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Creating Reusable Learning Objects

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Creating Reusable Learning Objects

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To my mother Madeline and my late father Joseph Sr.

Preface

The employment of learning objects has increased in recent years as practitioners endeavor to enhance the learning experience of their students. One of the primary reasons for their appeal is the potential to use them in multiple instructional domains. However, a dilemma arises in the form of Dr. David Wiley's Reusability Paradox which as summarized by D'Arcy Norman (2003) of the University of Calgary is:

> If a learning object is applicable in a specific context, it is therefore not reusable in other contexts. If a learning object is reusable in numerous contexts, it isn't particularly useful in any contexts. (Norman 2003)

This seems to pose an all or nothing perspective. Is there a middle ground? Can educators *modify* learning objects so that they are, to some degree, in multiple contexts? In this brief, I propose a methodology by which this can be accomplished. An illuminating example is developed to show how such a learning object can be used in this manner.

In Chaps. 1 and 2, an introduction to learning objects and their usages relative to the Reusability Paradox is examined. Chapter 3 describes the design principles which have been developed and used to create learning objects to provide a standardized approach. Chapter 4 discusses what may be the most difficult but also the most basic obstacle to those who want to employ learning objects in multiple contexts: there is no one accepted definition of what a learning object is. Despite this, there have been numerous types of learning objects which are delineated in Chap. 5, while Chap. 6 discusses the more in-depth technical standards for learning objects. Chapter 7 lays down the principles which are a part of the main component of reusability; that of interchangeability. Chapter 8 delineates how one can evaluate and select a learning object appropriate to their situation and can be used across multiple contexts. In order to understand that a learning object has a lifespan like any other entity, Chap. 9 outlines this timeline and the essential events that occur along it. While Chap. 10 shows how a structured approach can make for a much more efficient means to create learning objects across multiple contexts, Chap. 11 provides an in-depth example of their employment. Finally, Chap. 12 discusses how object-oriented programming via the Alice language targeted at grades 6–12 can give students a deeper understanding of creating, using, and reusing learning objects.

It is the goal of this brief to aid the educator in utilizing and maximizing the potential of learning objects and how they can positively impact their student's understanding the world.

Minneapolis, MN Joseph Frantiska, Jr., Ed.D.

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Chapter 1
Background and Significance

The modern field of instructional design is like others that are based on high technology—dynamic and progressively complex so there's always a new concept, procedure or software package coming along. One of the latest concepts to become part of the field is that of learning objects. Associated fields such as software engineering have the related concept of object oriented design and programming. In their text *Programming Concepts in Java*, J.N. Patterson, Hume and Christine Stephenson define an object as "An object is a set of data and the methods which operate on that data" (Patterson Hume and Stephenson 1998, p. 11).

One of the difficulties that can make learning objects an arcane subject is the lack of a singular definition. As far back as 1969, Ralph W. Gerard of the University of California-Irvine described the basic concept as "curricular units can be made smaller and combined, like standardized Meccano [mechanical building set] parts, into a great variety of particular programs custom-made for each learner" (Gerard 1969, pp. 29–30). This implies that the 'curricular units' can be reused for multiple contexts.

To bring about a standardized definition of learning objects so that there would exist a commonality of function to promote widespread usage, the Learning Technology Standards Committee (LTSC) of the Institute of Electrical and Electronics Engineers (IEEE) was formed in 1996 to develop and promote instructional technology standards (LTSC 2000). The term 'Learning Object', first popularized by Wayne Hodgins in 1994 when he named the Computer Education Management Association (CedMA) working group 'Learning Architectures, APIs and Learning Objects' was chosen to describe these small instructional components (Polsani 2003). A working group was established and it provided the following working definition:

> Learning Objects are defined here as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and

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> collaborative learning environments. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning.

This definition is rather general since many things could be "referenced during technology supported learning." Different groups outside the LTSC have created different terms that generally narrow the scope of the canonical definition down to something more specific. For example, the Wisconsin Online Resource Center (WORC) which is a partnership formed between the 16 two-year colleges of the Wisconsin Technical College System to develop high-quality, interactive, online learning resources give the following definition:

> Learning objects are a new way of thinking about learning content. Traditionally, content comes in a several hour chunk. Learning objects are much smaller units of learning, typically ranging from 2 minutes to 15 minutes.

The following principles about learning objects were developed:

1. They are self-contained as each learning object can be used independently.
2. They are reusable in that a single learning object may be used in multiple contexts for multiple purposes.
3. They can be grouped into larger collections of content, including traditional course structures.
4. Every learning object has descriptive information called metadata which allows it to be easily found by a search.

Does anybody really use or care about learning objects? Learning objects have had considerable impact on an international basis. As with any new concept, there can be some ambiguity in its usage and understanding, but it generally pertains to small, reusable units of learning (Campbell 2003; Polsani 2003). The conventional approach is to regard learning objects as reusable chunks of *content*.

Via a building block approach, these learning objects may then be incorporated into higher order learning designs. Pedagogically, the purpose of contexts is to enable learners to achieve learning objectives. The design of these contexts requires choices in the selection and organization of activity and content to assist the learning process (Boyle 2006).

Chapter 2
The Reusability Paradox

However, this is not a panacea as there are skeptics of reusable learning objects. David Wiley of Brigham Young University has developed the Reusability Paradox which has been summarized by D'Arcy Norman of the University of Calgary as:

> If a learning object is applicable in a specific context, it is therefore not reusable in other contexts. If a learning object is reusable in numerous contexts, it isn't particularly useful in any contexts (Norman 2003).

What does this imply for the practitioner who wants to reuse a learning object between contexts? As with many things, it is a matter of degree. Specifically, it has to do with the degree by which the contexts are different and the degree of modification that is needed to make the learning object reusable in the new context. The Reusability Paradox is a rather generalized statement in that it does not look at the aforementioned degrees and does not delve to any level of detail as to the meaning of words or phrases such as 'applicable', 'specific' and 'particularly useful'.

For example, if a learning object that shows how to calculate simple interest does not need to be modified very much to show how to calculate compound interest within the confines of the same context of banking. However, there will be significant modifications required to allow reuse of a learning object that shows how to convert between the Fahrenheit and Celsius temperature scales in the domain of meteorology to show how to convert Morse code to English words in the context of communications.

Figure 2.1 delineates the relationship between context specificity and the corresponding degree of reusability as defined by the Reusability Paradox. Its shape belies the restrictions imposed on learning objects with the area under the curve representing the learning objects whose specificity and reusability comply with the paradox. If the curve were to bow outwardly instead of its pronounced inward path, the paradox would not be of such concern to instructional designers and other practitioners in the field.

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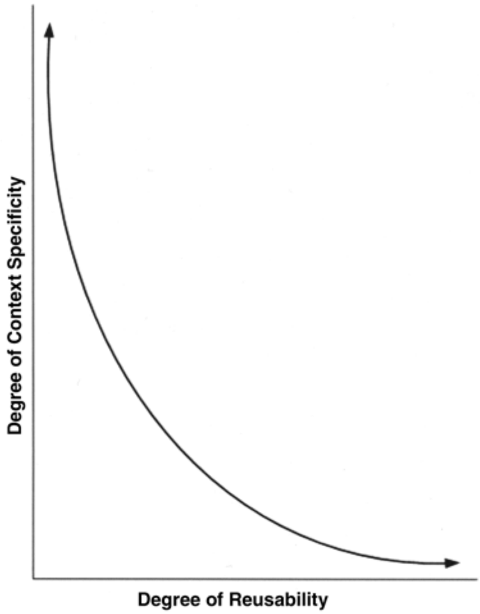

Fig. 2.1 The Reusability Curve showing the association between the degree of context specificity and the corresponding degree of reusability. *Source*: David Wiley

Chapter 3
Learning Object Design Standards

Three main design standards have been used to create learning objects that adhere to the four previously mentioned principles. The first two standards resulted from computer programming, another field that is concerned with building complex structures (programs) from smaller pieces or modules of computer code functionality (Boyle and Cook 2001).

Cohesion

The first standard is that of cohesion. In the field of computer science, cohesion is defined as the degree to which the associated modules of a program are-related and contribute to accomplishing a specific task. This is in much the same way that the manager of a sports team assesses whether all member of the ream are doing their part to achieve the team's objective. In the context of learning objects, this standard states that each unit should be dedicated to doing only one function. As in the sports team analogy, each learning object needs to be devoted towards a specific learning objective or task. Since each unit is self-contained and modular in nature, its implementation has greater flexibility in its usefulness. Again, this is a "building block" approach, that is, the usage of self-contained, dedicated units can be configured into a large number of configurations. Probably, the most common example of this is the Arabic alphabet in use today. While the English language is comprised of many words of varying degrees of complexity, they are all made up of singular or multiple representations of the 26 letters "A" through "Z". These letters are at an atomic level so that only a few instances of singleton representations of them are themselves words i.e., A or I. They are highly focused by themselves but when combined with others in a correct manner, they are the basis for all words in the language.

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Coupling

The second structuring standard is that of coupling. In computer programming, coupling, which is sometimes referred to as dependency, is the degree to which each module relies on other modules within a program. Therefore, it is the exact opposite quality of cohesion which emphasizes module independence. Thus, there is a similar relationship as with learning objects trying to achieve a balance between reusability and context specificity.

If a unit is very reliant on other units then it is not independently reusable and violates the first principle that a learning object must obey. There are two methods in which coupling can be controlled. The first method is that of navigational bindings. They are relations amongst pieces of software based upon how the navigation of a website or other instructional module is structured. The navigation structure dictates what modules invoke or are invoked by other modules. Strict navigational bindings to other modules can greatly increase coupling. The traditional hypertext-based approach to instruction with numerous linkages amongst instructional units is contradictory to the concept of learning objects and their desired reusability. The second method of coupling control is that of context bindings which dictate how the content of modules makes them dependent upon one another. An object's content should be independent of the content within other objects (Bradley and Boyle 2004).

These two methods allow the practitioner to design unique, reusable learning objects. Unfortunately, this imposes a potential danger in that such autonomous learning objects may limit the depth and breadth of the experiences that the learner will be exposed to. How can these constraints be relaxed so that the learner is exposed to a richer experience and still tend towards an optimal degree of reusability? The concept of the compound object is introduced. It consists of at least two autonomous objects (a base object and optional expansions) that are linked together. For example, the base object could be a webpage comprised largely of text that is directed towards one topic, such as an explanation of aerodynamics in Java. In this way, the learning object can operate on an independent basis.

Compound Objects

These two structuring standards assist in the development of learning objects that are autonomous and reusable. However, just as a sports team can accomplish more working together than as separate individuals, such independent objects can limit the utility of the learning experience. For that reason, a third structuring standard was introduced to enhance the utility of learning environments comprised of such cohesive, self-contained objects—compound objects. According to Tom Boyle of London Metropolitan University, "a compound object consists of two or more independent objects that are linked to create the compound. This compound consists of a base object and optional expansions" (Boyle 2003). The purpose of the expansions is to offer additional aid in attaining the stated learning objective(s). For example, as previously discussed, the base object could be a text-based webpage that focuses on an explanation of aerodynamics in Java which can operate as an independent learning object in its own right. The expansions are in the form of links to optional objects are placed in another area of the page.

Chapter 4
A Plethora of Definitions

As previously discussed, there are numerous definitions of what a learning object is. An additional problem is that many of the definitions are very broad and sometimes all encompassing. The LTSC defines them as “any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning”. Another definition is from McGee and Katz that views learning objects as “any digital resource that is designed to support learning, and may be re-used in different learning contexts (traditional or informal) for different purposes. We do not exclude technical data objects or information objects but rather see a division between these and those designed specifically to support learning” (McGee and Katz 2005, p. 1405).

Still, multiple definitions persist. Parrish (2004) proposes a process or strategic based definition encompassing the division of instructional content into discrete units with embedded, retrievable metadata and a somewhat context-free design that facilitates adaptability across multiple contexts. Kay and Knaack (2005) define learning objects as “reusable, interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners.” McDonald (2006) proposes a recursive definition in which a learning object is the result of the application of a finite set of rules to an existing learning object.

Learning objects have had considerable impact on an international basis. As with any new concept, there can be some ambiguity in its usage and understanding, but it generally pertains to small, reusable units of learning (Polsani 2003). The conventional approach is to regard learning objects as reusable chunks of content. Via a building block approach, these learning objects may then be incorporated into higher order learning designs. Pedagogically, the purpose of contexts is to enable learners to achieve learning objectives. The design of these contexts requires choices in the selection and organization of activity and content to assist the learning process (Boyle 2006). The quest for a single, generally accepted definition of exactly what a learning object is continues.

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With such broad definitions, the definition of a learning object is still rather nebulous. Videotapes, web sites, audio tapes, software, etc. are designed with a single target audience, one instructional objective, and one learning context in mind.

However, learning objects are designed with change in mind: change of content, change in access, and change of target audience. This requires that designers and instructors understand the concept of a learning object life cycle that describes the linear process of birth, use, and death of an object. The learning object life cycle is dynamic and iterative, and evolves over time and in relation to the context in which they are used. In fact, the learning object life cycle is actually comprised of birth, use, re-use and death of an object.

Chapter 5
Types of Learning Objects

There are numerous types of learning objects, each serving a specific purpose. One person who has contributed much to the development of learning objects is Dr. David A. Wiley of Brigham Young University. Dr. Wiley has created a taxonomy (classification system) of learning objects in 2000 called "Preliminary Taxonomy of Learning Object Types" (Wiley 2000, p 24). In this taxonomy, he developed five types of learning objects listed below with an example of each:

- *Fundamental*—A learning object that is at its atomic level. That is, it cannot be broken down farther. For example: a photograph of a tornado.
- *Combined-closed*—A learning object that contains two or more Fundamental learning objects combined so that the Fundamentals cannot be reused. For example: a video of a tornado with accompanying audio.
- *Combined-open*—A learning object that contains two or more Fundamental learning objects combined so that reuse of the Fundamentals is allowed. For example, a web page dynamically combining the previously mentioned image and video files together with textual material "on the fly."
- *Generative-presentation*—A learning object that possesses the ability to combine or generate and combine fundamental and combined-closed type learning objects. For example, a multimedia program capable of graphically generating the previously mentioned image and video files and positioning them to present a tornado formation scenario to the learner.
- *Generative-instructional*—A learning object that possesses the ability to combine fundamental, combined-closed types, and generative-presentation learning objects and evaluate learner interactions with those combinations, such as "remember and recite a series of steps that allow a tornado to form". For example, a website that allows the learner to successively add the steps for tornado formation in the proper sequence to create a tornado.

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LODA Object Types

In 2003, Clive Shepherd, a consultant based in Brighton, UK, and the Chairman of the eLearning Network developed Learning Object Design Assistant (LODA). LODA is a job aid that helps instructional designers to create effective, modular e-learning and performance support materials.

What constitutes a learning object as far as LODA is concerned? LODA's definition of a learning object is "A small, reusable digital component that can be selectively applied—alone or in combination—by computer software, learning facilitators or learners themselves, to meet individual needs for learning or performance support" (Shepherd 2003, p. 4).

LODA helps the user select from one of 41 different object types. Some of them are completely self-contained while others are used as components in larger, multi-object strategies for learning or performance support. They fall into the following three object categories:

Tutorial Objects

Concise, independent portions of learning that reflect a specific type of information, ability or approach. It may consist of information, drill and practice exercises and any other components that are required for learning to take place. They include the following types:

Facts and related information—Factual information that needs to be committed to memory or that will support other tutorial types such as the names of the planets or the creation of the U.S. constitution.

Concepts/classes—Differences between specific groups or classes of objects, procedures, people or thoughts possessing distinctive characteristics. Examples: viewpoints in religion; categories of software; the concept of relativity.

Structure—The configuration of an object or set of conditions. Examples: the parts of an airplane; a corporate organization diagram; an architectural drawing; the portions that constitute a system structural design.

Rule—An instruction that dictates behavior in a particular situation. Examples: do not bring your dog to the park; use the office equipment for business purposes only; if it starts to bleed, apply a tourniquet.

Principle—A declaration that is more comprehensive than a rule such as a regulation, concept, quality or belief. Examples: the law of gravity; customers are always right.

Attitude—An inherent inclination that tends to make a person react in a specific way with regards to a particular situation comprised of people, occasions and/or thoughts. Examples: attitudes about religion, customers, ecology, politics.

Process—A series of connected events culminating in an end result. Examples: how a bill becomes a law in the U.S. government; the human digestive process.

Procedure—A sequence of steps to accomplish a task. Examples: setting up a printer, handling a situation, troubleshooting, filling out a driver's license application.

Information Objects

Reference materials for performance support or as components in learning strategies requiring multiple learning objects. Examples: procedures; case histories; introductions and summaries; decision aids. They include the following types:

Facts and background information—Important facts that need to be remembered or information to support other tutorial types.

Concepts/classes—Distinctions between classes (types) of objects, events, people or ideas and their unique attributes. Examples: perspectives in politics; types of computers; the concept of equality; the concept of object-orientation.

Structure—The configuration of an object or environment. Examples: the parts of an airplane; a corporate organization diagram; the blueprint of a building; the components of a software interface.

Rule—What to do in specific situations, i.e. "if … then do …" Examples: never ask a question unless you know the answer; do not use the office phone for personal calls; teach arithmetic before calculus; if it starts to smoke, send an alarm.

Principle—A generalized assertion, e.g. a law, theory, value or belief. Examples: the law of gravity; customers are always right.

Attitude—An inclination to think, feel or act in a definite way relative to particular events, people, ideas, etc. Examples: attitudes about the Internet, clients, public speaking, politics, recycling.

Process—How something works. A series of events culminating in an object's function. Examples: how a DVD player works; the object life cycle; the metamorphosis of a butterfly; the process by which politicians are elected.

Procedure—How to do something. A sequence of steps required to achieve a specific goal. Examples: building a website, handling a situation, troubleshooting, filling out a form.

Decision aid—An instrument to help a person make a decision in a particular set of circumstances. Examples are videos, charts, online decision support systems. Uses: landing an aircraft, diagnosing a disease, choosing a suitable cemetery plot.

Definition—A statement of the meaning of a word or phrase.

Demonstration/worked example—An execution of the steps that comprise a procedure. Examples: a computer-based demonstration of how to conduct a sales presentation; a textbook example of how to build a tool shed.

Illustration/story/case history—A means to show how a process, procedure or rules can be applied in an actual situation. Examples: case law; anecdotes describing situations that went wrong; a story of how a product can be adapted for specific uses.

Paper—Reference material that supports any type of learning activity whether it is in an academic or industrial setting. Examples: an analytical report, a comparison of competing explanations, a comprehensive plan.

Program introduction—An explanation of the purpose and utility of a learning situation to provide the learner with motivation and an understanding of what the situation will comprise.

Program conclusion—A summarization given at the end of a learning situation that serves to integrate the major components of the learning to integrate and encourage the transfer of knowledge.

Practice Objects

Performance, evaluation and constructivist inquiry-based activities to be employed in learning strategies. Examples: situations, assessments, simulations. They include the following types:

Offline procedural practice—An activity that provides an opportunity to practice a procedure that does not require direct contact with the learning object. Examples: using spell check; rehearsing a play; assembling parts; combining pigments to produce a paint color.

Case study/scenario/problem—An activity in which the learner is presented with a specific situation and is required to react to that situation. Examples: a business case study, a criminal investigation, critiquing a video depiction of a criminal interrogation, a statement of earnings and debts for a corporation.

Simulation—A representation of a process that occurs in the real world, in which the user is able to initiate action or respond to situations or events. Examples: a flight simulator, war games.

Game—An activity with a goal and associated rules which provides the learner an opportunity to enhance a skill set through competition with others. Examples: a board game to teach geology, a video game to teach about fossils, a timed quiz about earthquakes.

Drill and practice—An activity that tries to increase ability in a task or skill through repetition. Examples: learning multiplication tables, cardiopulmonary resuscitation.

Test—An activity through either questions or practical application that is designed to assess aptitude of knowledge or skills with regard to specific learning objectives. Examples: a driving test, a graduate school entrance examination.

Questionnaire/inventory—A set of questions whose analyzed answers provide an insight into a learner's attitudes, personality, inclinations, etc. Examples: a marketing survey, an opinion poll.

Chapter 6
Technical Standards and Specifications

The Sharable Content Object Reference Model (SCORM) is a collection of standards and specifications for online learning. It defines communications between a user and a host system within a learning management system.

SCORM is a specification of the Advanced Distributed Learning (ADL) Initiative, which comes out of the Office of the United States Secretary of Defense. SCORM 2004 introduces sequencing, which is a set of rules that specifies the order in which a learner may experience content objects. They constrain a learner to a fixed set of paths through the training material, permit the learner to "bookmark" their progress when taking breaks, and assure the acceptability of test scores achieved by the learner.

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Chapter 7
Interchangeability

As previously discussed, in order to live and be usable over any period of time, learning objects must be interchangeable across systems. Interchangeability may be the most important factor in how objects are used and especially re-used given the constraints, needs, and policies of the organization or individual who either develops or locates a desired object. What works in a given context is the compelling entry point for many.

Access

An important quality of a learning object is that it can be accessed by instructors, designers and learners through a standardized retrieval process and site. Storage systems such as referatories and repositories are being designed to make searching easier and more accurate. A learning object repository is a searchable collection of learning objects. A referatory is a portal, generally a collection of links, that guides users to learning object repositories. Some current examples of learning object repositories are:

Merlot—An open repository of peer reviewed online multimedia resources for teaching and learning.

MedEd Portal—A repository sponsored by the Association of American Medical Colleges for peer reviewed teaching resources such as cases, lab manuals and assessment instruments.

HealCentral—The Health Education Assets Library is a digital library that provides freely accessible digital teaching resources for the health sciences.

MITOpenCourseWare—Free lecture notes, exams, and videos from MIT which covers their undergraduate and graduate courses.

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Fedora—Open source software for managing digital content. It was developed at Cornell University in 1997. Fedora provides a general-purpose management layer for digital objects.

DSpace—Open source solution for managing, accessing and preserving scholarly works. It is a software package of management tools for digital resources. It supports books, theses, three-dimensional digital scans of objects, photographs, film, video and other forms. The data is arranged as community collections of items, which bundle information together.

Metadata

Merriam-Webster's Online Dictionary (2015) defines metadata as "data that provides information about other data" (Metadata 2015). Locating a learning object may be accomplished through searching the Internet or a repository, but nothing can be systematically located for use or re-use without metadata. Or-Bach and Lavy (2004) describe three types of metadata: descriptive, administrative, and structural. Administrative metadata manages and preserves objects in the repository by detailing information such as format, copyrighting and licensing; structural metadata stores objects in a repository and for presentation by linking objects together to make up logical units; descriptive metadata describes the intellectual content of objects. No doubt that many first encounter a learning object through descriptive metadata tags. The purpose of learning object metadata is to provide a common nomenclature enabling learning resources to be described in a common way. Metadata can be collected in catalogs, as well as directly packaged with the learning resource it describes. Metadata has become a critical and well-articulated sub-field of learning objects as noted by the proliferation of different taxonomies.

Development Processes

Learning objects enter the development process depending upon the type of organization and specific need. Higher education has used the development process to help faculty members think deeply about course objectives and instructional design; whereas, the military, government, and corporate sectors implement the development process to create eLearning solutions. Identifying the most appropriate instructional model during the analysis and design phases is critical for the development of effective instruction since it ensures that learning outcomes are directly linked to the learning objectives (Francis and Murphy 2008). For example, if a teacher develops training on how hurricanes form. An analysis has been conducted and results have identified that the target audience's learning level varies widely. In an attempt to satisfy all the levels, the teacher will use one or more taxonomies (i.e., Bloom's, etc.) employing variant levels of the chosen taxonomy(s).

Re-use

The basic content that describes the hurricane formation at the lowest learning level will probably be used across all levels of instruction regardless of the taxonomy. In this way, the objects will have a high probability of re-use throughout most or all levels of learning.

In 1956, educational psychologist Benjamin S. Bloom of the University of Chicago devised a hierarchical classification of educational objectives based on cognitive complexity known as Bloom's taxonomy. There are six major categories, which are listed in Fig. 7.1, starting from the simplest behavior at the bottom to the most complex at the top. The categories are hierarchical in nature as the more basic level must be mastered before the next level's activities can begin (Bloom 1956).

However, Bloom noted a weakness of the cognitive taxonomy in that there was a basic distinction between the category that he designated as "knowledge" and the five other categories of his model. Specifically, the five other categories were concerned with the intellectual aptitudes and skills that people use when they interact with various types of knowledge.

In a revision of Bloom's Taxonomy published in 2001 by David Krathwohl, and Lorin Anderson who was a student of Benjamin Bloom, first defined the following types of knowledge (Anderson et al. 2001):

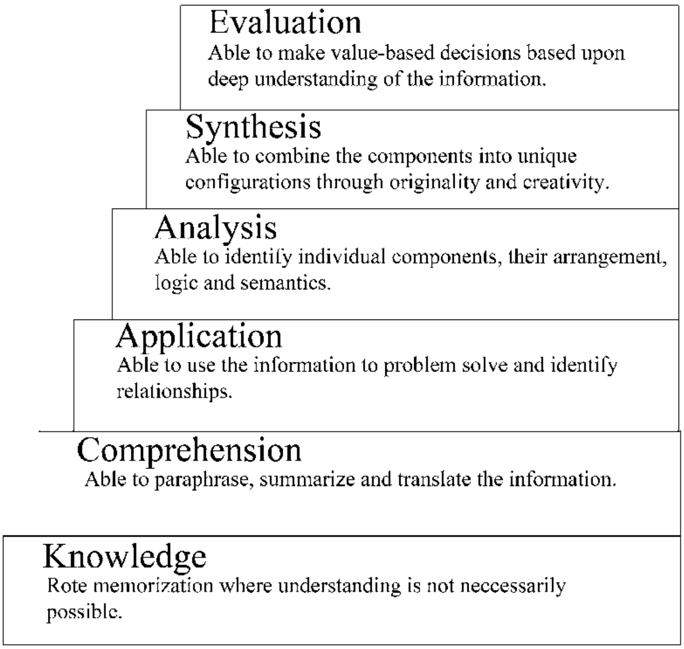

Fig. 7.1 Bloom's taxonomy of learning domains

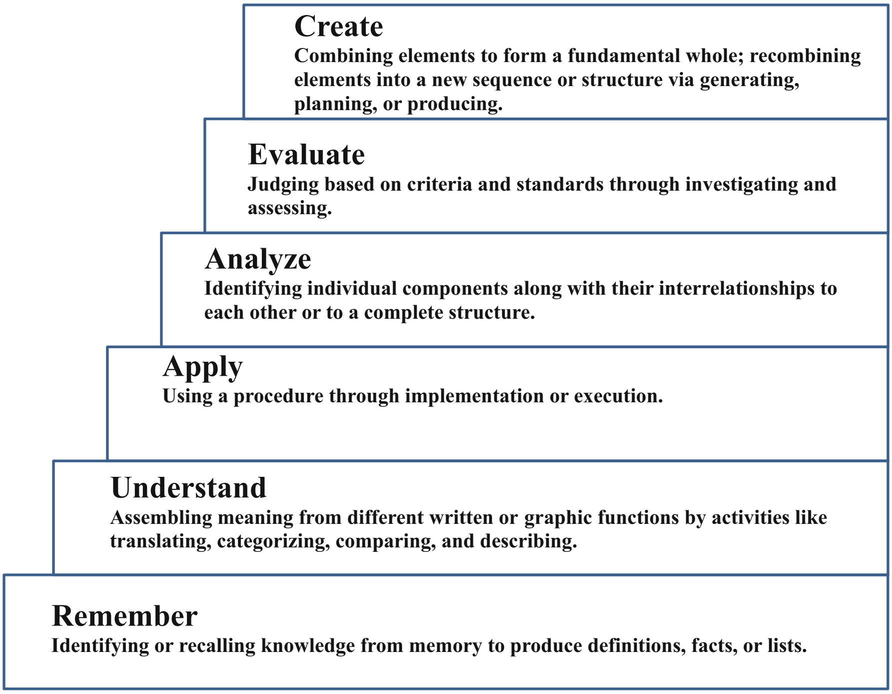

Fig. 7.2 Anderson and Krathwohl's s taxonomy of learning domains

Factual Knowledge—The primary information related to a given information domain that a student must be familiar with to solve problem or effectively use information within that domain.

Conceptual Knowledge—The relationships amongst various elements of the factual knowledge that allows them to function together as fully formed ideas.

Procedural Knowledge—How to perform a task along with associated, means of inquiry, and standards for employing algorithms, skills, practices, and methods.

Metacognitive Knowledge—An understanding of cognition as a general concept in addition to an understanding of one's own cognition.

These types of knowledge were used to create the modified taxonomy whose major difference from Bloom's original taxonomy is how these forms of knowledge are acted upon (Fig. 7.2).

Chapter 8
Evaluation and Selection

Prior to selecting a learning object, the user evaluates the object based upon specific criteria such as maintenance, user interface, and effectiveness. Maintenance involves making sure the object works the way it was designed to and that its content is appropriate in the required context. User interface is important especially in light of the potential of re-use across various audiences and contexts. Learning objects may be required to interact with other systems that have incompatible interface designs that hinder viewing and interaction. Also, criterion of the Americans with Disabilities Act accommodations may make the most appealing learning object unusable. Evaluation of effectiveness appears to be the most overlooked aspect of the learning object life cycle. Cisco Systems as well as other for-profit companies, does evaluate effectiveness of training, what Cisco refers to as '*impact*' but the primary focus is on learning achievement rather than effectiveness of learning object design and operation. All of these factors need to be taken into consideration when evaluating and selecting an appropriate learning object.

A Structured Evaluation Process

Meister-Emerich (2009) delineates a five step evaluation process for selecting learning objects as follows:

Identify Learning Outcomes

What is a learning outcome? A learning outcome specifies what a learner should be to accomplish once they have completed the learning experience. In order for the learning outcome to be realized, all learning objects must contribute to the outcome.

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Otherwise, the performance of the learner can be negatively impacted due to an unclear understanding of the learning environment content. Learning outcomes that are clearly developed will aid in the selection of appropriate learning objects.

Evaluate the Accuracy of the Learning Object

For a learning object to contribute to the required learning outcome, it must deliver accurate information using a delivery technique that is familiar to the learner. If the course developer is not able to acquire a learning object that provides accurate information, they may elect to use an inaccurate learning object so that the learner is challenged to locate and discuss the erroneous content.

Evaluate the Content's Usability

In addition to a learning object's accuracy of information, the learning object's usability with the given content must be assessed. One part of the usability is how the information is presented to the learner. One concept to be concerned with is that of the split-attention effect which occurs when a learner is required to divide his attention between the textual and graphical portions of the content. Another effect to be considered is that of redundancy. The redundancy effect occurs when the presented learning content is in both the graphical and textual portions and can impose an increase in the cognitive load of the learner (Morrison 2004). To mitigate these effects, the graphical and the text portions need to be properly integrated.

Learning objects can generate learning by the way that the learner is expected to interact with it. Learning events where the student creates learning are called generative whereby events in which the instructor supplies the learning are called supplantive (Smith and Ragan 2005). This divide between a learner being passive or active in the pursuit of learning is a key factor in judging the usability of a learning object within a given context.

Estimate Cognitive Level

Bloom's taxonomy serves as a guide as to what cognitive level is appropriate and expected in a learning object. Just as the previous discussion of usability, the cognitive level can require the learner to be passive or active in their interaction with the object and is another primary concern in the selection learning objects.

Establish the Location

Location refers to where in the learning environment that the learning object is to be used. It may only be employed in one area or in multiple ones. The developer needs to determine this as it also relates to its reusability within the same context but at different points within it.

Chapter 9
The Gestation of Learning Objects

Learning objects enter the development process depending upon the type of organization and specific need. Higher education has used the development process to help faculty members think deeply about course objectives and instructional design; whereas, the military, government, and corporate sectors implement the development process to create eLearning solutions. Identifying the most appropriate instructional model during the analysis and design phases is critical for the development of effective instruction since it ensures that learning outcomes are directly linked to the learning objectives. For example, let's say that a teacher develops training on how hurricanes form.

Analysis

First, analysis has been conducted and results have identified that the target audience's learning level varies widely. In an attempt to satisfy all the levels, the teacher will use one or more taxonomies (i.e., Bloom's, etc.) employing variant levels of the chosen taxonomy(s). The basic content that describes the hurricane formation at the lowest learning level will probably be used across all levels of instruction regardless of the taxonomy. In this way, the objects will have a high probability of re-use throughout most or all levels of learning.

Conversely, in situations where highly specialized content is required due to the target audience's needs, objects will be required to be designed so that the instruction is both relevant and efficacious to that highly specific need. As a result, these objects might not be necessarily reusable or instructionally efficacious in a different instructional context or target audience. Like pieces of a jigsaw puzzle, objects cannot be chosen from a collection "on the fly", as they are not inherently interchangeable, and if interchangeability is attempted, the results are rarely acceptable. Therefore a great deal of information must be known about a learning object in order for it to be used

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effectively across different instructional contexts and target audiences. The ability to have significant knowledge about an object requires that the object is associated with the correct metadata. This will allow the developer to properly choose the object that best meets both the needs of the designer as well as the target audience.

However, learning objects are designed with change in mind: change of content, change in access, and change of target audience. This requires that designers and instructors understand the concept of a learning object life cycle that describes the linear process of birth, use, and death of an object. The learning object life cycle is dynamic and iterative, and evolves over time and in relation to the context in which they are used. In fact, the learning object life cycle is actually comprised of birth, use, *re-use* and death of an object.

Use and Re-use

The use and re-use of learning objects is of course how many users come into the learning object life cycle. Use may be limited to a one-time experience, but inherently learning objects should be used repeatedly by different people and possibly in different ways. In their study, Elliot and Sweeney estimated that by reusing objects, their projects was developed three times faster than if it had been built by developing entirely new objects (Elliott and Sweeney 2007). Re-use should not only pertain to the re-use of objects, but should also focus on the efficient and effective re-use, re-purpose, and reference (R^3) of objects. Katz et al. (2004) define R^3 as follows:

> *Re-use* is the use of an existing object in a new learning event without any modification to its instructional treatment, context, or content. *Re-purpose* refers to the use of an existing object in a new learning event with modification to its instructional treatment, context, or content. *Reference* is the use of an existing object(s) as an information source or resource for generating ideas for new learning events. For example, if teaching color theory, an object may have relevance for physics, art, culinary arts, or interior design. In this case the content remains the same in each situation of re-use, but the context and possible instructional strategy changes. The object may be re-purposed for different levels of abilities, linguistic or cognitive sophistication, or even depth. Finally, the object may be linked to or embedded in a larger sequence of learning objects.

Polsani (2003) views a learning object's reusability as its primary reason for employment in a scenario and recommends that learning objects should be created with a high level of generalization in mind. This provides independence in a variety of scenarios along with the capability to join with other learning objects. In turn, this leads to the concept of interchangeability and the eventual optimization of its reuse.

Interchangeability

In order to live and be usable over any period of time, learning objects must be interchangeable across systems. Interchangeability may be the most important factor in how objects are used and especially re-used given the constraints, needs, and policies of the organization or individual who either develops or locates a desired object. What works in a given context is the compelling entry point for many.

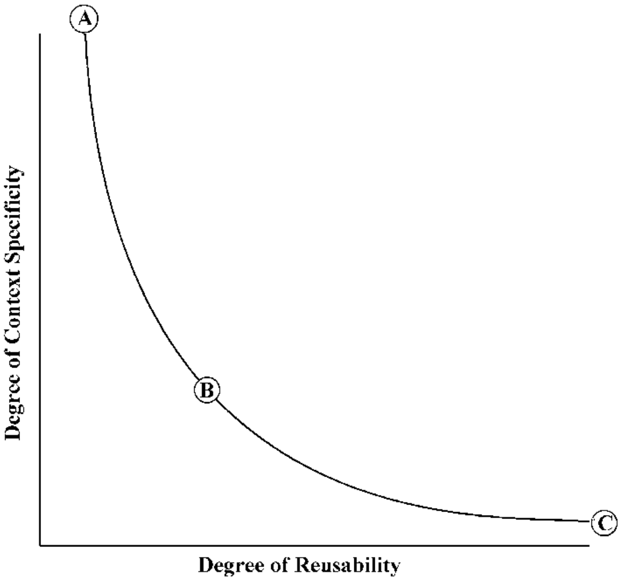

Fig. 9.1 The points of extreme context specificity and reusability along with the optimal point along the Reusability Curve. *Source*: David Wiley; *Modifications*: Joseph Frantiska, Jr.

The reusability and the context specificity of a learning object can be looked upon as inversely proportional as the reusability paradox states. But isn't this paradox true for any item that can be used over a wide range of applications? For example, if there is a particular antibiotic that is meant to destroy a specific species of bacteria, then its specificity is at a maximum and its reusability is at a minimum. Conversely, if an antibiotic can destroy all members of a particular strain (subset) of a bacterial species but not those outside of another strain, then its specificity is at a minimum and its reusability is at a maximum.

So there is a spectrum that a learning object's degree of reusability can span. It can go from minimal ("one trick pony") to maximal ("a jack of all trades"). Of course, its corresponding degree of context specificity travels that same spectrum but in the opposite direction. Therefore, when the reusability is at its maximum, the context specificity is at a minimum. In turn, it really should be referred to as "a jack of all trades and a master of none". Does that imply that the optimal situation is when both quantities are at the middle of the spectrum?

First, what do we mean to optimize something? The Merriam-Webster dictionary defines optimize as "…to make as perfect, effective, or functional as possible" (Optimize 2014). Not perfect but as perfect as possible under the given circumstances. That is, just because something is maximized that does not necessarily mean that it is optimized.

For the degree of reusability to be maximized (but not necessarily optimized), the context specificity must drop to its minimal value. If we were to keep the context at a minimum that is, fully decontextualized, we are left with a learning object which can be used in many situations but how well can it perform in any of these contexts? In Fig. 9.1, point A is asymptotic relative to the degree of context specificity and point C is asymptotic relative to the degree of reusability. In the middle is point B which represents the point where the degree of reusability and degree of context specificity may both be optimal.

Chapter 10
A Structured Approach

Is it possible to create a learning object with minimal modification(s) and still be truly usable in multiple contexts? As an example, the endeavors of sailing and flying are both similar and dissimilar. The obvious point where they are dissimilar is the media in which they are performed (water vs. air). However, they are similar in how they traverse their respective media along with the similar laws of physics that govern this travel. One of the critical aspects of flying that a student pilot must understand is angle of attack. Angle of attack refers to the angle between the wing and the oncoming air also known as the relative wind. As the pilot gradually pulls back on the control column to make the aircraft climb, the angle will increase. When the pilot pushes the column forward to make the aircraft descend, the angle will decrease. When the angle of attack increases to the point where the flow of air cannot continue to flow smoothly over the surface of the wing, it will stop generating sufficient lift and is said to have stalled. In sailing, a student sailor must understand that a sail can also stall. When the wind is coming from the rear or either side, there is sufficient angle between the wind direction and the boat's direction of travel. However, as the angle decreases when the wind direction and the boat direction start to converge, the sail will stop creating a sufficient amount of low pressure and stall or "luff".

Figure 10.1 shows how these two different vehicles encounter the similar principles in order to allow them to traverse their respective mediums.

Such a learning object represents a bridge between the two points of extreme. How does this translate into a standard or methodology that can be followed to achieve this goal? The following steps are an attempt:

1. Fully apply the standard of cohesion by breaking down the learning object to its most atomic level as in the aforementioned alphabet letter example. This will probably require all or most of its context specificity to be eliminated which will result in a maximum of reusability. This is merely an extreme example of chunking which means to break down information into manageable portions. If course, "manageable" can be viewed as a very nebulous term.

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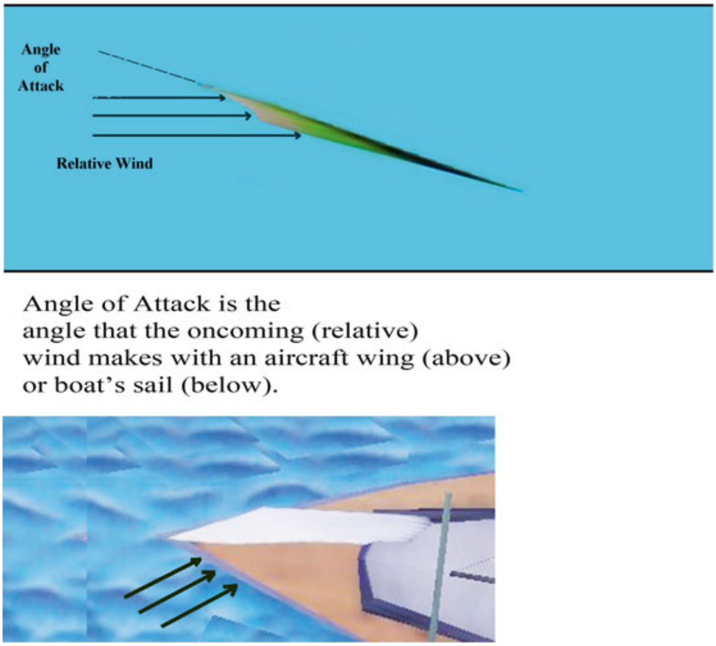

Fig. 10.1 The similar principle of angle of attack and it's generation of lift on either a wing (above) or sail (below). *Source*: Joseph Frantiska Jr.

2. Completely understand the information domain within which the learning object will exist, be used and re-used.
3. Combine the atomic portions only to the extent where the requirements of the domain are satisfied so that the reusability is increased but the context specificity is not decreased to the point where its range of applicability to problems within the domain is less than its maximum. That is, address the standard of coupling.

This process can analogized to a person who has ten cars and must tear them down to their individual parts in order to use those parts to construct seven vehicles that are highly customized for a specific purpose. The customizer follows a circuitous process where one path leads from complete cars to a full deconstruction to the atomic level and the return path from the atomic level back to complete cars that may be different in number and composition from the original ones.

Along these same lines of chunking to an extreme level, McGee (2003) states "Wiley suggests that this transfer to the notion of 100 % granular learning objects; the chunking of content to its smallest parts. Courses then, at a low level of granularity may be combinations of chunked information, at least in theoretical

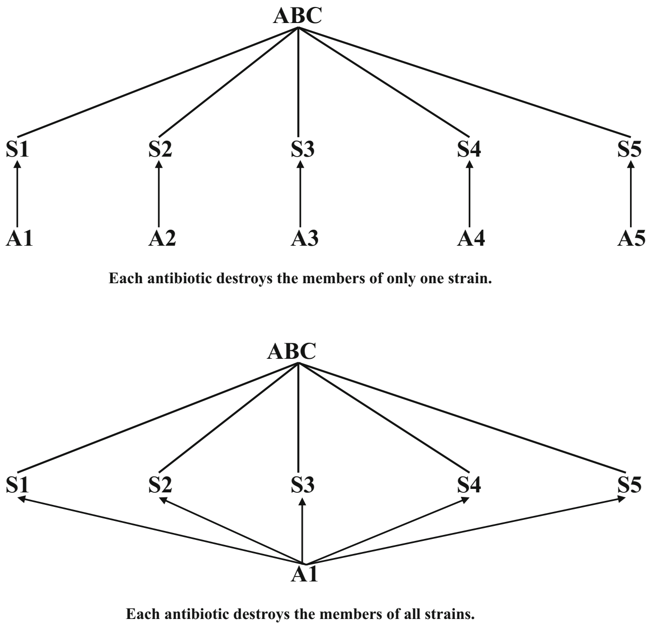

Fig. 10.2 The antibiotic—bacteria scenario illustrating the extreme aspects of antibiotic efficacy. *Source*: Joseph Frantiska Jr.

discussions of learning object use. Most instructional design models require content that is chunked, making them an easy fit when designing a manageable and reusable object. However, this suggests that content can be reduced to small chunks and support learning, which reflects an approach to learning as conceptualized in Bloom's taxonomy but is contrary to deeper learning principles". So the juggling act continues…

To demonstrate that this approach can be used for other domains, let's look at microbiology. Using the aforementioned antibiotic—bacteria example as a domain, suppose there is a particular bacterial species ABC with strains ABC_S1, ABC_S2, ABC_S3, ABC_S4 and ABC_S5. Also, there are five antibiotics (A1 through A5) that have been deemed to have some effect on the species. The goal is to achieve a middle ground whereby the smallest number of antibiotics or combination thereof can destroy the maximum number of species members. Figure 10.2 depicts the extreme situations where there is a strict one-to-one relationship between strains (above) and antibiotics and where there is a one-to-many relationship between one antibiotic that can destroy all strains (below). How can the effectiveness of the antibiotics be optimized so that there is a minimum amount of modification so that the minimum number of antibiotics can be used (and re-used) to destroy the maximum number of strain members?

Step 1—Deconstructing the Domain to the Atomic Level

Applying this situation to the problem of learning object reusability, suppose that an instructional designer is tasked with developing learning objects to model each antibiotic with the appropriate associated properties and capabilities. What must be done to optimize the applicability of the learning objects? Using the above methodology, the successful completion of step 1 gives the basic five antibiotics A1 through A5. However, Frantiska Jr. (2007) brings up a word of caution in doing so since breaking something down to its atomic level creates numerous combinations of information which can in turn allow for the creation of numerous flavors of learning objects. At first glance, there seems to be no negative aspects of this procedure. However, if used improperly the numerous combinations of information can cause confusion and therefore increase dissonance in the learner. In order to alleviate this problem, a through learner analysis needs to be done. A complete absence of dissonance as Frantiska Jr. (2004) points out may bring about an absence of motivation to seek out new and additional information. There would also be little or no motivation to avoid any particular source of information.

Step 2—Understanding the Domain to Understand the Reuse of the Learning Objects

The second step is of course entirely dependent on the information domain in question. The most difficult aspect will be interpreting the domain as to how and why the learning object will be re-used. Also, it is important to understand the impact that the object's usage has on its reuse.

Step 3—Combining the Atomic Portions to Optimize the Reuse of the Learning Objects

The third step is fraught with somewhat nebulous words such as "extent" and "satisfied". However, this is to be expected since most complicated domains have strong aspects of uniqueness. Therefore, it is also to be expected that a methodology must possess some generalities to encompass as many domain elements as possible. This is why the concept of chunking is imperative in the learning object reusability optimization process.

Frantiska Jr. (2004) defines chunking as "to break down information into manageable portions". Just as the third optimization step has the aforementioned nebulous words so too does the definition of chunking with the word "manageable". Rather nebulous and subjective, not only can it take on numerous meanings within a particular subject matter but also when it is based on a particular learner audience.

What size do you make the chunks/portions for learners who are in first grade, eleventh grade, graduate school, or are senior citizens? What are the impacts of the subject matter whether it is calculus, history, or art appreciation? The teacher/developer needs to address these questions with regards to the proper degree and approach of chunking to for a particular educational website or module.

The most important thing to understand about such a methodology is that it is just that—a methodology. There is no magic wand that can be waived over a project with the objects appearing out of thin air constructed so that their reusability is optimized. The best approach is to have an approach. That is, employ some structured means by which a set of objects is produced whose reusability is as close to optimal as the situation allows. The methodology presented here forces the developer to see the objects at their most basic level allowing all combinations that are possible within the limitations of the current information domain. Of course, as previously stated care must be used in combining the elemental portions so that an incorrect composition is created. The most obvious consequence of doing this is the creation of a learning object that will either not teach the required concepts or commit the greater problem of teaching/reinforcing an incorrect concept.

Using the sailing/flying learning object as an example, while there are many aspects that must be covering in order to fully train a person to be a sailor or pilot, the previously discussed relationship between the angle of attack and the generation of lift is particularly applicable to the problem of learning object reusability. The instructional designer who is tasked with developing this dual-purpose learning object must proceed through the three steps as in the aforementioned car customizer analogy. The most important question on his/her mind needs to be "Once the decomposition to the atomic level is complete, how far up the reconstruction path does the particular domain and desired end product require?" This required degree of granularity is of course dependent on the complexity of the domain and its uniqueness. Also, the required complexity of the final learning object(s) will also determine its degree of reusability.

Chapter 11
An Illustrative Example

Let's develop an example that will delineate the process of selecting and modifying a learning object in one domain for employment in another domain. Obviously, the difficulty of performing such a process is proportional to the degree of dissimilarity of the two domains. For instance, trying to extend a learning object for astronomy to the field of zoology may prove difficult. However, let's look at the field of meteorology. One of the weather phenomena that everyone knows is a tornado. It is a short-lived rotating funnel-shaped column of air that can cause tremendous damage and loss of life (Fig. 11.1 *left*). However, there are other phenomena that look similar but are different in composition and original. Two of these are the fire whirl (Fig. 11.1 *center*) and the dust devil (Fig. 11.1 *right*).

So we will develop a learning object(s) that describe how a tornado forms and see what we need to do to modify it for re-use as a tool to show how a fire whirl or dust devil forms. First, what type of learning object is most appropriate for this scenario? The information object type does not seem to be the best choice since we are interested in more than just the information but also the sequence of events. The practice object type does not seem appropriate as our primary interest for this situation does not lie in the areas of practice or assessment. Another possibility is the information object type particularly the demonstration/worked example. As previously discussed, this object type is used to show "…An execution of the steps that comprise a procedure". While the formation of a tornado or other related weather phenomenon is comprised of a series of steps, we are not primarily interested in the steps themselves but how they all contribute to the overall process of tornado formation. Therefore, we might want to look at the tutorial object type; specifically the process object. The process object is used to show "…How something works. A series of events culminating in an object's function". This seems to be the most appropriate selection for our particular scenario.

We are also concerned with what we need to do to re-use this object to show the related formations of dust devils and fire whirls. The primary area to look at is the differences in tornado formation versus the dust devil or fire whorl formation.

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Fig. 11.1 A tornado (*left*) a fire whirl (*center*) a dust devil (*right*). *Credit*: NOAA

One problem with the tornado/fire whirl/dust devil example is that while all of the phenomenon can use the same learning object with appropriate modifications, they are all still within the same domain namely meteorology.

Let's look at using the meteorology learning object from a largely different domain. The learning object used in exploring tornadoes has as a major aspect a cylindrical or conical rotating mass. There are similar occurrences that are in other areas of endeavor. One such area is that of physics. Take for instance the stereotypical example of using a spinning ice skater to demonstrate the concept of the conservation of angular momentum.

What is angular momentum? Well, let's first see what regular or linear momentum is. The Merriam-Webster dictionary defines linear momentum as:

> A property of a moving body that the body has by virtue of its mass and motion and that is equal to the product of the body's mass and velocity.

For example, the momentum of a car that weighs 2000 kg and is traveling at 13 m/s has a momentum of 26,000 kg m/s.

Angular momentum is like linear momentum but applies to a rotating object. The angular momentum of an object can be defined as the product of its moment of inertia and its angular velocity. An object's moment of inertia can be thought of as how resistant the object is to a change in its angular velocity. Angular momentum like linear momentum is conserved. Why is this important in the development of this learning object?

Forces always try to maintain a balance. Therefore, a rotating object with a constant mass such as a rotating column of air will spin at a constant rate as long as it is not disturbed in any way. Conversely, if its mass is increased as can happen to a forming tornado as it pulls in debris from its environment, the law of conservation of angular momentum requires that for the total angular momentum to be constant than it must rotate faster.

This is seen when an ice skater is rotating on a single point of the ice with his/her arms (and therefore mass) spread out. The skater is initially rotating at a certain speed, but when the arms are drawn in towards the body, thereby concentrating its mass, the law of conservation of angular momentum will cause the skater to rotate more rapidly.

How do we have to modify the learning object? In this example, it is driven by the factors that cause the formation, life and death of each phenomenon. If we were to initially develop the learning object to demonstrate the life cycle of a tornado, we first need to look at how a tornado is formed, exists and the factor(s) that cause its demise.

A tornado is formed when close, intersecting currents of air in the lower atmosphere through friction cause the air between themselves to spin. A tremendous amount of energy is required for this to happen and in most instances that energy is derived from a very strong type of thunderstorm called a supercell. As time progresses the air forms a horizontal spinning cylinder known as a mesocyclone. If there is a sufficient mechanism of vertical air movement in the supercell such as updrafts, the cylinder can be made to rise into a vertical spinning column of air. If the column reaches the ground, we will see the classic tornado formation.

Another phenomenon that has some of the basic properties of a tornado such as a tall rotating column of air and strong winds is the fire whirl. However, while it possesses this basic appearance, it is formed in quite a different manner. As can be seen in Fig. 11.1 *center*, a fire whirl is comprised of a spinning column of fire and obviously is not in the vicinity of many clouds or rain. It also is very small in comparison to the tornado. Whereas a tornado is typically from a few 100 yards to a mile or more in diameter and hundreds or thousands of feet tall, fire whirls are usually no more than 3 ft in diameter and less than 100 ft tall. Only when the conditions are just right can fire whirls grow to be 10–50 ft wide and up to 1000 ft tall. Also, while the winds within a tornado can reach 300 miles/h, the winds in a fire whirl are usually less than 100 miles/h.

With regard to the usage (and re-usage) of the learning object, how does the formation of a fire whirl differ from that of a tornado? A fire whirl forms when there is an area of hot rising air which comes in contact with turbulent air and causes the rising air column to rotate. Flammable, carbon-rich gases released by burning vegetation on the ground that produces carbon-rich gases are the fuel for most fire whirls. Since the lower level of a fire whirl does not have enough oxygen to support combustion, the fuel needs to reaches a higher level where there is enough fresh, heated oxygen to ignite it. This gives a fire whirl its classic tall and narrow appearance. Converging low-level winds drawn into the fire impart a spin to the column like the aforementioned spinning ice skater, pulling her arms inward. Therefore, while tornadoes and fire whirls both require currents of air to start the rotation, the mechanism and of course the environment is quite different.

The other similar phenomenon is that of the dust devil as seen in Fig. 11.1 *right*. As the figure shows, a dust devil can form in the absence of clouds or precipitation as the word "dust" implies. They can be tens of yards in diameter and up to a half mile in height. While it has the same rotating columnar structure of the tornado and fire whirl, it does not have the thermal impetus that the fire whirl possesses or the power of a thunderstorm that the tornado feeds off of. So how does a dust devil form?

Dust devils can form in urban or rural areas. The environment is generally clear, hot and calm. Sometimes one area of the ground can heat up faster than the surrounding area such as an asphalt parking lot or a dirt covered area surrounded by a cooler grassy area. The air above this hotter area of ground is hotter than the air surrounding and above it. The rising column of hot air near the surface can grow vertically through a pocket of cooler, low-pressure air above it. The hotter, lighter air at the center wants to go up due to buoyancy. Since nature hates a vacuum, this air must be replaced and it is by air moving toward the center and due to the conservation of angular momentum its rotation speed increases. Thus the vortex is created.

Other hot air speeds horizontally inward to the bottom of the vortex to replace the air that is rising and the rotation becomes more powerful and self-sustaining. As the hot air rises away from the hotter ground, it cools and rises more slowly until it eventually stops rising. As it rises, it dislodges air which then drops outside the vortex core. The cooler air drops down far enough to be pulled into the lower part of the vortex and maintains the system.

Given the dynamics of the formation of these three similar but different phenomena, how will the learning object be created and then modified for re-use? To show the nuances of the process, the learning object takes the form of an animation created in Macromedia (now Adobe) Director. Let's create it initially for the formation of a tornado as this is most familiar to the public and the most understood. The following illustrations delineate how the tornado forms (Frantiska Jr. 2001) (Figs. 11.2, 11.3, 11.4, 11.5, 11.6, 11.7 and 11.8).

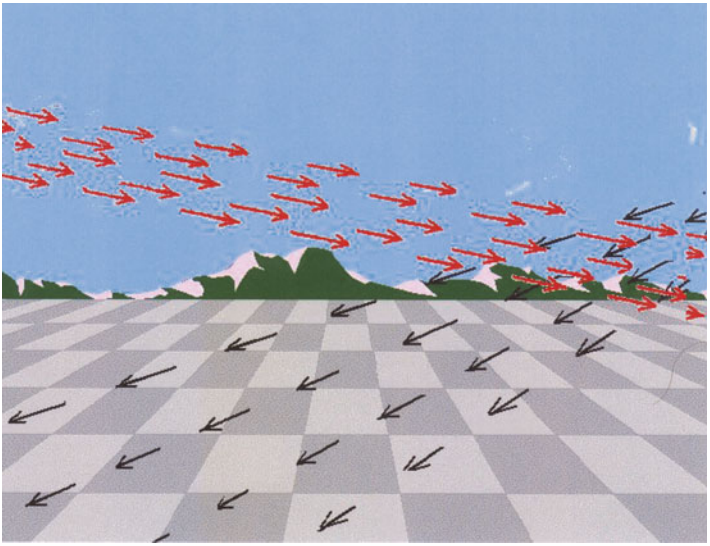

Fig. 11.2 Winds crossing each other which begin the tornado formation sequence

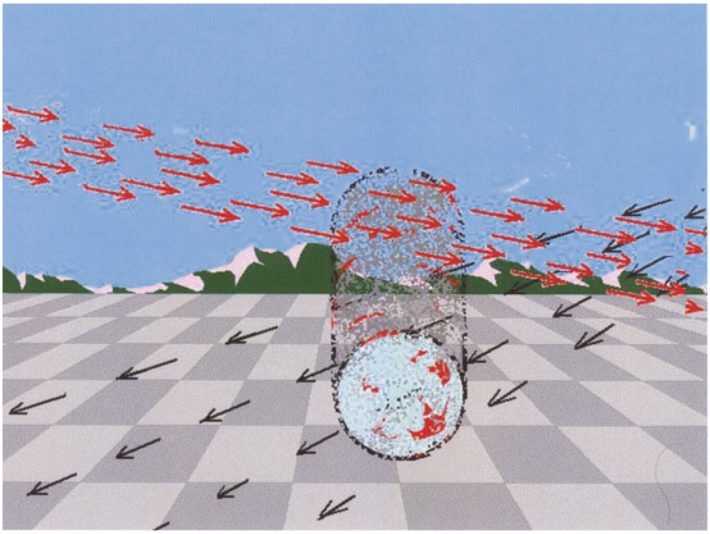

Fig. 11.3 The crisscrossing winds form a horizontal rolling cylinder of air

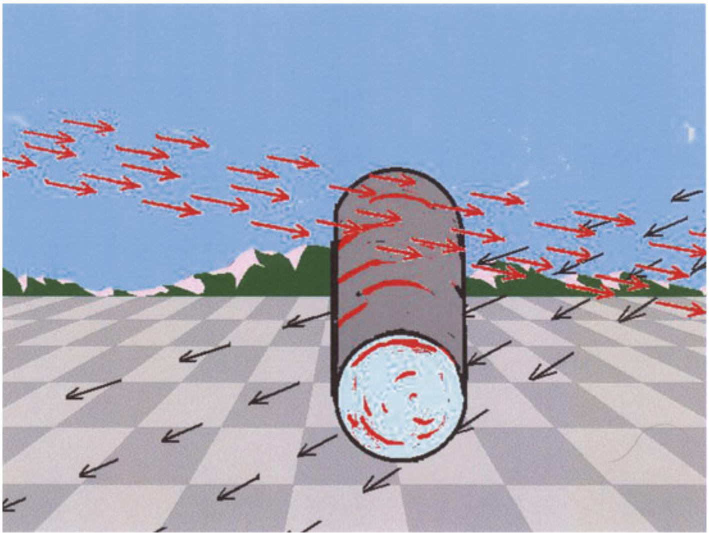

Fig. 11.4 The rolling cylinder of air rotates faster and becomes darker with increased water and debris

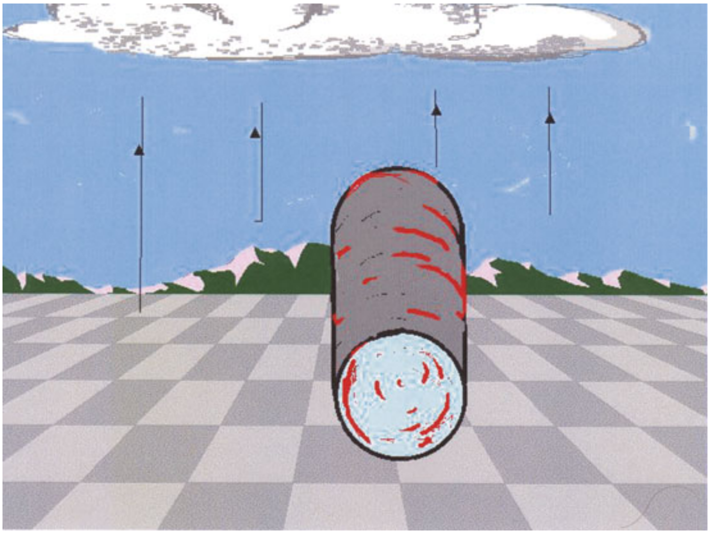

Fig. 11.5 An updraft begins to raise the horizontal cylinder to a vertical position

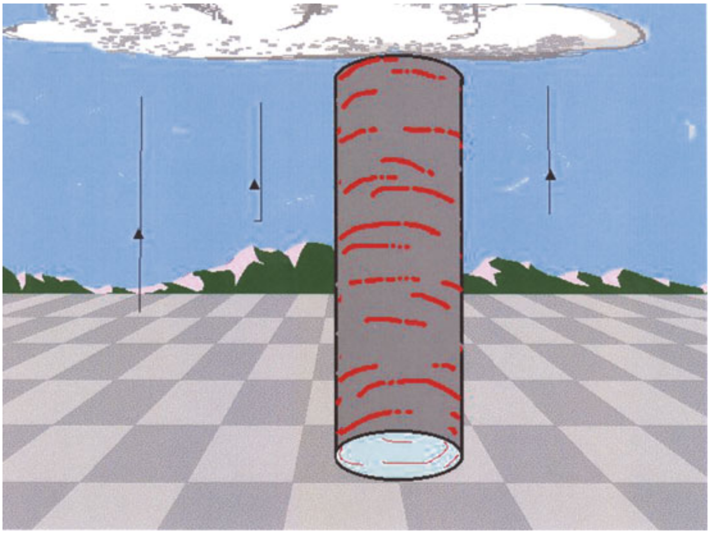

Fig. 11.6 Cylinder in a vertical position is darker and spins faster due to increased mass from ground debris

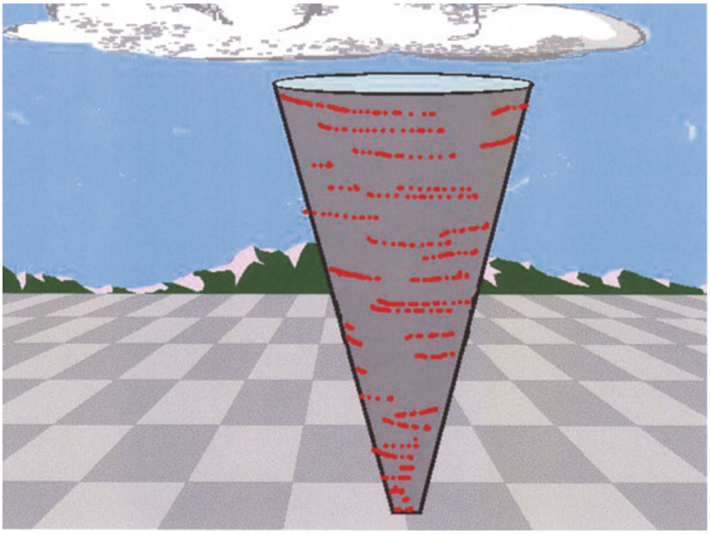

Fig. 11.7 Due to conservation of angular momentum, the cylinder has begun to transform into the classic funnel shape

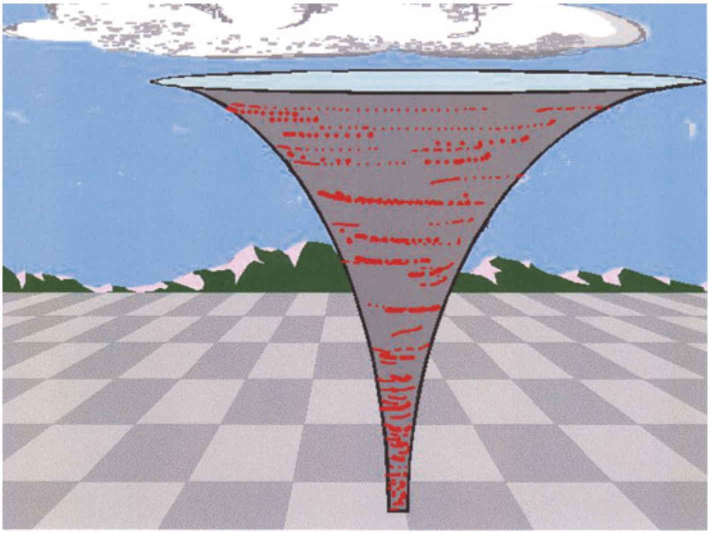

Fig. 11.8 The funnel has reached its mature stage with maximum wind speed and mass

These illustrations are screen captures of the animation at the critical phases of a tornado's creation respectively:

1. Converging currents of air.
2. Initial horizontal rolling cylinder of air.
3. Mature horizontal rolling cylinder of air.

4. The mature cylinder is raised into a vertical position by strong updrafts.
5. The now vertical cylinder pulls in more matter and spins faster due to the conservation of angular momentum.
6. Conservation of angular momentum creates the cylinder into a classic funnel shape.
7. The funnel has reached a maximum velocity and mass.

In order to see how this learning object needs to be modified for re-use, we need to analyze the corresponding phases of dust devils and fire whirls. First, what needs to occur for a fire whirl to be born? The steps are as follows:

1. Based on the previous discussion of fire whirl formation, the phases can be discerned as:
2. A localized heat source provides a rising column of air.
3. The column of air pulls carbon-rich gases upward.
4. The air/gas column rises until it reaches a high enough level containing sufficient oxygen to support combustion.
5. The air currents pulled into the rising column can converge and create a spinning moment that acts to cause the entire column to spin.

Next, we need to look at the dynamics involved in the creation of a dust devil.

1. A localized area becomes hotter than its immediate surroundings and forces the air above it to rise.
2. If it passes through areas of cooler air at a higher level, the converging air currents rushing in to replace it can create a spinning motion.
3. As additional mass from debris is pulled in, the conservation of angular momentum can increase and maintain the spinning motion.

Chapter 12
The Object Oriented Programming Perspective

One area that deals with objects and the concept of reuse is that of object oriented programming (OOP). OOP is a departure from the standard programming paradigm and constructs in that OOP generates entities called objects that each possess their own descriptive data which dictates its state as well as procedures called methods that dictate their behavior. Additionally, objects of the same type are grouped into a structure known as a class. Finally, there are the concepts of polymorphism and inheritance. Polymorphism is the capability to request that a given set of operations be performed by a wide range of different objects. Inheritance is the capability to create a new class of objects from an existing class whose characteristics are replicated in the new class.

Table 12.1 shows a comparison of object oriented programming concepts and a concrete example of the animal kingdom. In the example, animals and ships are analogous in that both belong to a larger grouping or class, they can be described by unique data and they behave in a specific way.

Alice is an innovative 3-D programming environment targeted for students in grades 6–12 that makes it easy to create an animation for telling a story, playing an interactive game, or a video to share on the web. It was initially developed at the University of Virginia and then Carnegie-Mellon University by the late Dr. Randy Pausch. Alice was designed to be a student's initial experience with object-oriented programming. It introduces elementary programming concepts via the object oriented programming paradigm within the context of creating animations and basic video games. Three dimensional objects such as people, animals and vehicles inhabit a virtual world with students developing the animation of the objects.

Alice provides students with an interactive drag and drop interface to create programs where the instructions correspond to standard statements in a production oriented programming language, such as Java and C++. Alice gives students immediate feedback as to the progress and degree of success of their animation programs. The students are able to see the direct link between the program statements and the behavior of the animation objects. In working with the objects in a virtual world,

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Table 12.1 A comparison of object oriented terminology in multiple domains

Entity	Object-oriented programming	Example	Animal kingdom	Example
Organism	Object	Aircraft carrier	Animal	Lion
Grouping	Class	Ship	Species	Mammal
Description	Data	Dimensions	Characteristics	Mane (male)
Behavior	Methods	Launch and recover planes	Psychology	Predatory carnivore
Intergenerational (genetic)	Inheritance	Float on water	Inheritance	Physiology
Intraspecies	Polymorphism	Generate power (nuclear/diesel)	Polymorphism	Hunt prey

Fig. 12.1 The basic Alice environment

students experience all of the programming constructs found in an introductory programming course.

To explore what Alice can provide to students with respect to concepts and knowledge, Fig. 12.1 shows the basic Alice environment.

If we were to setup a scene in Alice for the flying/sailing example, we might want to show the similarities between a sail and a wing as the basis for a learning object. Both are essentially airfoils, that is, shapes that cause an air mass to divide with a portion flowing over each side of the airfoil. Many people understand that a wing generates lift by its unique shape as it moves through the air. What a lot of people don't realize is that a sail also generates aerodynamic lift. Older sails such as the square riggers seen on images of Christopher Columbus' ships provide the maximum

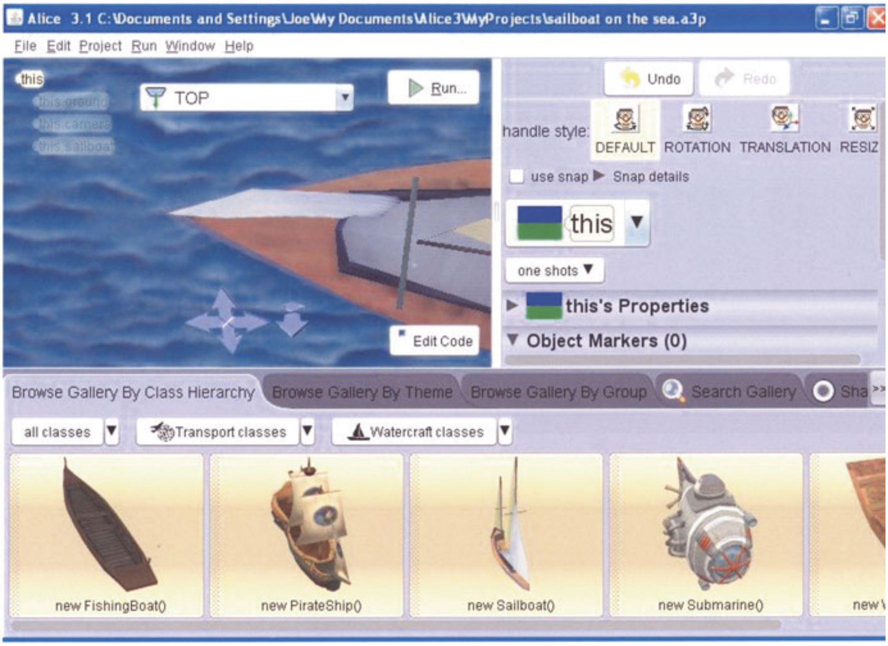

Fig. 12.2 The Alice environment with a sailboat's headsail as seen from above

thrust if the wind is coming directly from behind and pushing the ship through the water. Modern sails can also generate thrust through the generation of lift when the wind is coming from a number of directions making for a much more efficient sail. Figure 12.2 shows the Alice environment after the creation of a sailboat with the forward or head sail the primary focus as the boat is seen from above.

To show the corresponding features of a wing, Fig. 12.3 details the side view of a hang glider's wing. The profile has the same basic shape as the boat's headsail and similarly generates lift.

As to the aforementioned illustrative example of the tornado/fire whirl/dust devil example, how do we construct the initial tornado learning object and then adapt it for re-use in the examination of the formation of dust devils and fire whirls?

First, we need to analyze the differences and similarities of the three weather phenomena. Table 12.2 delineates these properties:

Examining Table 12.2 shows that all three have the same mechanism that sustains them; the debris pulled into them increases their mass and through the conservation of angular momentum, they achieve a temporary state of balance and sustainment. Also, we see that the environmental factors conducive to formation are similar. Specifically, there needs to a difference in air masses to create the energy that acts as an impetus with a tornado needing differing air pressures while the others need differing air mass temperatures. Finally, they are all comprised of air and debris that is pulled into the column of air. While the dust devil and fire whirl have hot air, tornadoes contain air that is significantly cooler.

Fig. 12.3 The Alice environment with a hang glider's wing seen from the side

Table 12.2 The factors involved in the formation of a tornado, dust devil and fire whirl

Phenomenon	Tornado	Dust devil	Fire whirl
Necessary environment for formation	Pressure difference	Localized area hotter than the surroundings (temperature difference)	Localized area hotter than the surroundings (temperature difference)
Composition	Cool air and debris	Hot air and debris	Hot air and debris
Horizontal air currents	Converging	Cooler air layer pulled into hotter air column	Converging currents pulled in at the base and acting upwards
Vertical air currents	Updraft from thunderstorm pulling from above	Heat rising from the surface	Heat rising from the surface
Sustainment force	Conservation of angular momentum and increasing mass due to debris	Conservation of angular momentum and increasing mass due to debris	Conservation of angular momentum and increasing mass due to debris

All of these pieces of information provide an understanding of what needs to be done to modify the tornado learning object for re-use in the corresponding fire whirl and dust devil learning objects. We now need to employ the steps previously mentioned to perform the appropriate modifications.

Step 1—Deconstructing the Domain to the Atomic Level

We have essentially done this step in creating Table 12.2 as we have broken down the three phenomena into their basic pieces that when properly reconstructed will produce the original phenomenon.

Step 2—Understanding the Domain to Understand the Reuse of the Learning Objects

While the first and third steps are more clinical or if you will mechanical in their employment, the second step of understanding the domain and the subsequent reuse requires a more intimate level of comprehension. Not only do the portions of the learning object need to be ascertained but their placement and what they will contribute to the learning process. The questions that need to be addressed are:

How does the environment cause the formation of the various phenomena?

In the tornado situation, there are pressure differences that cause the criss-crossing air currents while in the dust devil and fire whirl situations, the differences are in the temperatures of neighboring layers of air. Therefore, the mechanics are quite alike in that differences of air qualities are responsible for the phenomena formation.

What specific parts of the environment work in concert to cause the formation?

As previously stated, the differing areas of the neighboring air masses create air currents which form the phenomena in question. Specifically, this difference causes the air currents to form due to higher pressure air moves to the lower pressure air and the hotter air moves to the cooler area. In this way, not only are the currents formed but in a majority of the time when currents are moving towards each other they want to continue moving and will seek the path of least resistance. Therefore, if there is room, they will move to parallel paths to continue along their tracks. If they are close enough, the friction between these air currents can cause them to rotate around each other. In this way, the classic rotation seen in all three phenomena is created.

What parts of the phenomena are similar? How? In addition to the air mass differences causing the mainly horizontal air currents and rotation, there needs to a source of vertical movement to bring the phenomena into the mature stage, For tornadoes, this is due to a nearby thunderstorm which has large vertical air currents which is how thunderstorms are able to reach their towering heights. For dust devils and fire whirls, the localized hot area creates a vertical air current since hot air's natural tendency is to rise. Also, for the phenomena to be relatively long-lived there needs to be a sustaining force which will act to keep them going. The aforementioned conservation of angular momentum is the source of sustainment for all three. In each, the horizontal air currents pull debris in and because of the added mass due to this, the phenomena will rotate faster and pull in more debris which thereby increases the mass and the cycle continues. It is thought that tornadoes will begin to dissipate when the vertical current extends far enough down to cut off the horizontal currents which pull in the debris. A three phenomena move across their terrain, since fire whirls and dust devils are created in a relatively small heated area will dissipate when they move to a significantly cooler area.

What parts of the phenomena are different? How? Probably the greatest difference is that while there is rotation and air currents caused by air mass differences, tornadoes are formed by pressure differences and the others are dependent on temperature differences. Therefore, the locations of formation can be more restrictive in the case of fire whirls and dust devils than that of tornadoes.

Step 3—Combining the Atomic Portions to Optimize the Reuse of the Learning Objects

Based upon the information from step 1 and the analysis of step 2, we now need to decide how to accurately combine the portions at the atomic level so that they constructed so that they represent the new domain.

Assuming that the tornado learning object is complete, to re-use it for purposes of demonstrating fire whirl formation, we need to do the following:

1. Delete the portions devoted to the raising of the horizontal rotating cylinder to a vertical position as the fire whirl only exists in a vertical position.
2. While the classic mature phase of a tornado is funnel-shaped, a fire whirl is largely cylindrical but of a smaller diameter than a mature tornado. Therefore, the portions where the conservation of angular momentum brings the rotating cylinder of the middle stage of a tornado need to be changed so that the conservation of angular momentum changes a larger initial cylinder to one which is of a smaller diameter but of a greater height.
3. The horizontal air currents need to be seen at height above the surface as they are from a cooler layer of air that the fire whirl has risen through. The rotation spreads above and below this point.
4. The fire needs to begin away from the surface as it needs to find an area of sufficient oxygen to ignite.
5. Fire needs to be placed within the fire whirl structure throughout its creation i.e. it spreads throughout.

Based on this analysis, the basic storyboarding for the fire whirl sequence would look something like the sequence of Figs. 12.4, 12.5, 12.6, 12.7, 12.8, 12.9, 12.10, 12.11, 12.12, 12.13, 12.14, and 12.15:

To re-use the tornado learning object for purposes of demonstrating dust devil formation, we need to do the following:

1. Since fire whirls and dust devils are similar in terms of their formation, steps 1 and 2 of the fire whirl formation sequence need to be replicated for the dust devil formation sequence.

2. Contrary to the dust devil or tornado sequences, he horizontal air currents need to be seen at the surface as they are from the cooler air surrounding the localized heated area that generates the vertical updraft. The rotation spreads above this point.

Based on this analysis, the basic storyboarding for the dust devil sequence would look something like the following:

Fig. 12.4 The fire acts as a source of rising air i.e. a lifting force

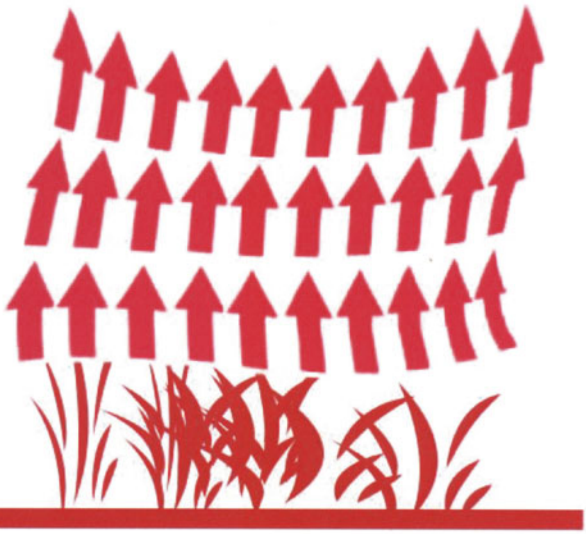

Fig. 12.5 The air above the fire is heated and begins to rise

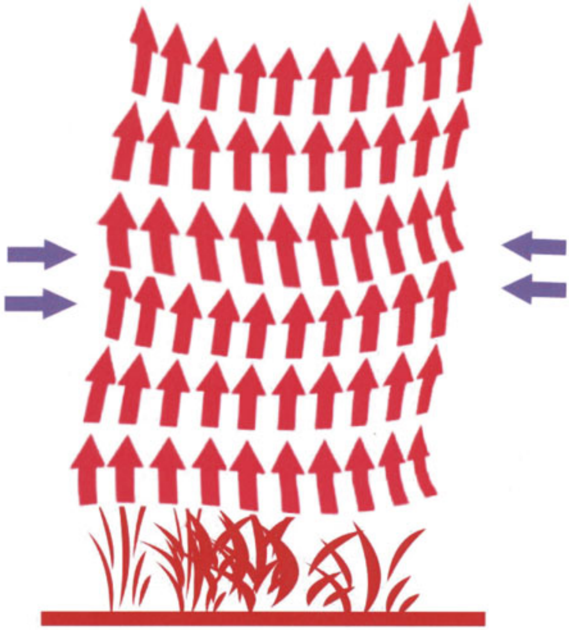

Fig. 12.6 The rising heated air rises through a layer of cooler air and the cooler air currents flow towards the rising column of air

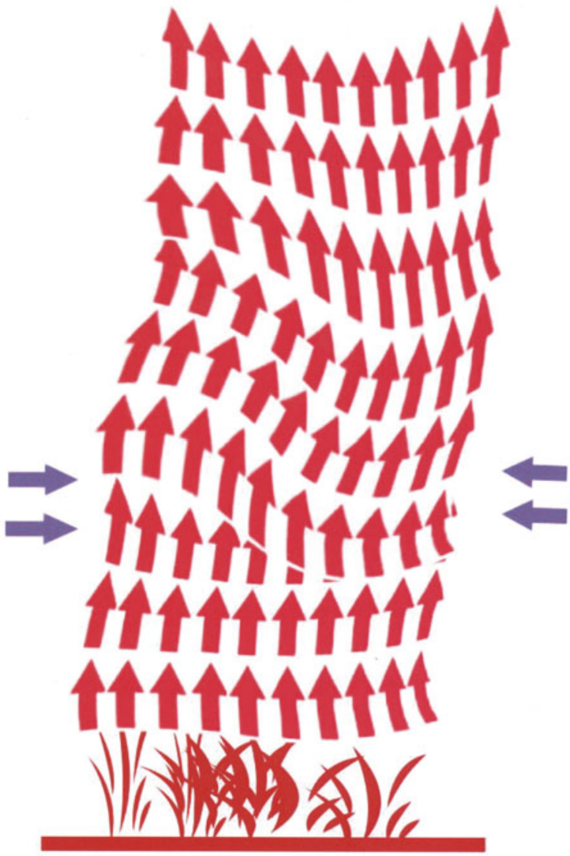

Fig. 12.7 The friction and interaction of the cooler air currents against the column causes the column above the air currents to rotate

Fig. 12.8 The rotation travels downward to encompass the entire column as the conservation of angular momentum has caused the column to narrow and rotate faster

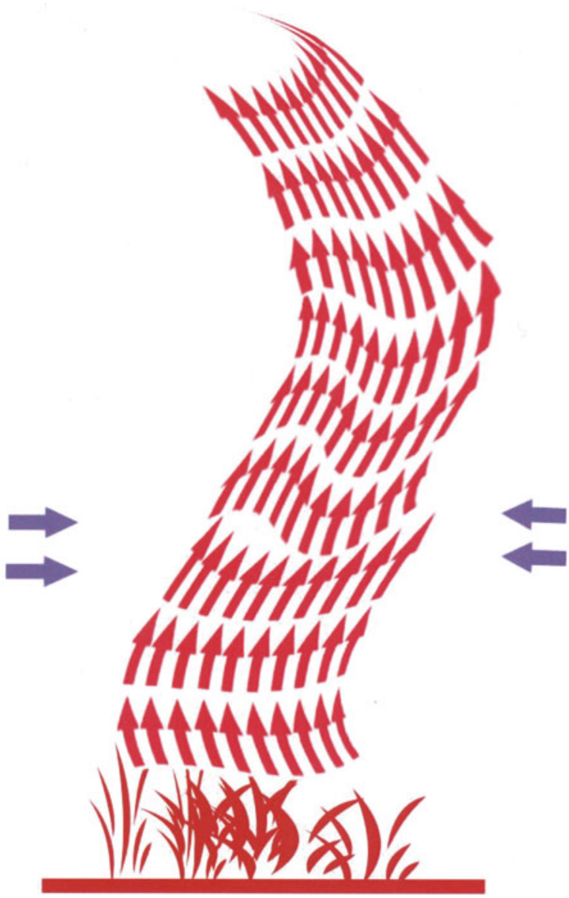

Fig. 12.9 A localized area hotter than the surroundings is a source of rising air providing a lifting force

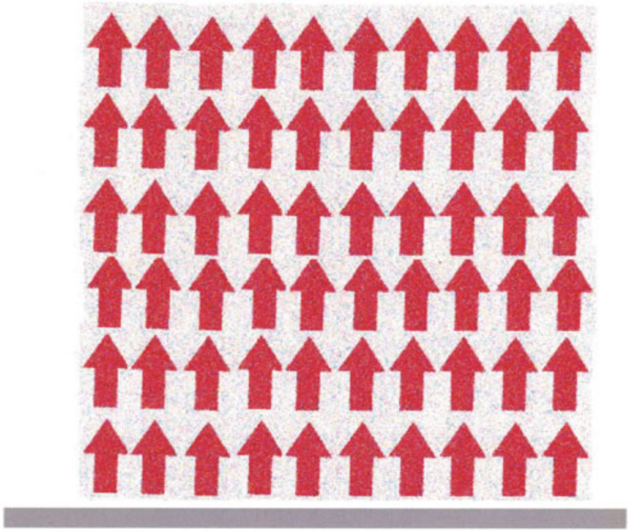

Fig. 12.10 The column of air above the heated area is in turn heated and begins to rise. As the air rises, it pulls in dust and debris

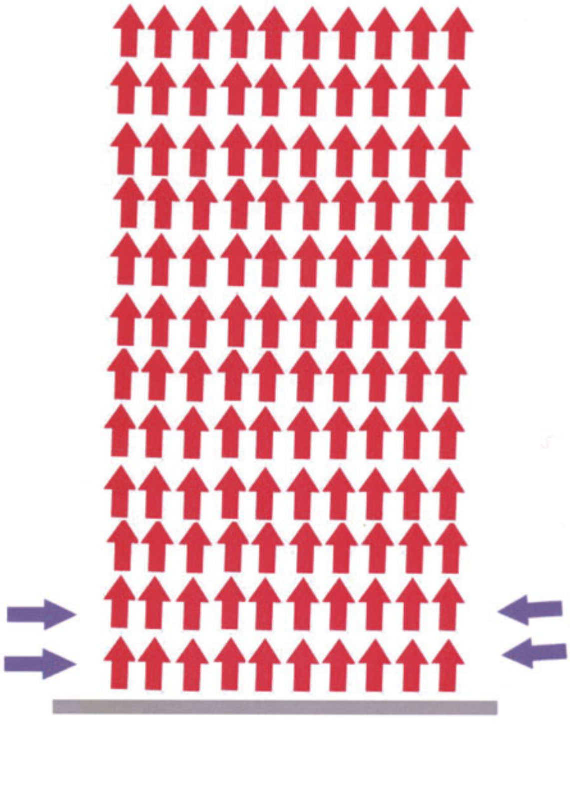

Fig. 12.11 The rising heated air rises and cooler air currents flow into the rising column of air at its base

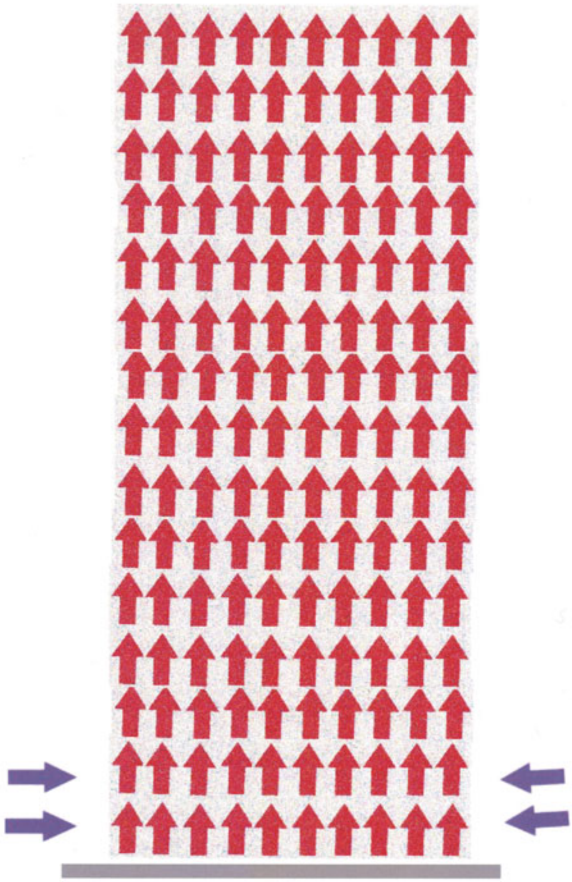

Fig. 12.12 The cooler air currents create friction against the rising column and cause it to rotate

Fig. 12.13 The rotation continues as the column of air becomes more massive as it pulls in more debris

Fig. 12.14 The rotating column narrows due to the conservation of angular momentum

Fig. 12.15 The entire column continues to rotate faster and narrows due to the constant stream of debris adding to the mass and the conservation of angular momentum

Chapter 13
Summary/Conclusion

As the title of this brief implies, there is a process of optimizing a learning object's reusability. That is, there are rules and procedures that can be applied in a structured yet flexible way. This approach, as with most approaches, provides a structure to the process along with procedural steps that can be looked upon as rules that give the developer a roadmap to follow to give them a reliable means ending in the desired end product. Yet there also exists a fair amount of art in the process as a closer look at the rules reveals that they are in fact rules of thumb. The Merriam-Webster dictionary defines a rule of thumb as "A method of procedure based on experience and common sense" and "A general principle regarded as roughly correct but not intended to be scientifically accurate". Therefore, judgment and experience play major roles in the process.

As in the sailing/flying learning object example, there are many parameters that the object's reusability is dependent on. In turn, these parameters are very dependent on the domain at hand. This aspect of custom-made solutions requires that the rules can be at best rules of thumb. However as the first definition implies, as the developer works in various domains they can expect to rely on an increasing amount of experience. This experience together with the rules provides the developer with the ability to develop a degree of true insight into their work as the methodology becomes innate.

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