
        <schema>ADL SCORM</schema>
        <schemaversion>1.2</schemaversion>
        <lom>
          <general />
          <lifecycle />
          <metametadata />
          <technical />
            <educatonal>
              <MajorConcept> The Beginning </MajorConcept>
              <BackgroundKnowledge> 0 </BackgroundKnowledge>
              <LearningLevel>1</LearningLevel>
              <difficulty>2</difficulty>
            </educational>
          <rights />
          <classification />
        </lom>
      </metadata>
      <file href="LO1.html" />
      <file href="Q1.html" />
      <file href="Q2.html" />
    </resource>
  </resources>
</manifest>
```

NOTE: The <educational> tags extend the base SCORM structure in order to implement an adaptive learning system. The <file> tags are physical resources associated with this learning object, which include any assessment resources, such as quizzes.

Contrast Modular Adaptive Learning System to Historical Approaches

MATLAB/Mathematica/Maple/Excel Simulations

Simulations offer a student the opportunity to experiment with the parameters and quickly see the results. Some of these simulations have a steep learning curve for modifying the underlying code. They also do not have an innate way of assessing a student's understanding of the concept.

Static "Canned" Tutorials

Tutorials often are inflexible, lacking the ability to adapt to an individual's capabilities.

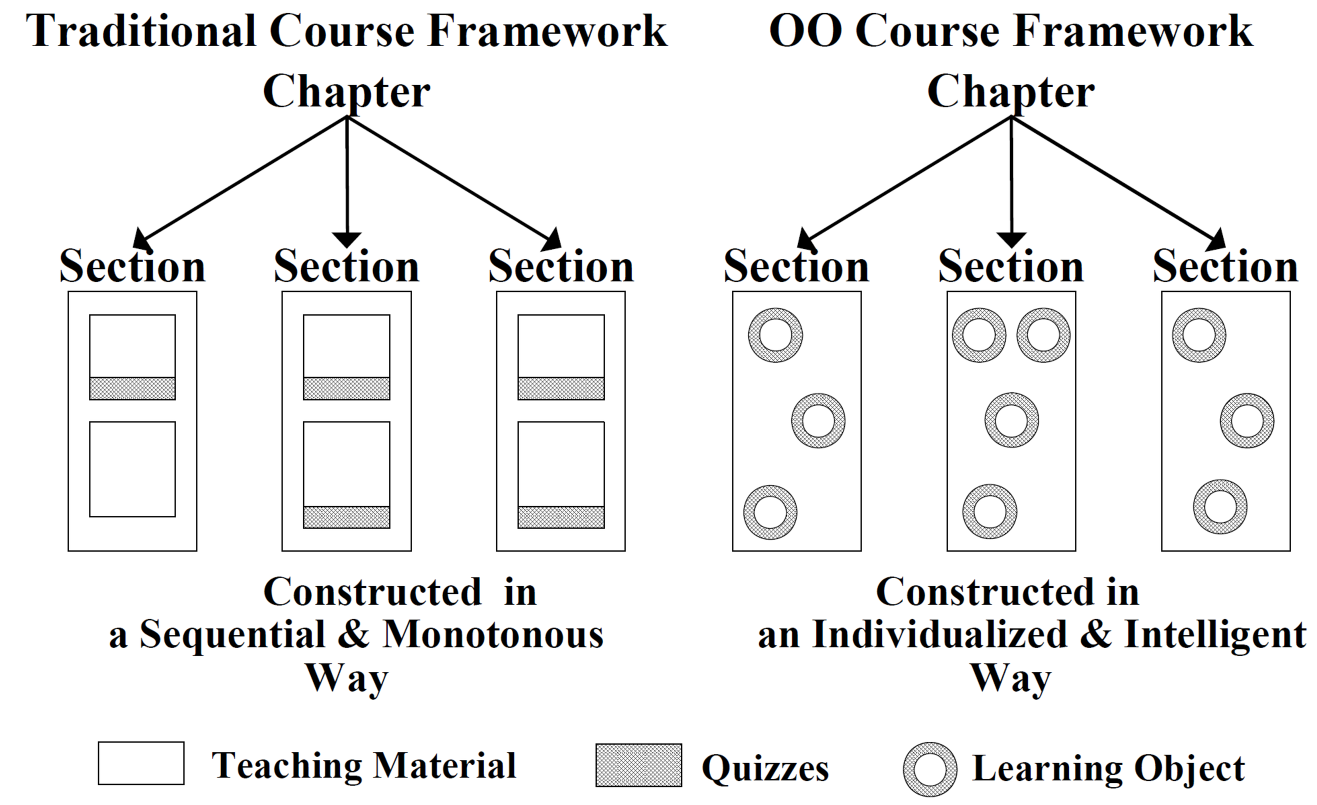


Figure 1. Comparison between traditional and modular course frameworks
Figure from Tseng (2008)

Why Apply OOSE to Physics and Physics Education Research

Physics is a fertile field with a lot of innovation from Physics Education Researchers that can be used to develop the learning objects. Physics concepts are easily translated into learning objects. Simple physics concepts can be built into more complex concepts. For instance, one-dimensional physics concepts translate into more complex multi-dimensional physics concepts.

Conclusions and Future Work

Benefits

- Uses standards-based learning objects derived from PER
- Promotes interdisciplinary learning
  - Reinforce similar concepts across multiple disciplines
  - Generate software objects easily from learning objects
- Provides an additional resource for "flipped" classrooms

Roadmap outlining the next steps towards a prototype:

- Define each of the four databases (Learning Object Repository, Student Profile Database, Teaching Materials Database and Learning Records Database)
- Design Learning Object Authoring Interface (web)
- Design Teaching Materials Importing Engine, Course Construction Engine and Evaluation Engine
- Design Course Visualization Engine (web)
- Develop initial learning object to test prototype
- Evaluate effectiveness and modify

Select References

Douglas, I. Instructional Design Based on Reusable Learning Objects: Applying Lessons of Object-Oriented Software Engineering to Learning Systems Design. in 31st ASEE/IEEE Frontiers in Education Conference. 2001. Reno, NV: IEEE.
Redish, E.F. and J.M. Wilson, Student Programming in the Introductory Physics Course: M.U.P.P.E.T. The American Journal of Physics, 1993. 61: p. 222-232.
Tseng, S.-S., et al., An Object-Oriented Course Framework for Developing Adaptive Learning Systems. Educational Technology & Society, 2008. 11(2): p. 171-191.