

# Knowledge Objects

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In a previous paper (Merrill, 1998) we suggested that: "...If an instructional strategy does not include presentation, practice, and learner guidance consistent with the knowledge and skill to be taught, then it will not teach. ... If a product does not teach, then it has no value." We also asked, "What constitutes an instructional strategy?" And we suggested that, "... A complete instructional strategy consists of a knowledge structure consistent with, and appropriate for, the knowledge and skill being taught, ..."

Instructional design requires answering two major questions: What to teach? And How to Teach? In our previous paper we provided suggestions, based on scientific principles, for how to teach. In this paper we direct our attention to the prior question: What to teach?

Ironically instructional design and development activities most frequently focus on using new and innovative instructional delivery systems. Contrary to popular opinion, a change in delivery system seldom improves the instructional effectiveness of an instructional product. Much less often instructional design and development activities focus on improving instructional strategies. As previously stated, "... effective, scientifically sound instructional strategies are poorly understood. They are almost always inconsistent with the goals of instruction in the instructional products that I have a chance to review." (Merrill, 1998). Finally, in almost all cases instructional designers rely on subject matter experts (SMEs) to determine what to teach. Unfortunately, as Robert Mager stated, "Most subject matter experts aren't!" The result is that too often the resulting instructional products do not contain necessary knowledge components and the knowledge components that are included are often incomplete or inappropriate for the goals of the instruction.

Determining the necessary and appropriate knowledge components for a given instructional goal is critical. *Determining what to teach is the most important activity of the instructional design process.* Learning cannot occur if the necessary knowledge components are missing. Learning will not be effective or efficient if the knowledge components are incomplete or inappropriate.

How do we know what to teach? What are the necessary knowledge components for different kinds of instructional goals? What are appropriate knowledge components for different kinds of instructional goals? This paper, and subsequent papers in this series, focuses on knowledge analysis, determining the knowledge components that are necessary and appropriate for a given kind of instructional goal.

For the past 10 years we have been investigating various approaches to knowledge analysis. The result of this effort is the development of a system of knowledge representation based on *knowledge objects*. (See Jones, Li & Merrill, 1990; Merrill et al, 1993; Merrill et al, 1996; Merrill, in press).

## What is a knowledge object?

A knowledge object is a precise way to describe the subject matter content or knowledge to be taught. A knowledge object is a framework for identifying necessary knowledge components. A knowledge object is a way to organize a data base (knowledge base) of content resources (text, audio, video, and graphics) so that a given instructional algorithm (predesigned instructional strategy) can be used to teach a variety of different contents. Knowledge objects should consist of components that are not specific to a particular subject matter domain. It is desirable to have the same knowledge object components (knowledge object

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<sup>1</sup> For additional information about knowledge objects visit our web site [www.id2.usu.edu](http://www.id2.usu.edu). The ID<sub>2</sub> Research Group at USU has designed computer-based ID tools which implement some of the ideas described in this chapter. For more information on these tools visit our web site. These tools, the IDXelerator™ and IDVisualizer™ are available as commercial products from Knowva Solutions. See their web site at [www.knowva.com](http://www.knowva.com).

syntax) for representing a variety of domains (e.g. mathematics, science, humanities, technical skills, etc.). It is desirable to have a predetermined knowledge syntax rather than have user defined knowledge components. A predetermined knowledge object syntax enables prespecified and preprogrammed instructional algorithms (strategies). User defined knowledge components seriously limit the generalizability of a knowledge base.

A knowledge object is a way to organize a knowledge base so that different instructional algorithms can use the same knowledge objects to teach the same subject matter content. For example, the same knowledge object can be able to be used for presentation, exploration, practice, simulation. The same knowledge object is be able to support *parts-of*, *kinds-of*, *how-to*, and *what-happens* types of knowledge.

A knowledge object consists of a set of fields (containers) for the components of knowledge required to implement a variety of instructional strategies. These components include: the name, information about, and the portrayal for some entity; the name, information about, and the portrayal for parts of the entity; the name, information about, values, and corresponding portrayals for properties of the entity; the name, and information about activities associated with the entity; and the name and information about processes associated with the entity. In the following paragraphs we will attempt to clarify these components.

A knowledge object can have five major components. These include the following:

- the entity, some device, person, creature, place, symbol, object, thing;
- parts of the entity;
- properties of the entity (properties are qualities or quantities associated with the entity);
- activities associated with the entity (activities are actions that can be performed by the learner on, with, to, the entity);
- processes associated with the entity (processes are events triggered by an activity or another process that change the value of properties of the entity).

### **Information components of a knowledge object**

All knowledge objects have a name and a portrayal and may have other associated information.

Consider *the Sentence* as a knowledge object<sup>2</sup>.

The name is *The Sentence*.

Information about the sentence might include a definition:

*“ a group of words that expresses a complete thought”*

There are many possible portrayals (all sentences)

*“These words are a sentence.”*

*“Sentences enable us to express our thoughts in written and spoken form.”*

### **Parts component of a knowledge object**

All entities can be subdivided into smaller entities or parts. Parts have a name, associated information, and portrayal as do entities. Parts can be subdivided into parts of parts, etc. for as many levels as may be necessary to adequately represent the entity.

For example: A sentence has two parts a subject and a predicate.

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<sup>2</sup> Some of the content for this example comes from Chapter 9: The Sentence from the book *English Workshop*, Holt, Rinehart and Winston, 1995.

Part: name = *subject*

Information about: “ *tells whom or what the sentence is about*”

Portrayal: The words, *These words*, is the subject of the sentence, *These words are a sentence.*

Part of a part: name = *simple subject*

Information about: “*the main word in the complete subject*”

Portrayal: The word, *words*, is the simple subject of the sentence, *These words are a sentence.*

Part: name = *predicate.*

Information about: “*the part that says something about the subject*”

Portrayal. The words, *are a sentence*, is the predicate of the sentence, *These words are a sentence.*

Part of a part: name = *simple predicate*

Information about: “*the main word or word group in the complete predicate*”

Portrayal. The word, *are*, is the simple predicate of the sentence, *These words are a sentence.*

### Properties component of a knowledge object

Properties cannot stand alone but must always be associated with an entity, activity or process. A property has a name. A property has a set of legal values that the property can assume. A property has some portrayal or indicator associated with each possible property value.

For example a sentence can express one complete thought or more than one complete thought.

Property: *number of complete thoughts*

Values: *one, more-than-one*

Portrayal for value of *one*: “*A sentence expresses a complete thought.*”

Portrayal for value of *more-than-one*: “*A sentence expresses a complete thought, starts with a capital letter, and ends with a period, question mark, or exclamation point.*”

Property: *purpose*

Values: *make-a-statement, ask-a-question, make-a-request, express-emotion*

Portrayal for *make-a-statement*. “*Sentences enable you to express your thoughts.*”

Portrayal for *as-a-question*: “*Are you able to express your thoughts in complete sentences?*”

Portrayal for *make-a-request*: “*Please, write a complete sentence.*”

Portrayal for *express-emotion*: “*It drives me crazy when you don't use complete sentences!*”

Property of a part: *number of simple subjects*

Values: *one, more-than-one*

Portrayal for *one*: “*A period is used to end a declarative sentence.*”

Portrayal for *more-than-one*: “*A period, a question mark, or an exclamation point are used to end a sentence.*”

### Kinds component of a knowledge object

Many entities can be subdivided into different kinds or classes of things. Each of these classes share the properties of the parent entity but the members of one class have different values on one or more of these properties than the members of another class. Class membership is defined by values on these discriminating properties.

For example:

Sentences can be divided into four classes: *declarative, interrogative, imperative, exclamatory*.

Kind: *declarative*.

Property: *purpose* Value: *makes-a-statement*

Kind: *interrogative*.

Property: *purpose* Value: *asks-a-question*

Kind: *imperative*.

Property: *purpose* Value: *makes-a-request*

Kind: *exclamatory*.

Property: *purpose* Value: *expresses-emotion*

Examples for each of these different kinds are found by finding the portrayals which share the value of the properties that define the class. In the sentence example each kind is defined by a value on a single property. Often a kind (class) is defined by values on two or more properties.

#### For example

Consider the knowledge object *Poetic Foot*

Name: *poetic foot*

Property: *number-of-syllables*

Legal value = 2 Portrayal: **a.vid a.bove bel.ly be.tray**

Legal value = 3 Portrayal: **bat.tle.ment ap.per.tain ed.i.ble in.ter.fere**

Property: *stressed-syllable*

Legal value = first Portrayal: **a.vid bel.ly bat.tle.ment ed.i.ble**

Legal value = last Portrayal: **a.bove be.tray ap.per.tain in.ter.fere**

Kind: trochic foot Property: *number-of-syllables* Value: 2 Property: *stressed-syllable* Value: first  
Portrayal: (those portrayals that have *number-of-syllables* = 2 and *stressed-syllable* = first) these include: **a.vid bel.ly**

Kind: iambic foot Property: *number-of-syllables* = 2; *stressed-syllable* = last

### Knowledge Base

A knowledge object is a way to organize a data base (knowledge base) of content resources (text, audio, video, and graphics) so that a given instructional algorithm (predesigned instructional strategy) can be used to teach a variety of different contents. A knowledge base is a set of multimedia resources that *instantiate* the knowledge object. *Instantiate* means that in the knowledge base there is a record for each instance of the knowledge object and that the fields in this record provide values for each of the parts and properties of the knowledge object.

**For example<sup>3</sup>**

Following is a knowledge object and knowledge-base records for sentences. Each of the components of the sentence knowledge object are represented by a field in the knowledge base.

<b>Knowledge Object Component</b>	<b>information</b>
<b>entity</b> the sentence	“a group of words that expresses a complete thought”
<b>parts</b>	<b>information</b>
subject	“tells whom or what the sentence is about”
simple subject	“the main word in the complete subject”
predicate	“the part that says something about the subject”
simple predicate	“the main word or word group in the complete predicate”
<b>properties</b>	<b>legal values</b>
purpose	make-a-statement ask-a-question make-a-request express-emotion
number of complete thoughts	one more-than-one
<b>kinds</b>	<b>definition (defining property values)</b>
declarative	purpose = make-a-statement
interrogative	purpose = ask-a-question
imperative	purpose = make-a-request
exclamatory	purpose = express-emotion

**Sentence portrayals (instances) in the knowledge base**

<b>S<sub>1</sub></b>	The smell of a wood fire makes me think of camping.
<b>part:</b> subject	The smell of a wood fire
<b>part:</b> simple subject	smell
<b>part:</b> predicate	makes me think of camping
<b>part:</b> simple predicate	makes ... think
<b>property:</b> purpose	make-a-statement
<b>property:</b> number of complete thoughts	one
<b>S<sub>2</sub></b>	Sammy walks, runs, or bicycles to school.
<b>part:</b> subject	Sammy
<b>part:</b> simple subject	Sammy
<b>part:</b> predicate	walks, runs, or bicycles to school.
<b>part:</b> simple predicate	walks, runs, bicycles
<b>property:</b> purpose	make-a-statement
<b>property:</b> number of complete thoughts	one

<sup>3</sup> To conserve space in this article we have not included all of the parts, properties, or kinds of sentences. The knowledge object can be expanded by adding additional parts, properties, or kinds.

A knowledge base for sentences will have many records illustrating all of the various property values and thus kinds of sentences.

What is the advantage of representing our examples in a knowledge base defined by a knowledge object? First, every instance in our knowledge base is complete, that is, it has all of the components of the knowledge. In most text books examples are not complete. One sentence might be used to illustrate a declarative sentence but its subject and predicate are not indicated because another sentence was used to illustrate subjects and predicates. By having a knowledge base with all of the components of knowledge indicated any record in the knowledge base can be used to illustrate any part, property, or kind of the knowledge object being taught.

Second, if we know all of the components of knowledge we can write a computer program for different strategies for teaching this knowledge. There can be strategies for teaching parts and for teaching kinds. There can be presentation strategies, exploration strategies, and practice strategies. Each of these strategies, because they know the components of knowledge as represented in the knowledge base, can use any of the records in the knowledge base. This also makes it possible to build tutorial programs that allow the student to request additional examples, to do additional practice, to explore variations on an example. Furthermore, each execution of the program can be unique since the examples for illustration, exploration, or practice can be randomly selected from the knowledge base for each individual student.

In subsequent papers in this series we will illustrate a variety of instructional strategies. In these papers we will show in detail how these different kinds of instructional strategies use the components of knowledge as represented in knowledge object knowledge bases.

### **Activities component of a knowledge object**

So far in this paper we have not yet dealt with activities and processes. In the remaining paragraphs we will change our example in order to illustrate these additional components of knowledge objects. It should be apparent that not all knowledge objects need have instances of every component.

Activities are actions taken by the student. Activities can be divided into sub activities or steps. Steps have a name, may have associated information, and trigger a process. In this system the definition of an activity is some action on the part of the student which triggers a process. A trigger is a message to a process to execute, that is, change the value of some property.

### **Processes component of a knowledge object**

The principal component of a process is its consequence. A consequence is defined as a change in the value of some property. Processes are conditional, that is they execute only when their conditions are met. A condition is defined as the value on some property. An important component of a process is the ability to display information in the form of some multimedia object or combination of multimedia objects (text, audio, video, or graphic). Finally a process has one or more triggers to other processes.

### **PEAnets**

This relationship among processes, entities and activities is called a PEAnet, a process, entity, activity network. In this network an activity triggers a process, the process changes the value of some property of an entity if the conditions (values on properties) have a certain value.

#### **For example:**

Consider a knowledge object for a simple electric circuit consisting of two parts, a switch and a lamp. The switch has a property we could call *position* with two values *up* and *down*. The lamp has a property we could call *lighted* also with two values *on* and *off*. The switch has a process *toggle the switch*. This process changes the value of the property *switch position* to *up* if it is *down* (a condition) and changes the value of the property *switch position* to *down* if it is *up* (a condition). This process is triggered by a student action, *flip the switch*. This process has no other conditions. This process, *toggle the switch*, also triggers the process *light the lamp*. Whenever the student performs the action, *flip the switch*, the process *toggle* is executed.

Our lamp also has a process *light the lamp*. This process changes the value of the property *lighted* to *on* if it is *off* and if *switch position* has a value of *up*. This process changes the value of the property *lighted* to *off* if it is *on* and if *switch position* has a value of *down*.

This description of a simple circuit probably seems very complex to the reader. Why do we need to have such detail? The answer is that a careful specification of PEAnet relationships makes it possible to define an instructional algorithm that can simulate the device or system described by the knowledge object. This simulation algorithm can be written once and used for any number of different devices or systems. The author need only specify the components of the PEAnet and provide appropriate indicators (portrayals) for the values of the properties. In subsequent papers in this series we will illustrate how to build strategies for visualization simulations using PEAnet knowledge structures.

### Summary

We have presented a more precise approach to content analysis and specification. We have defined knowledge objects as a way to describe the necessary and appropriate components of knowledge that are required for different kinds of instructional strategies. The components of knowledge objects include an entity, parts of this entity, properties of this entity, kinds (classes) of this entity, activities associated with the entity, and processes associated with the entity. A knowledge base is a set of records each of which portray (instantiate) an instance of the knowledge object. We have argued, and will show in subsequent papers, that knowledge objects and knowledge bases facilitate the specification of instructional strategies and make possible prebuilt instructional algorithms and automated instructional design.

### References

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